Selected Deposits of Strippable Coal in Central Rosebud County, Montana

GEOLOGICAL SURVEY BULLETIN 995-I

A CONTRIBUTION TO ECONOMIC GEOLOGY

SELECTED DEPOSITS OF STRIPPABLE COAL IN CENTRAL ROSEBUD COUNTY, MONTANA

By Roy C. Kepferle

ABSTRACT

Central Rosebud County, Mont., is near the western edge of the Fort Union-Powder River coal region of North and South Dakota, Wyoming, and Montana. In anticipation of an increase in the demand for the low-rank coal of this region, both as fuel for electric power plants and as a raw material for various synthesizing processes, the Geological Survey in 1951 searched for deposits of coal suitable for large-scale strip mining in central Rosebud County. At least 10 persistent coal beds in this county are minable, and all are nearly flat-lying. The thickest and cleanest beds are in the Tongue River member of the Fort Union formation of Paleocene age. Seven localities in three of these coal beds are particularly suited to strip mining.

The coal in each deposit is more than 5 feet thick and is generally free of partings. The rank is subbituminous B or C. The coal has a low ash and sulfur content and is well suited for the manufacture of synthetic liquid fuels. In common with other low-rank coal, it slacks readily and tends to ignite spontaneously. The rocks above the coal beds consist mainly of massive friable sandstone, soft shale, and a few thin beds of limestone.

Each deposit of strippable coal is covered by less than 120 feet of overburden. Maps of each deposit show the general geology and geography of the area, and the thickness of the coal. Contour lines show where the land surface is 60 feet, 90 feet, and 120 feet above the top of the coal bed. The reserves of strippable coal contained in each deposit are given according to the total tonnage that lies beneath 0 to 60 feet, beneath 60 to 90 feet, and beneath 90 to 120 feet of overburden. The reserves contained in the 9 strippable deposits total 604 million short tons of coal in an area of 19,762 acres.

INTRODUCTION

The deposits of coal described in this report were mapped by the U. S. Geological Survey as a part of the Interior Department's program for the integrated development of the Missouri River basin and in anticipation of an increase in the demand for the low-rank coal of the Missouri River basin. This report describes seven localities in central Rosebud County, Mont., where large reserves of coal (table 1) are particularly well suited to recovery by strip-mining methods.

TABLE 1.—*Measured and indicated reserves of strippable coal in selected deposits of central Rosebud County, Mont., in millions of short tons*

Deposit and bed	Average thickness (feet)	0–60 feet overburden		60–90 feet overburden		90–120 feet overburden		Total	
		Acres	Original reserves	Acres	Original reserves	Acres	Original reserves	Acres	Original reserves
Sweeney Creek deposit, Terret bed	9	912	14.5	447	7.1	221	3.6	1,580	25.2
Snyder Creek deposit, Terret bed	11	521	10.1	183	3.6	127	2.5	831	16.2
Greenleaf Creek deposit, Knoblock bed	12	1,557	33.1	701	14.9	393	8.3	2,651	56.3
Miller Creek deposits, East deposit, Rosebud bed	9	494	7.9	251	3.9	249	4.0	994	15.8
North deposit, Rosebud bed	9	449	7.1	114	1.9	24	.3	587	9.3
South deposit, Knoblock bed	16	456	12.9	320	9.1	319	9.0	1,095	31.0
South Coal Bank Coulee deposit, Rosebud bed	24	286	12.1	131	5.6	99	4.2	516	21.9
Castle Rock deposit, Rosebud bed	22	4,143	161.3	1,934	75.3	1,713	66.7	7,790	303.3
West Fork Armells Creek deposit, Rosebud bed	19	1,587	53.4	1,028	34.5	1,103	37.1	3,718	125.0
Total	-------	10,405	312.4	5,109	155.9	4,248	135.7	19,762	604.0

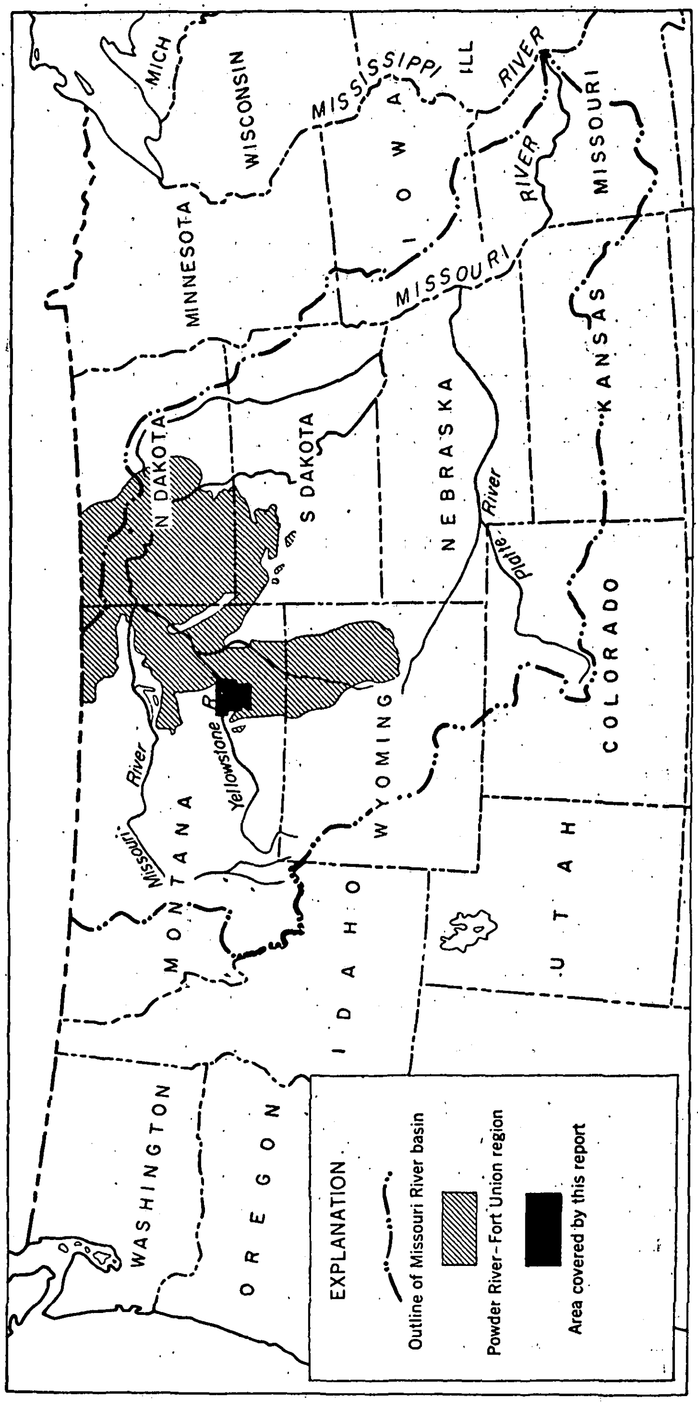

FIGURE 48.—Index map of northwestern United States, showing Fort Union-Powder River coal region and area described in this report.

Commercial mining of coal by stripping dates in the United States from about 1910, when large full-revolving power shovels were first used in the midwestern coal fields (Koenig, 1950, p. 27). For many years the tonnage recovered by strip mining was relatively small, the average for the years 1920–24 being only about 2 percent of the nation's annual production; by 1950, however, strip mined coal was 23.9 percent of the total (U. S. Bureau of Mines, 1951, p. 20). This rapid growth is explained by the fact that a large part of the nation's coal can be produced more cheaply by strip mining than by underground mining. In the mines of Illinois, for example, the amount of coal produced per man-day in 1950 was 18.7 tons by strip mining, as compared to 8 tons by underground mining (U. S. Bureau of Mines, 1951, p. 20). In addition to the more efficient use of manpower, strip mining requires a smaller initial investment than does underground mining, except in very small mines. The investment necessary to equip a modern strip mine in the Midwest was roughly estimated in 1949 to be about $4 a ton of annual capacity. In the same area the investment necessary to equip a modern underground mine was estimated to be $5 to $7 a ton of annual capacity (Koenig, 1950, p. 28). Furthermore, in strip mining, as much as 95 percent of the coal in the ground is recovered (W. V. Styles, superintendent of Foley Brothers, Inc., a mining company operating at Colstrip, oral communication), whereas in underground mining, only about 50 percent is recovered (Averitt and Berryhill, 1950, p. 8).

At Colstrip, in south-central Rosebud County, large-scale strip mining has been demonstrated to be a most efficient method for recovering coal. The Colstrip mine in 1950 produced 1,708,149 tons of coal or 92.78 tons per man-day—more than two-thirds of the total amount of coal mined in Montana that year (U. S. Bureau of Mines, 1951, p. 21, and E. L. Dorsett, superintendent of the Northwestern Improvement Company mine at Colstrip, personal communication).

LOCATION OF THE AREA

Rosebud County is part of the Fort Union-Powder River region of the northern Great Plains. (See fig. 48.) This region contains the largest reserves of strippable coal in the United States. The extensive beds of coal are thick, fairly flat-lying, and range in rank from lignite, in the Dakotas and the extreme eastern parts of Montana and Wyoming, to subbituminous coal in the western part of the region. In places the coal beds lie at fairly shallow depths and can be mined advantageously by stripping the generally soft overburden. The area described in this report covers about 1,680 square miles in central Rosebud County, Mont. It is bounded on the north by the north line of T. 6 N., on the east by Custer and Powder River Counties, on the south by the Tongue River Indian Reservation, and on the west by Treasure and Big Horn Counties. (See fig. 49.)

Other deposits comparable in size to those described in this report exist outside central Rosebud County. Those in Custer, Powder River, Richland, Dawson, and Wibaux Counties, Mont., have recently been studied by the U. S. Geological Survey (Brown and others, 1954; Culbertson, W. C., 1954; and May, P. R., 1954).

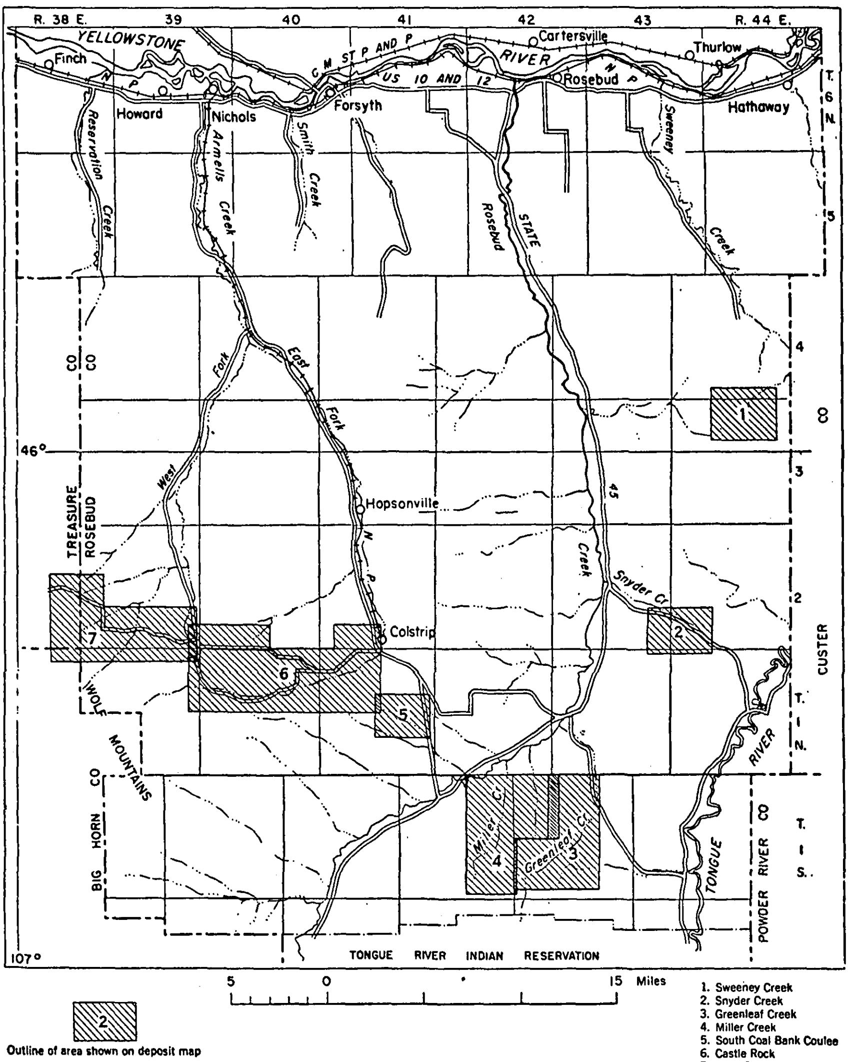

FIGURE 49.—Map of Central Rosebud County, Mont., showing deposits of strippable coal described in this report.

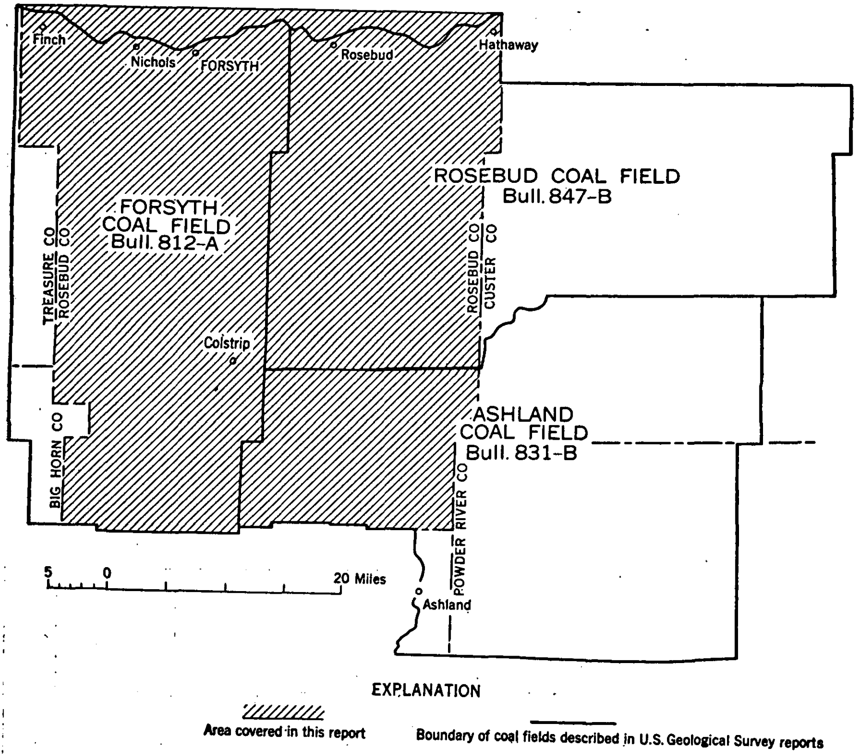

FIGURE 50.—Index map of central Rosebud County and adjoining parts of Big Horn, Custer, Powder River, and Treasure Counties, Mont., showing locations of coal fields described in bulletins of the U. S. Geological Survey.

PREVIOUS GEOLOGIC WORK

All of central Rosebud County had been investigated by the U. S. Geological Survey, 2 previous to the present investigation. The results of these earlier investigations have been presented in the following publications: the Forsyth coal field, by C. E. Dobbin (1929); the Ashland coal field, by N. W. Bass (1932); the Rosebud coal field, by W. G. Pierce (1936); and a water-supply paper by B. C. Renick (1929). The locations of the three coal fields are shown in figure 50. The writer has drawn freely from each of these reports in investigating the selected deposits of strippable coal described in this report.

ACKNOWLEDGMENTS

Valuable information about strip mining was given by E. L. Dorsett, superintendent of the Northwestern Improvement Company's mine at Colstrip, and W. V. Styles, superintendent of Foley Brothers, Inc., which maintains the stripping operation at the Colstrip mine. H. G. Young, county surveyor of Rosebud County, kindly allowed the use of his office facilities and furnished additional data about county roads and land surveys. The hospitality and information given by the Vern Wimer family, A. L. Farley, and other ranchers in the area greatly facilitated the investigations.

Most of the field work forming the basis of this report was done during the summer of 1951 with the assistance of Duncan Goldthwaite; some of the basic field work was done the previous year by W. C. Culbertson and R. J. Dunham.

GEOGRAPHY

SURFACE FEATURES

The characteristic surface features of central Rosebud County are the dissected plateaulike uplands of the interstream divides, the badlands along the margins of these divides, and the terraces and flood plains along the main stream valleys. These features reflect to a great extent the varying degrees of hardness of the underlying rocks.

The uplands extend from the southern boundary of the area northward almost to the Yellowstone River. They form the Rosebud Creek-Tongue River divide in the east, the Rosebud Creek-Armells Creek divide in the central part, and the Armells Creek-Sarpy Creek divide in the extreme western part of the area. Their surfaces are generally supported by resistant beds of sandstone or clinker. The most prominent of the uplands are the Tongue River-Rosebud Creek divide near the northern boundary of the Northern Cheyenne Indian Reservation; and the Wolf Mountains, which stand 800 to 1,000 feet above the adjoining country along the Sarpy Creek-Armells Creek divide in the southwestern part of the area. Many of the upland surfaces in the central and northern parts of the area have a subdued, rolling, and barren appearance where the surface strata are soft clay and shale. The descent from the uplands toward the valleys is usually steep near the uplands but flattens to irregular dissected slopes that merge with the valley bottoms. Badlands are developed along both sides of the lower Rosebud Creek valley.

The flood plain of the Yellowstone River is as much as 2 miles wide and is bordered by a succession of gravel-covered benches which, within 4 to 8 miles of the south side of the river, rise by steps to the uplands. Similar benches extend from the Yellowstone Valley up the valleys of Rosebud Creek and Armells Creek, and also occur along the valley of the Tongue River, as well as along many of the lesser streams in the area.

The altitude in central Rosebud County ranges from about 2,435 feet on the Yellowstone River near Hathaway, to about 4,780 feet at the top of the Wolf Mountains, resulting in a maximum relief of 2,355 feet. The local relief, however, seldom exceeds 300 feet.

CLIMATE

The region is semiarid. The average annual precipitation is about 14 inches except in the Wolf Mountains, where the average precipitation is 4 to 6 inches more. Of the total precipitation, about 70 percent falls as rain from April to September; the rest falls as snow during the other 6 months. The temperature drops as low as 40 F below zero in the winter, and rises to more than 100 F in the summer. The summer season is short; below-freezing temperatures may be expected as early as the middle of September and as late as the middle of May.

SETTLEMENT AND LAND USE

Forsyth, the county seat of Rosebud County, is the only incorporated town in the area. In 1950 it had a population of 1,906. The largest of the unincorporated settlements in the area are Colstrip (population about 300) and Rosebud (population about 200). The population density of the area, excluding the towns, is less than 1 person per square mile.

More than 90 percent of central Rosebud County is used for the raising of livestock. Less than 5 percent of the land is under cultivation, chiefly for small grains. About two-thirds of the crops are raised by dry-farming methods; irrigation is generally restricted to the flat valley bottoms where water is available.

DRAINAGE AND WATER SUPPLY

The Yellowstone River, which flows eastward, receives all the runoff of the area, principally by means of the northward-flowing tributaries, Tongue River, Rosebud Creek, and Armells Creek. (See fig. 49.) The Tongue River drains the southeastern part of the area and flows into the Yellowstone River at Miles City, Mont. Rosebud Creek drains most of the southern and central parts of the area and empties into the Yellowstone less than a mile west of Rosebud. Armells Creek drains most of the western part of the area and flows into the Yellowstone about 4 miles west of Forsyth.

The Yellowstone and Tongue Rivers are the only streams within the area that offer a fairly large, continuous supply of water. Another large available supply of water is the Bighorn River, which flows northward into the Yellowstone about 30 miles west of the western boundary of Rosebud County. The discharge and rate of flow of these streams vary greatly during the year, as well as from one year to the next. Throughout the period of record the maximum discharge of the Yellowstone River near Miles City was recorded on June 19, 1944, as 96,300 cfs. The minimum discharge of the river was recorded on December 14, 1932 when the flow was greatly affected by ice and was only 996 cfs. The maximum discharge of the Tongue River near Decker, Mont., was recorded on June 5, 1944 as 5,710 cfs., and the minimum discharge on April 17 to May 8, 1940, when the water level was so low that no accurate reading could be obtained and the discharge was probably less than 0.5 cfs. The maximum discharge of the Bighorn River near St. Xavier, Mont., was recorded on June 16, 1935, as 37,400 cfs., as compared to the minimum discharge of 228 cfs. on December 9, 1937. The average monthly discharge usually reaches a maximum in June, and a minimum either during the winter when the rivers are frozen over, or in late summer during the dry season. (See table 2.) Much water is diverted from the main streams and tributaries for irrigation.

Intermittent streams are generally a source of water only during heavy rains or the spring thaw, when they often attain flood stage. Ground water is sufficient for local domestic and limited industrial use, although it is so heavily mineralized in many places that it is unfit for use in boilers or for human consumption. The ground water resources in central Rosebud County have been discussed in detail by Renick (1929).

TABLE 2.—*Average discharge of the major streams in the vicinity of central Rosebud County, Mont., in 1,000 acre-feet* [1]

[Adapted from the U. S. Geological Survey Water-Supply Papers]

Month	River and gaging station		
	Yellowstone River, Miles City [2]	Tongue River, Decker [3]	Bighorn River, St. Xavier [4]
January	240. 2	9. 1	92. 3
February	255. 8	8. 3	87. 6
March	454. 5	14. 4	175. 0
April	482. 6	24. 6	154. 9
May	1, 046. 1	69. 9	343. 3
June	2, 242. 5	99. 2	710. 5
July	1, 238. 8	31. 5	386. 0
August	420. 9	8. 3	172. 7
September	374. 2	11. 0	137. 0
October	418. 6	19. 5	152. 2
November	352. 3	18. 5	134. 5
December	264. 1	10. 8	109. 6
Total	7, 790. 6	325. 1	2, 655. 4

[1] 1.9835 acre-foot = 1 cfs. flowing for 24 hours.
[2] Records used were for years 1922-23, and 1928-47.
[3] Records used were for years 1928-47.
[4] Records used were for years 1929-47.

TRANSPORTATION

Rosebud County is served by two railways, both of which pass through Forsyth. The Chicago, Milwaukee, St. Paul and Pacific Railroad is on the north side of the Yellowstone River and extends eastward through Miles City and westward through Roundup. The Northern Pacific Railway follows the south side of the Yellowstone River and extends eastward through Miles City and westward through Billings. Colstrip, the main coal mining center in Rosebud County, is connected to the main line of the Northern Pacific by a spur extending up Armells Creek. Work was begun in 1923 on a proposed railway paralleling the Tongue River and extending from Miles City to Sheridan, Wyo., but the project was abandoned soon after it was begun.

Paved U. S. Highway 10–12 follows the south side of the Yellowstone and is an important trans-State route. From this road, a paved road extends southward up Armells Creek to Colstrip, State Route 45 extends southward up Rosebud Creek, and State Route 6 extends northwestward across the Yellowstone River at Forsyth. Both of the State routes are graded, fairly well drained, gravel-surfaced roads. A county road comparable to these is the Tongue River road which leads from Miles City to Ashland, and crosses the southeastern part of the area. The only other gravel-surfaced county roads in the area are those paralleling Reservation and Sweeney Creeks in the northern part of the area, and those paralleling Snyder Creek and the Greenleaf Creek-Lay Creek drainage basins in the southeastern part of the area. Other county roads are graded but not surfaced. Trails or private secondary roads lead to the more remote parts of the area and are generally passable except when wet or covered with snowdrifts.

LAND OWNERSHIP

The area of this report is within the limit of land grants to the Northern Pacific Railway, under which the railroad was given title to all odd-numbered sections in each township. Of the even-numbered sections, those numbered 16 and 36 were granted to the State of Montana as school land, and the other 16 remained the property of the Federal Government until homesteaded or sold. The railroad has sold much of its land, but has retained the mineral rights on most tracts. Of the Government lands, the better and more accessible tracts have been disposed of, although some of the mineral rights and most of the coal rights have been reserved. Generally, both the surface and mineral rights of the lands owned by the State of Montana have been retained by the State. An increase in exploration and drilling for oil in 1951 and early 1952 have resulted in the leasing of mineral rights on many tracts to oil companies.

ELECTRIC POWER

The only electric power in central Rosebud County comes from power plants in Billings and Miles City that are operated, respectively, by the Montana Power Company and the Montana-Dakota Utilities Company. The line from Billings extends to Colstrip by way of Hardin and has an operating capacity of 55,000 volts. The line from Miles City parallels the Yellowstone River, extends to Forsyth, and has an operating capacity of 57,000 volts. The Montana-Dakota Utilities Company also furnishes power to the Mid-Yellowstone Electric Co-operative, Inc., which supplies domestic consumers along the Yellowstone River. The Bureau of Reclamation plans to extend through Forsyth and Hardin the 115,000-volt line that now reaches from the generators at Fort Peck to Miles City.

STRATIGRAPHY

All the rocks exposed in central Rosebud County are of sedimentary origin and range in age from Upper Cretaceous to Recent (Andrews, Lambert, and Stose, 1944). The upper part of the marine Judith River formation (Upper Cretaceous) is the oldest formation cropping out in the mapped area; it is exposed in the bluffs along the Yellowstone River between Reservation Creek and the western boundary of the county. The Judith River is overlain by the marine Bearpaw shale (Upper Cretaceous), which crops out west of Armells Creek in low rounded hills that are covered by a mantle of terrace gravels. The upper part of the Bearpaw shale consists of a sandy zone which is transitional to the overlying nonmarine Hell Creek formation (Upper Cretaceous), and is probably equivalent to the Colgate sandstone member of the Fox Hills sandstone of eastern Montana. The Hell Creek formation is composed chiefly of sandstone and shale and is from 630 to 675 feet thick. Badlands in the Hell Creek formation occur along much of the northern part of Rosebud Creek valley, along Armells Creek up to its forks, and on Smith and Reservation Creeks. The Hell Creek formation is conformably overlain by the Tullock member of the Fort Union formation. Because this investigation is concerned primarily with the thick coal beds in the Fort Union formation, the reader is referred to works cited in the bibliography for detailed descriptions of the Judith River, Bearpaw, and the Hell Creek formations.

FORT UNION FORMATION

The Fort Union formation of Paleocene age overlies the Hell Creek formation. It attains a thickness of about 2,175 feet in central Rosebud County, and is composed of 3 members—the Tullock, the Lebo shale, and the Tongue River.

TULLOCK MEMBER

The Tullock member of the Fort Union formation consists of light yellowish-gray sandstone, sandy shale, and several thin coal beds. The thickness of the member ranges from 240 to about 300 feet. It crops out in the valleys of Armells, Smith, Reservation, Rosebud, and Sweeney Creeks. The Wright coal bed of the Forsyth coal field (Dobbin, 1929) marks the base of the Tullock member in the western half of the area, but east of Rosebud Creek the Wright bed is discontinuous and the contact between the Tullock member and the underlying Hell Creek formation is not well defined. West of the Rosebud Creek-Tongue River divide the top of the Tullock member is marked by either the Big Dirty coal bed or by a resistant calcareous sandstone rimrock 2 to 14 feet thick. East of the Rosebud Creek-Tongue River divide, however, the top of the Tullock member is not evident because the Big Dirty coal bed is not persistent, the rim-forming sandstone of the western side of the divide is not present, and the lithology is similar to that of the overlying Lebo shale member.

LEBO SHALE MEMBER

The Lebo shale member of the Fort Union formation is made up of loosely consolidated dark-gray to black clay and shale beds that contain many zones of ironstone concretions, as well as several thin coal beds of little economic value. Gray and yellow sandstone lenses as much as 10 feet thick occur locally, though none is persistent for more than a few hundred feet. The member ranges in thickness from 105 feet in the western part of the county to about 220 feet in the eastern part, and averages about 170 feet. This member forms much of the surface in the northern half of the mapped area and extends southward for many miles up the valleys of both Rosebud Creek and the Tongue River. It is loosely consolidated and subject to rapid erosion; consequently, it supports little vegetation. In the valleys it erodes readily into a narrow, intricately dissected zone of badlands, and on the divides it forms a broad zone of rolling treeless country.

TONGUE RIVER MEMBER

The Tongue River member is the uppermost unit of the Fort Union formation in this region. The contact with the Lebo shale member is marked by an upward transition through a zone of sandy shale to the predominantly light-colored beds of sandstone and shale that distinguish the Tongue River member from the other members of the Fort Union formation. It crops out chiefly in the southern half of the mapped area (fig. 49) and in the uplands between the major stream valleys. Although the upper part has been removed by erosion, 1,686 feet of the member remain beneath the top of the Wolf Mountains (Dobbin, 1929, p. 16), and 1,600 feet remain beneath Garfield

Peak in the extreme southern part of the area along the Tongue River-Rosebud Creek divide (Bass, 1932). Besides the sandstone and shale, the Tongue River member contains sandy shale, carbonaceous shale, a few thin fresh-water limestone beds, and coal beds. At least 10 of the coal beds in this member are persistent and attain a minable thickness at accessible localities; of these beds, 3 contain deposits of coal that are described in this report as being particularly favorable for recovery by strip-mining methods. Much of the coal has been burned along the outcrop. The heat from the burning has baked and fused the overlying rocks, thereby producing thick beds of pink, red, or brown clinker, or "scoria" as it is called locally. These clinker beds are much more resistant than most of the other strata in the Tongue River member, and usually form protective caps above fairly steep slopes.

Although many of the individual beds are lenticular and can be traced in detail for only short distances, groups of beds are generally persistent and can be followed continuously over large areas. Because of the differences in hardness of successive strata in the Tongue River member, the land surface formed by the member is characterized by isolated buttes, mesalike hills, and long narrow divides, all of which are capped by the more resistant remnants of the strata. In some of the less dissected parts of its area of outcrop, however, the Tongue River member forms rather broad and nearly flat-lying upland surfaces.

The Tongue River member in Rosebud County contains fossil remains of plants (Dobbin, 1929, p. 17–18), fresh water molluscs, and gastropods. A few silicified vertebrate remains taken by the writer from the base of a thin coal bed about 350 feet above the Rosebud bed, in the NE¼, NW¼ sec. 7, T. 1 N., R. 40 E., have been identified by D. H. Dunkle of the United States National Museum as bones of the rhynchocephalian reptile, *Champsosaurus*. A specific determination could not be based on the fragmentary suite collected. *Champsosaurus* is restricted in geologic distribution to Late Cretaceous and Paleocene time.

GRAVEL DEPOSITS AND ALLUVIUM

Gravel terraces as much as 70 feet thick lie at as many as 13 different levels above the Yellowstone River in central Rosebud County. These deposits range in age from Oligocene to Recent and are made up of well-rounded fragments of igneous rocks, quartzite, limestone, and clinker in a matrix of fine sand and silt. Some of the fragments are as much as 1 foot in diameter, but most are pebbles and cobbles ranging from 1 to 4 inches in diameter. Although most of the gravel is loosely consolidated, some of the thicker deposits are cemented into a conglomerate.

285995—54——8

The highest of these gravel deposits lies 1,050 to 1,100 feet above the Yellowstone River and probably correlates with the gravel deposits of Oligocene age that cap the Cypress hills in Canada (Alden, 1932). One such deposit caps a plateau on the Armells Creek-Sarpy Creek divide in the northwest corner of T. 3 N., and the southwest corner of T. 4 N., R. 39 E., and another caps one of the highest hills and ridges in the northern part of T. 4 N., R. 41 E. (Dobbin, 1929, p. 21–22).

The next highest gravel deposits in the county lie in the central part of T. 5 N., R. 41 E., about 700 feet above the Yellowstone River, and in the southeast quarter of T. 5 N., R. 44 E., about 785 feet above the Yellowstone. These two deposits are tentatively correlated with the Flaxville gravel of Miocene or Pliocene age (Dobbin, 1929, p. 22, and Pierce, 1936, p. 65).

Most other terraces in central Rosebud County are of Pleistocene age. The most widespread of these lies about 200 feet above the Yellowstone River and forms the broad Forsyth Flats between Forsyth and Rosebud. Some stream-deposited gravel beds lie along nearly all the main stream valleys in central Rosebud County and are best developed along Rosebud Creek and Greenleaf Creek. Practically all the deposits lie on the west side of the creeks and are less than 300 feet above the present stream level.

The most recent material to be deposited in this area is the alluvium in the channels of the streams and coulees. Most of this alluvium consists of fine silt, clay, and sand, but at some places it also contains a considerable amount of gravel. It attains a thickness of 40 feet along the bottoms of some of the larger valleys and forms some of the most productive farmland in the area.

STRUCTURE

Central Rosebud County lies in a broad, shallow structural basin between the Porcupine dome on the north, the Bighorn Mountains to the southwest, and the Black Hills to the southeast; the basin has a maximum structural relief of about 1,900 feet. The main subsidiary structures of this basin are the Tongue River syncline and the Ashland syncline. The axis of the Tongue River syncline extends northeastward along the Tongue River; the axis of the Ashland syncline plunges gently southeastward across the southern part of the area, passing about 4 miles south of Colstrip, and finally connecting with the Tongue River syncline about 2 miles south of Ashland near the center of T. 3 S., R. 44 E. (Dobbin, 1929, p. 23, and Bass, 1932, p. 47–48). Most of the strata appear to be flat-lying, because their slight inclination is not apparent to the eye. The maximum dip of the beds is near the Porcupine dome, where they dip generally southeastward about 3°. Elsewhere in the area, the dip seldom exceeds 1°, and though the direction of inclination is still southeastward, it is modified by many minor irregularities, most of which probably are associated with the Porcupine dome. The more noticeable of these irregularities are three anticlines that cross the area nearly parallel to the axis of the Ashland syncline. One of these passes through the Castle Rock strippable deposit and is expressed by gentle doming (Dobbin, 1929, p. 23); another, modified by a fault zone, extends northwestward from the northwest corner of T. 2 N., R. 41 E.; a third, mapped by Pierce (1936, p. 68) in the Rosebud coal field, plunges southeastward from T. 5 N., R. 42 E.

The rocks are slightly faulted at a few places in the investigated area, but no evidence of faulting was seen in any of the deposits of coal described in this report.

COAL

All the thick extensive beds of minable coal in the investigated area are in the Tongue River member of the Fort Union formation. The Lebo shale and Tullock members of the Fort Union formation, as well as the Hell Creek formation, contain a few coal beds, but they are thin, discontinuous, or interbedded with partings of clay, shale, or bone.

PHYSICAL AND CHEMICAL CHARACTERISTICS

Most of the coal described in this report is black and clean at fresh exposures, and generally has a banded appearance due to the presence of long shiny lenses of vitrain or pre-vitrain. Each of these lenses is derived from a single, relatively large fragment of woody tree trunk or root, and may range from a fraction of an inch to several inches in thickness.

Impurities commonly found in the coal are concentrations of clay matter in many thin layers throughout the coal bed; pyrites; resin globules; crystals of selenite, gypsum, and calcite; and silicified tree remains. Jarosite, a basic sulfate of potassium and ferric iron, is associated commonly with most of the coal beds in this region. It appears as a yellow powder in cavity-fillings, veinlets, or as a coating on the coal bed or adjacent rocks.

The rank of the coal, as determined according to the standard specifications of the American Society for Testing Materials (1939, p. 1–6), is subbituminous B and C. (See table 3.) The heating value calculated on the moist, mineral-matter-free basis, ranges from 8,730 Btu to 10,120 Btu.

TABLE 3.—*Analyses of coal from Rosebud County, Mont.*

[Analyses by U. S. Bureau of Mines]

Laboratory No.	Source	Form of analysis [1]	Percent						Heating value (Btu.)
			Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Air-dry loss	
96584	Wright bed, Wright mine, sec. 7, T. 5 N., R. 40 E.	A	23. 7	28. 6	35. 7	12. 0	0. 6	6. 5	8, 080
		B	--------	37. 5	46. 8	15. 7	. 8	--------	10, 590
		C	--------	44. 5	55. 5	--------	1. 0	--------	12, 560
96587	Sawyer bed, open pit, sec. 30, T. 1 N., R. 40 E.	A	26. 6	28. 9	37. 7	6. 8	1. 8	8. 1	8, 080
		B	--------	39. 4	51. 4	9. 2	2. 5	--------	11, 010
		C	--------	43. 4	56. 6	--------	2. 7	--------	12, 130
96585	Hamre bed, Hamre mine, sec. 29, T. 5 N., R. 40 E.	A	16. 6	21. 8	25. 2	36. 4	. 6	5. 1	5, 430
		B	--------	26. 2	30. 2	43. 6	. 7	--------	6, 510
		C	--------	46. 4	53. 6	--------	1. 2	--------	11, 540
A-35365	Rosebud bed, Colstrip mine, sec. 34, T. 2 N., R. 41 E.	A	24. 4	28. 3	39. 9	7. 4	. 6	5. 1	9, 050
		B	--------	37. 4	52. 8	9. 8	. 8	--------	11, 970
		C	--------	41. 4	58. 6	--------	. 9	--------	13, 260
A-31175	Rosebud bed, Eureka (Miller Coulee) mine, sec. 24, T. 1 N., R. 41 E.	A	23. 1	29. 9	41. 5	5. 5	. 7	8. 1	9, 500
		B	--------	38. 8	54. 0	7. 2	. 9	--------	12, 350
		C	--------	41. 8	58. 2	--------	1. 0	--------	13, 300
96583	Lee bed, McKay mine, sec. 34, T. 1 S., R. 41 E.	A	23. 9	28. 7	40. 3	7. 1	. 6	8. 4	9, 160
		B	--------	37. 7	52. 9	9. 4	. 8	--------	12, 030
		C	--------	41. 6	58. 4	--------	. 8	--------	12, 270
D-51574	Wall bed, Alderson mine, sec. 21, T. 2 S., R. 41 E.	A	28. 7	27. 5	39. 6	4. 2	. 3	15. 0	8, 630
		B	--------	38. 6	55. 5	5. 9	. 5	--------	12, 100
		C	--------	41. 1	58. 9	--------	. 5	--------	12, 860
95879	Brewster-Arnold bed, Brewster-Arnold mine, sec. 23, T. 6 S., R. 42 E.	A	27. 3	28. 9	39. 2	4. 6	. 6	9. 7	8, 850
		B	--------	39. 8	53. 9	6. 3	. 8	--------	12, 170
		C	--------	42. 5	57. 5	--------	. 9	--------	12, 990
A-42289	Terret bed, Holt mine, sec. 20, T. 3 S., R. 44 E.	A	27. 3	27. 5	41. 3	3. 9	. 4	6. 8	9, 020
		B	--------	37. 8	56. 8	5. 4	. 6	--------	12, 400
		C	--------	40. 0	60. 0	--------	. 6	--------	13, 110

[1] A, sample as received; B, sample air dried ;C, sample ash and moisture free.

Of the analyses given in table 3, none is from samples taken from the deposits of strippable coal, although three analyses are probably representative of the coal within the deposits. The sulfur content in all samples of coal from the Tongue River member is consistently low, as is also the ash content. The Wright and Hamre beds, which have a high ash content in the analyses shown on table 3, occur in the Tullock member.

Important characteristics of both subbituminous coal and lignite are the tendencies to lose moisture on exposure to air, to slack, and to ignite spontaneously. Because of these tendencies the mines of the region produce only enough coal to satisfy the immediate, generally seasonal demands of the consumers. Several methods of storing have been found successful in preventing the loss of moisture and the accompanying breaking up of the coal. One method is to submerge the coal under water; another is to store it in open pits or in compacted piles; yet another is to store it in piles capped with an airtight cover such as road tar. The preserving quality of water is well demonstrated in the coal beds: that part of a bed that is always beneath the water table yields firm, brittle coal, while the part which has been subjected to successive wetting and drying is often slacked to such an extent that it is a mere powder.

CLINKER AND ITS RELATION TO COAL

The extensive burning of thick coal beds, probably caused by spontaneous combustion at the outcrop, has destroyed much of the coal originally present in the area. This burning has resulted in the formation of abundant and conspicuous masses of reddish-brown clinker. The term "clinker" includes all of the several types of rock that have been produced from the fusing and baking of the overlying sediments by the intense heat of the gases that rise from a burning coal bed. Immediately overlying the coal and around natural chimneys used by the escaping gases at the time of burning, the rocks are completely melted and have a slaggy vitreous appearance, show flow lines, and contain frothy vesicular masses. The rocks that were farther away from the source of heat show partial fusion or mere baking. In the fused zone most of the rocks are gray, black, yellow, or greenish; elsewhere the predominant color is brick-red or reddish-brown. The rocks overlying a burning coal bed crack and slump as their support is burned away; hence, a breccia of fused angular blocks of baked rock is common near the base of most clinker zones. Clinker strongly resists weathering and erosion so that it forms the cap rock on many of the buttes, mesas, and ridges in the area; it also makes good all-weather road surfacing, and is extensively used for that purpose where supplies are available.

The burning of coal beds has little or no effect on the underlying rocks. The clinkered zone extends upward from the level of the original base of the coal beds for distances that depend generally on the original thickness of the coal bed. A burned out coal bed 5 to 15 feet thick normally produces a clinkered zone 20 to 50 feet thick, and thicker beds may produce clinker more than 100 feet thick. Burning of the coal bed may extend back from the original outcrop for more than a mile; the actual distance depends largely on the thickness and competence of the overburden and on the thickness of the coal. Thick coal beds apparently burn more extensively than do thin beds; as a result, exposures of thick coal are fewer because clinker now marks the trace of their former outcrop line. The burning has not been confined to any one period of time; clinker fragments in the Pleistocene gravel deposits indicate that some of the coal burned at a fairly early date. Conversely, the Rosebud bed is still burning in sec. 2, T. 1 N., R. 40 E.

PRINCIPAL COAL BEDS

The coal beds that contain strippable coal deposits described in this report are the Terret bed, the Rosebud bed, and the Knoblock bed. These beds are in the Tongue River member of the Fort Union formation. Their stratigraphic relationships within this member are shown by the columnar sections of figure 51, and their locations and general thicknesses are shown by the maps in figures 52 and 53. Much of the information used in compiling these maps and columnar sections was derived from previous publications; some was obtained by prospecting with a power auger; and the rest was obtained from water-well logs and from prospects made by the Northwestern Improvement Company.

TERRET COAL BED

The Terret coal bed was named in the Ashland coal field (Bass, 1932, p. 51) and lies entirely within the Ashland field and the Rosebud field (Pierce, 1936). For the most part it underlies the uplands along the Rosebud Creek-Tongue River divide in the southeastern part of the mapped area. (See fig. 52.) There, it is about 140 to 160 feet above the base of the Tongue River member. Two strippable deposits mapped in this bed are the Sweeney Creek deposit (fig. 54) and the Snyder Creek deposit (fig. 56). West of the Snyder Creek deposit, the bed consists of thin benches separated by partings; the bed pinches out in the southern part of T. 1 N., R. 44 E., but reappears in the southwestern part of T. 1 S., R. 44 E. The maximum reported thickness of the coal is 17 feet on the Snyder Creek deposit. The thickness probably averages about 12 feet along most of the divide from Snyder Creek to Sweeney Creek, but northward, in T. 4 N., R. 44 E., the bed splits into several benches not suitable for mining.

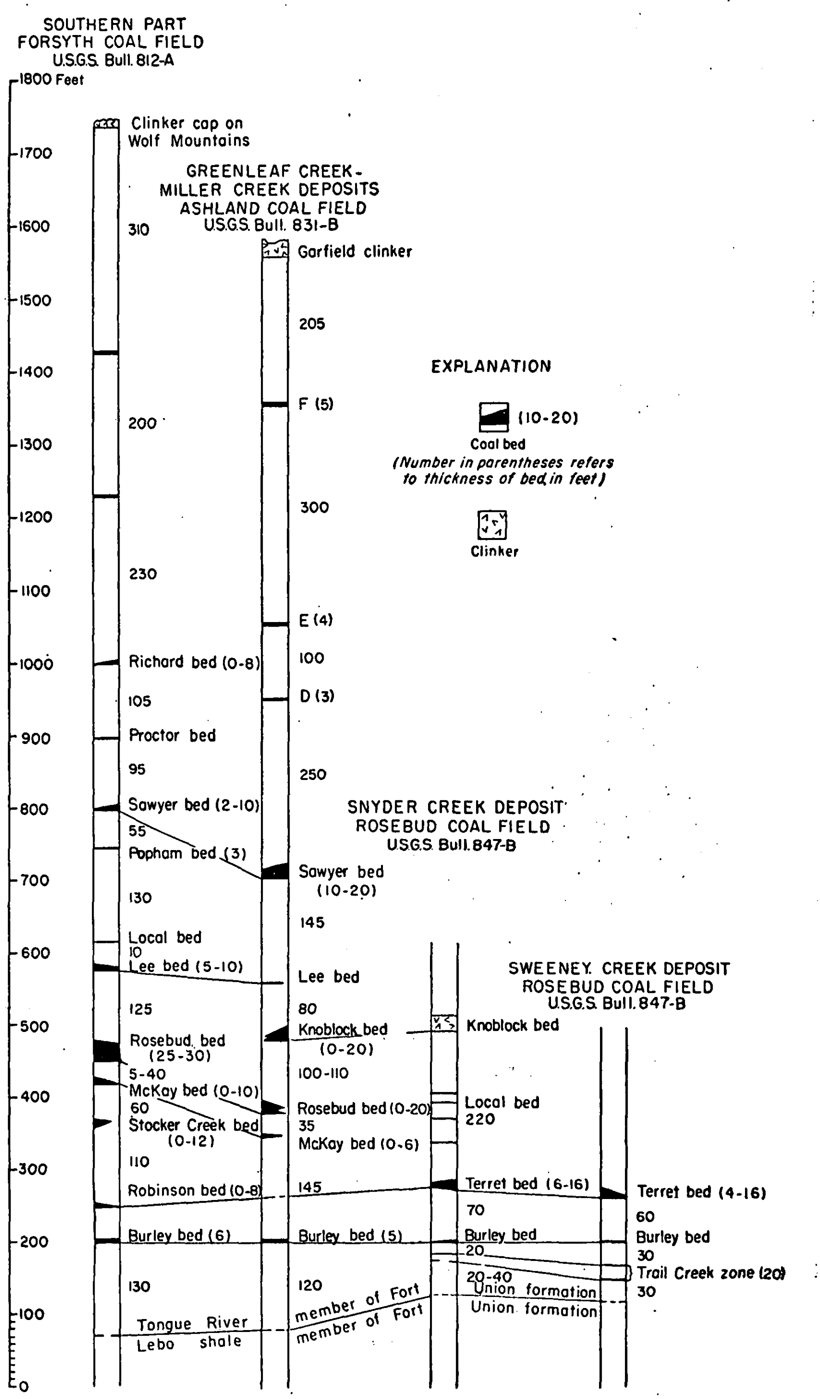

FIGURE 51.—Generalized columnar sections showing stratigraphic position and correlation of the coal beds in and near the strippable coal deposits in central Rosebud County, Mont.

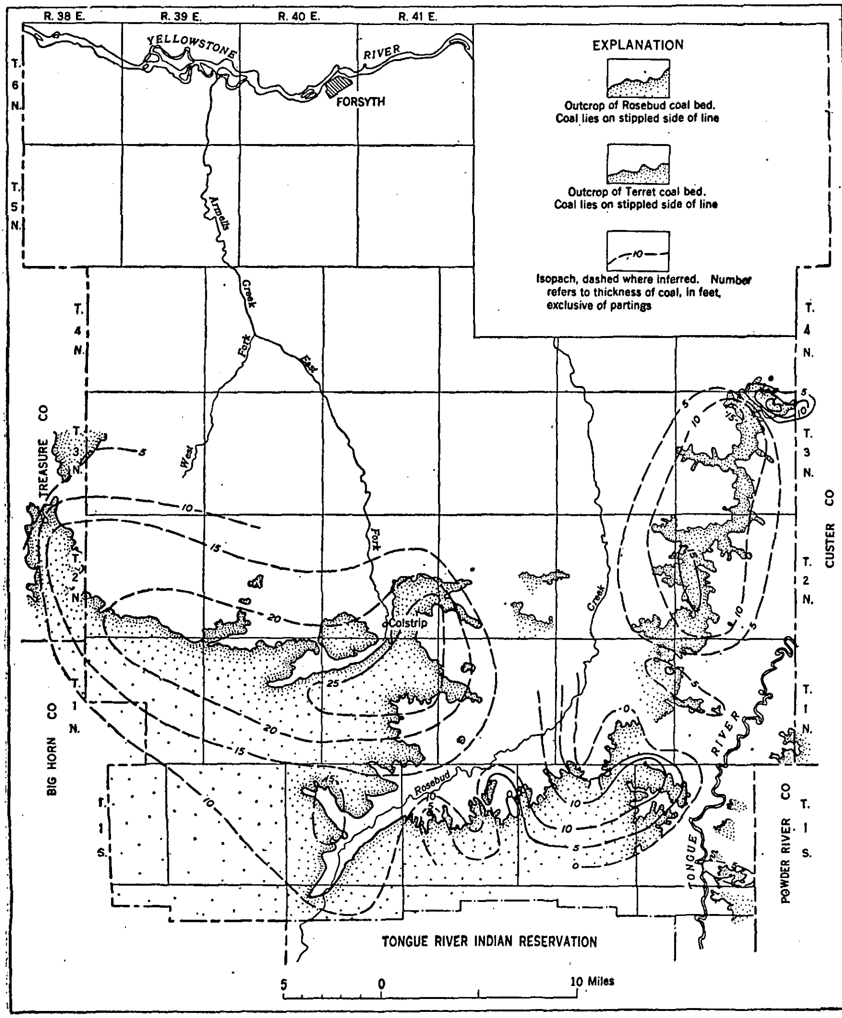

FIGURE 52.—Isopach map of Rosebud and Terret coal beds in central Rosebud County, Mont.

ROSEBUD COAL BED

The Rosebud coal bed is the most widespread and the thickest bed in the mapped area. (See fig. 53.) It was named by Dobbin (1929, p. 27) in the Forsyth coal field. It lies about 360 feet above the base of the Tongue River member of the Fort Union formation and crops out mainly along the headlands of East and West Forks of Armells Creek, and at a few places along Rosebud Creek and its tributaries. The bed is fairly persistent west of Rosebud Creek where it averages about 20 feet in thickness, but east of Rosebud Creek it thins and finally disappears.

A petrographic analysis of a sample of the Rosebud coal bed taken from the Colstrip mine showed that the coal contained 51 percent

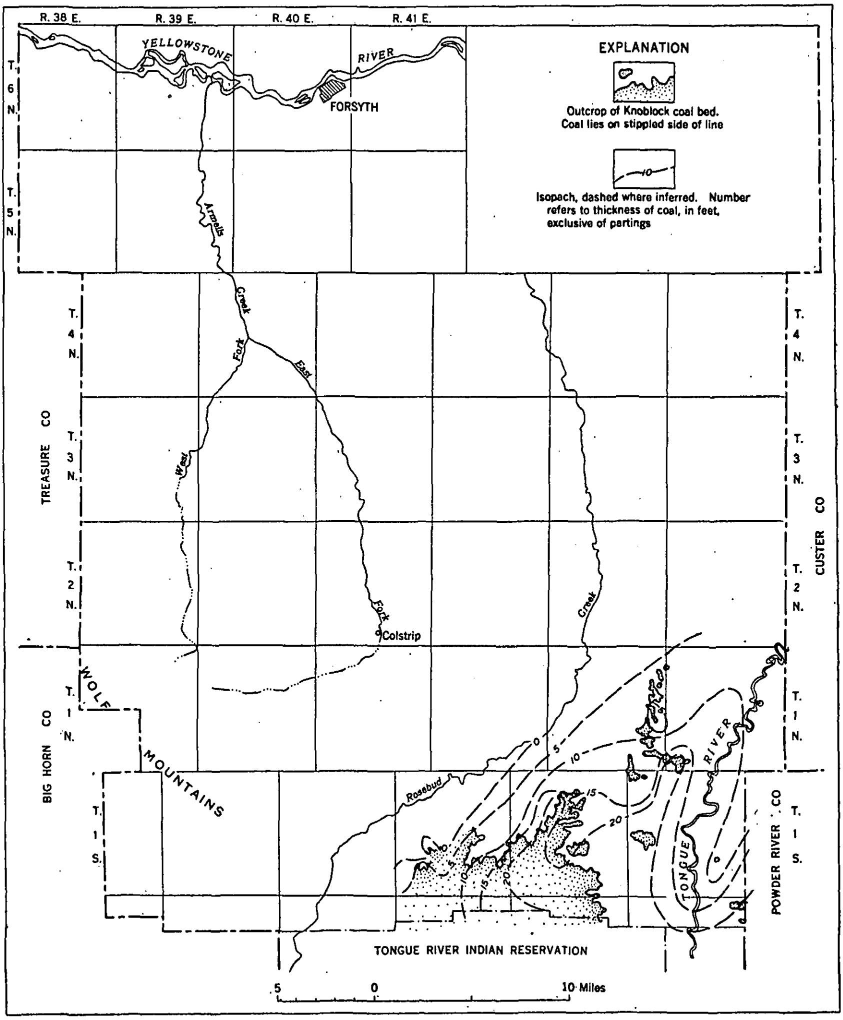

FIGURE 53.—Isopach map of Knoblock coal bed in central Rosebud County, Mont.

anthraxylon (vitrain), 33 percent translucent attritus, 13 percent opaque attritus, and 3 percent fusain (Fisher and others, 1942, p. 74). In one of the strippable deposits, the Rosebud bed contains an unusual concentration of selenite that occurs as a vein or fracture filling along a definite band in the coal bed. This band ranges from a few inches to more than a foot in thickness.

Five strippable deposits were mapped in this bed; they are, in order of decreasing amount of reserves: the Castle Rock deposit (pl. 51); the West Fork Armells Creek deposit (pl. 53); the South Coal Bank Coulee deposit (fig. 60); the North Miller Creek deposit (pl. 50); and the East Miller Creek deposit (pl. 50).

In a few places another coal bed, the McKay bed, lies beneath the Rosebud coal bed. Although the interval separating the two beds is only 7 to 30 feet, the McKay bed would probably be unprofitable to recover simultaneously with the Rosebud bed, because it appears to be less persistent than the Rosebud and its thickness ranges from 2 to 10 feet. The strip mine at Colstrip does not mine the McKay bed, though in that area it underlies the Rosebud bed at a depth of 10 to 18 feet and has an average thickness of about 9 feet.

KNOBLOCK COAL BED

The Knoblock coal bed underlies only part of the Ashland coal field area east of Rosebud Creek. (See fig. 53.) In the Rosebud Creek valley the bed occurs about 400 feet above the base of the Tongue River member, but in the Tongue River Valley, it is only about 300 feet above the base. The bed averages about 20 feet in thickness beneath the southern part of the uplands between the two valleys, but it thins rapidly to the north. Wide expanses of clinker formed by the burning of the Knoblock coal bed are a conspicuous feature of much of the northern part of these uplands.

Two strippable deposits were mapped in the Knoblock bed: the Greenleaf Creek deposit (pl. 49) and the South Miller Creek deposit (pl. 50).

UTILIZATION OF THE COAL

The local demand for coal in the Fort Union-Powder River region is small. Very little of the coal is mined for domestic use; most of it is used as fuel for locomotives. At the time the region was first settled, several small mines in central Rosebud County were worked intermittently to supply the needs of the sparse population. As natural gas or petroleum products gradually replaced coal as a fuel, most of the local commercial mines closed. In 1951 a small strip mine in sec. 24, T. 1 N., R. 41 E., the Miller Coulee mine, was the only remaining commercial source of coal for domestic use; it sold only slightly more than 1,000 tons of coal.

The Northwestern Improvement Company in 1924 began strip-mining the Rosebud coal bed on a fairly large scale near the present town of Colstrip. The mine has operated continuously since that time, its entire output being used by the Northern Pacific Railway as locomotive fuel. More than 38 million tons of coal have been produced from this mine since it was first opened. The present requirements of the railroad are slightly more than 1½ million tons of coal a year. The equipment now in use, however, is capable of mining more than 2½ million tons a year (W. V. Styles, oral communication). The coal is loaded directly into railroad cars, where it generally breaks into pieces small enough to be burned in locomotives without additional crushing or cleaning. In spite of the large reserves of coal and the relatively low cost of mining by the mining techniques at Colstrip, the use of diesel oil as fuel for locomotives is increasing to such an extent that the regional demand for coal has dwindled.

Increased exploitation of the coal is dependent on an increase in the industrialization of the western part of the Missouri River basin. Should industrialization continue at its present rate, within a comparatively short time the eventual demand for power will make it necessary to supplement hydroelectric plants with gas turbine or steam electric plants that burn natural gas, petroleum products, or coal. In this area, coal probably would be the most suitable fuel.

Another possible use for the low-rank coal of the Fort Union-Powder River region is the production of synthetic liquid fuels and other chemical derivatives of coal, for lignite and subbituminous coal are well suited for use in several synthesizing processes. In view of the considerable demand for water by synthetic fuel plants, the number in this region would, in general, be limited by the amount of water available in the Yellowstone River.

An additional potential market for the coal from this region is in the Pacific Northwest. The rapid increase in the industrialization of the States of Oregon and Washington calls for a corresponding increase in the use of fuel. If it should become necessary to import additional supplemental quantities of coal from other localities, the Fort Union-Powder River region is particularly well suited to meet this demand, for it contains not only an abundant supply of coal that can be mined cheaply, but it has excellent rail connections with the Pacific Northwest. These facts compensate for the low rank of the coal and for the handicaps of its tendency to slack and burn spontaneously.

SCOPE AND METHOD OF INVESTIGATION

Assuming that the future demand for coal in this region will be supplied from strip mines, this report includes a description of the deposits that offer attractive possibilities for a development of this type. As such, they contain sufficient reserves to satisfy the prospective needs of the area for many years, and include those deposits that probably will be developed first because of their nearness to prospective points of consumption or railroad shipping. It is emphasized that these deposits do not exhaust by any means the number of places in the area where coal can be strip mined economically.

STANDARDS OF SELECTION

The factors that determine the suitability of a coal bed for strip mining have an economic basis; they vary from mine to mine and from year to year, according to the cost of mining the coal and the value of the coal produced. Thus, coal deposits that cannot be mined profitably today may be mined profitably 10 years from now. Arbitrary standards, therefore, have been used in selecting and mapping the strippable deposits discussed in this report. These standards are based on advanced stripping practices of the present, with an allowance for probable advances in the future.

Of the many factors that affect the cost of mining coal by stripping, those most applicable to selecting the best deposits in central Rosebud County are: thickness of the coal, thickness of the overburden, shape of the deposit, nature of the terrain over the deposit, and the reserves of strippable coal within the deposit. Other factors pertain to the nature of overburden, dip of the coal beds, and the stripping ratio. The nature of the overburden in central Rosebud County is such that it can be removed easily with the aid of light blasting. The dip of the coal in the area is generally so low that the strata appear to be flat-lying, and stripping operations would not be affected unless the dip permitted the accumulation of water in the strip pits. Standards based on a stripping ratio—which is expressed as the number of cubic yards of overburden that must be removed to recover a ton of coal—were not used for selecting strippable deposits because they would merely duplicate or modify the standards that were based on the thickness of coal, thickness of the overburden, and amount of reserves.

THICKNESS OF COAL

The minimum thickness of a coal bed that can be stripped advantageously was arbitrarily placed at 5 feet, partly in order to restirct the present studies to the thicker coal beds, and partly because of the acceptance of this figure in studies of coal reserves as the dividing line between "thin" and "intermediate" lignite or subbituminous coal. (See Combo and others, 1949, 1950, and Averitt and Berryhill, 1950.) The term "thickness of coal" refers to the thickness of a coal bed exclusive of (1) partings, (2) benches of coal that are separated from the main bed by partings of more than 6 inches thick, and (3) benches of coal that are less than 6 inches thick and are separated from the main bed by any parting more than ½ inch thick. The average thicknesses of the deposits described below range from 9 to 24 feet.

THICKNESS OF OVERBURDEN

The thickness of overburden that can be removed economically from the coal depends largely on the type and capacity of the earth-moving equipment used. A large part of the equipment now in use can move as much as 60 feet of cover, and, in some parts of the country, that figure is considered as a rough maximum for strip mining, except under very favorable conditions. At the Colstrip mine the average thickness of overburden moved in 1950 to uncover a thickness of 23 to 28 feet of coal was 85 feet, the maximum thickness being 125 feet. For the purpose of this report, the maximum thickness of overburden was chosen arbitrarily to be 120 feet. On the maps of the deposits the overburden is divided into three thickness ranges: 0 to 60, 60 to 90, and 90 to 120 feet. In the table of reserves (table 1), the reserves are given according to overburden thickness ranges of 0 to 60, 60 to 90, and 90 to 120 feet.

SHAPE OF DEPOSIT

For economy in mining, areas to be stripped should be relatively wide in proportion to their length, though this requirement is flexible. Long, narrow areas of the "shoestring" type can seldom be stripped advantageously unless the coal bed is fairly thick.

NATURE OF TERRAIN

The terrain most suitable for stripping operations is one of broad surfaces of low relief. Intensely dissected areas are not generally recommended, though the disadvantages of rough terrain may be offset by advantages of other kinds. The nature of the terrain is important in determining the shape of a deposit High relief associated with steep slopes is particularly unsuitable for stripping because of the resulting narrowness of the strip of coal between the outcrop and the maximum thickness of overburden considered strippable.

RESERVES

Reserves of coal contained in any strippable area described in this report should be sufficient to insure that a strip mine could operate continuously for at least 5 years, because it would be uneconomical to move heavy stripping equipment into an area for a shorter period. Future mining operations in southeastern Montana are expected to require a minimum reserve of 15 million tons of coal. Of this reserve, at least 10 million tons should lie beneath less than 60 feet of overburden. Single deposits that are estimated to contain reserves of less than 15 million tons were not selected as strippable deposits, unless, as in the Miller Creek area (pl. 50), two or more adjacent deposits contain an aggregate of more than 15 million tons.

METHOD OF SELECTION

The initial selection of the deposits was based on an analysis of the reports of earlier geologic studies and water-well logs. From this analysis the areas underlain by coal beds of minable thickness were noted and the largest of these were later studied in the field. Particular attention was given the areas that were designated in the earlier studies as strippable deposits. If the area seemed to fulfill the requirements of the standards of selection, it then was investigated in detail.

METHOD OF DETAILED INVESTIGATION

U. S. Geological Survey maps of the three coal fields in the area were enlarged to a scale of 1:24,000 and used as bases for mapping the deposits of strippable coal. Refinements were made wherever possible by comparison with aerial photographs or by detailed plane-table mapping.

The field investigation consisted of determining the thickness of the strippable coal bed, and of locating and mapping the lines along which the overburden was 60 feet, 90 feet, and 120 feet thick. After each deposit had been mapped, the average thickness of the coal bed was determined from the information available, and the reserves for each deposit were calculated. Subsequently an approximate average stripping ratio was determined for each deposit. The methods used in each operation are discussed below.

DETERMINATION OF THICKNESS OF STRIPPABLE COAL

The average thickness of coal in each strippable deposit (table 1) was determined from a weighted average of thicknesses obtained from the following sources: (1) exposures measured during the present investigation; (2) exposures measured and reported in the literature of the U. S. Geological Survey; (3) logs of power-auger holes; (4) logs or reports of sediments penetrated during the completion of water wells; and (5) reports of thicknesses of coal found in mines or prospects now abandoned.

The reliability of the information about the different sources of thickness deserves mention. The most reliable are measurements of surface exposures. The power auger gave less accurate, though fairly reliable, results: small partings less than 6 inches thick sometimes could be detected, and the top and the bottom of the coal beds usually could be located within 1 foot. Information derived from logs or reports of water wells, and from reports of abandoned mines or prospects, because of its second-hand nature, is generally less reliable than that derived from either measured exposures or the power auger; hence, such information is used in this report only when it can be corroborated to some extent by exposures nearby or auger holes.

PLOTTING OF OUTCROP AND OVERBURDEN LINES

The outcrop traces of most of the thicker coal beds are shown on the geologic maps of the reports listed in figure 50. These lines were refined and revised on enlarged copies of these maps in light of information acquired during the present investigation. Then the overburden lines that connect points 60 feet, 90 feet, and 120 feet above the coal were added to the base maps. Most of the overburden lines were first drawn on aerial photographs by reference to marker beds known to be parallel to the coal bed, or by reference to elevation control points that were located by reconnaissance methods with the altimeter, compass, hand level, and odometer; or by plane table and alidade. Control points are of three types: those where the depth to the coal is known directly, as in a well, a mine, or a prospect hole; those directly on the coal bed; and those where the depth to the coal can be inferred by the relationship between the point, a control point nearby on the coal, and the dip of the coal bed.

Because of the scarcity of the information about, the depth of the coal bed and the reconnaissance method of mapping, the overburden lines are of necessity somewhat generalized. Before actual mining operations are begun in any deposit, therefore, it should be mapped and drilled in sufficient detail to permit calculation of the yardage of overburden, as well as the tonnage of the coal contained in the deposit.

ESTIMATION OF RESERVES

Data on the thickness and areal extent of each deposit are sufficient for reserves to be estimated with fair accuracy. Almost all the strippable coal is within 2 miles of a point on the outcrop or other point where the thickness of the bed is known, and most of the coal under less than 60 feet of overburden is within three-quarters of a mile of such a point. The coal beds that contain strippable deposits generally persist with little change in thickness for long distances along their outcrop, thereby indicating that they are equally persistent back from the outcrop. This indication is confirmed generally by the available subsurface measurements. The estimates of reserves, therefore, are believed to be in the "indicated" category of the reliability classification used by Averitt and Berryhill (1950, p. 11).

In calculating the reserves in a deposit, the average thickness of the coal bed was determined from a weighted average of the thicknesses of the bed at several points throughout the deposit. Next, the acreage of coal in the various overburden categories of less than 60, 60 to 90, 90 to 120 feet of overburden was determined from the deposit maps with a planimeter. The acreage was then multiplied by the average thickness of coal to obtain the volume of coal in acre-feet. The average weight of 1 acre-foot of Montana subbituminous coal being about 1,770 short tons (Averitt and Berryhill, 1950, p. 16), the product of the volume of coal in acre-feet and 1,770 expresses in short tons the total original reserves of strippable coal. The original reserves in each deposit, classified in the three overburden thickness categories, are shown in table 1.

ESTIMATION OF STRIPPING RATIO

The stripping ratio, as used in this report, is the relationship between the volume of overburden, in cubic yards, and the tonnage of coal.

To calculate the volume of overburden accurately requires much more closely spaced information than it was practical to obtain during the present study. A rough calculation of the volume was made, however, and from it the average stripping ratio was determined for each deposit. In calculating the overburden for each deposit, the average thickness of the cover in each thickness range was estimated as closely as possible. These thicknesses were multiplied by the acreage in the respective overburden thickness ranges, the product being the approximate volume of the overburden in acre-feet. As one acre-foot equals 1613.3 cubic yards, the product of the volume of overburden in acre-feet and 1613.3 expresses the volume of overburden in cubic yards. By dividing the volume of overburden in each deposit by the tonnage of coal reserves in the deposit, the approximate average stripping ratio was obtained for each deposit. The average stripping ratio thus obtained probably is accurate to within 0.5$\pm$cubic yard. The average stripping ratios in the selected strip deposits range from 2 to 6½ cubic yards of overburden for each ton of coal.

SELECTED DEPOSITS OF STRIPPABLE COAL

The nine selected deposits of strippable coal are discussed below in order from northeast to southwest. The three Miller Creek deposits are discussed under one heading.

SWEENEY CREEK DEPOSIT

The Sweeney Creek deposit of strippable coal (fig. 54) lies mainly in secs. 2, 3, 4, and 10, T. 3 N., R. 44 E., Rosebud County, Mont. The nearest railroad is at Rosebud, Mont., about 27 road miles north and west of the deposit. Of this distance, 23 miles are on trails and gravelled roads which roughly parallel Sweeney Creek valley; the rest is by way of U. S. Highway 10–12. The deposit is in the Rosebud coal field (Pierce, 1936, p. 101). The Sweeney Creek deposit is one of the most remote and has the roughest terrain of any deposit described in this report.

Topography and land use.—The Sweeney Creek deposit underlies the uplands at the northern end of the Tongue River-Rosebud Creek divide, where the divide splits into three main ridges. In the southern part of the area, clinker from the Terret coal bed supports irregular escarpments as much as 90 feet high. Fairly close to these escarpments are the crests of the ridges which form the drainage divide between Beaver and Eagle Creeks and Sweeney and Cow Creeks.

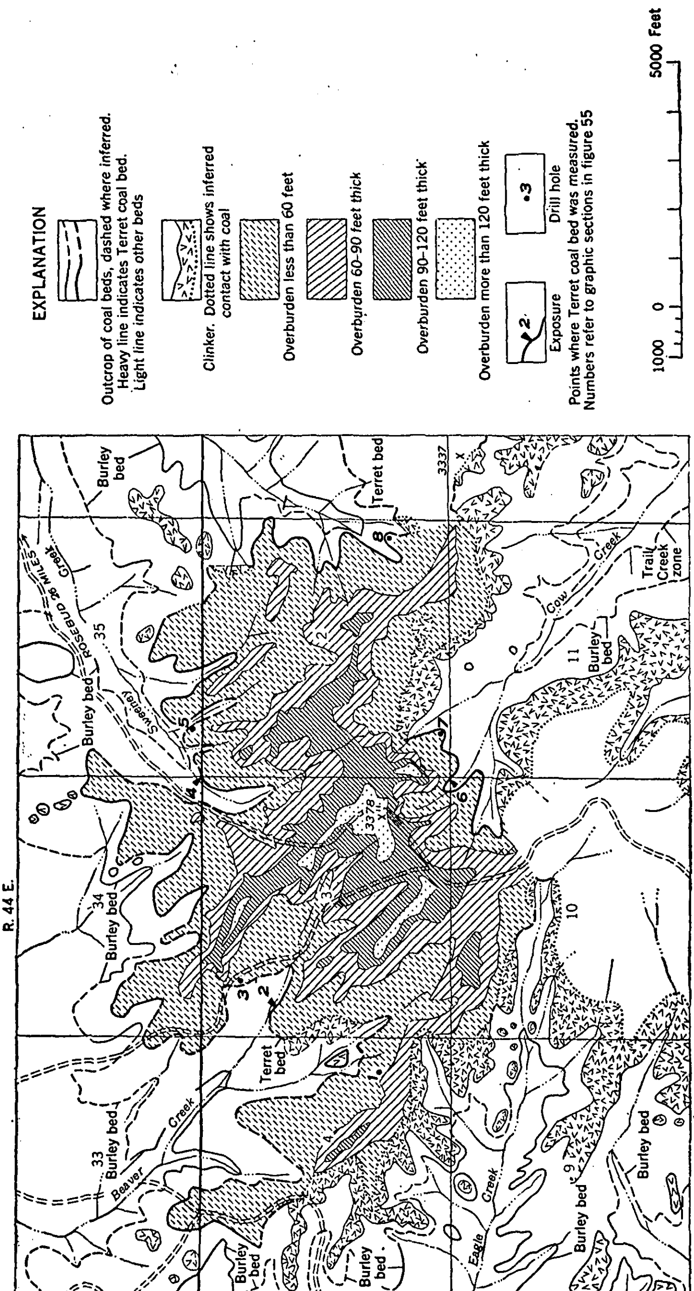

FIGURE 54.—Map of Sweeney Creek strippable deposit in Terret coal bed, Rosebud County, Mont.

The southern slopes of the ridges are steep, deeply gullied, and are covered with pine and juniper. The northern slopes are more gentle and the resulting land surface, though somewhat dissected, is generally more rounded and is covered with grass. A hill standing about 190 feet above the coal dominates the center of the divide and overlooks the entire deposit, offering a vantage point from which one can scan the countryside for miles around. Two ridges in the W½ sec. 3 rise to more than 135 feet above the coal, but they are so narrow that they probably would be removed in any continuous stripping operation that would remove 120 feet of overburden. The altitude of the strippable coal bed averages about 3,190 feet; the maximum relief of the entire mapped area is about 300 feet.

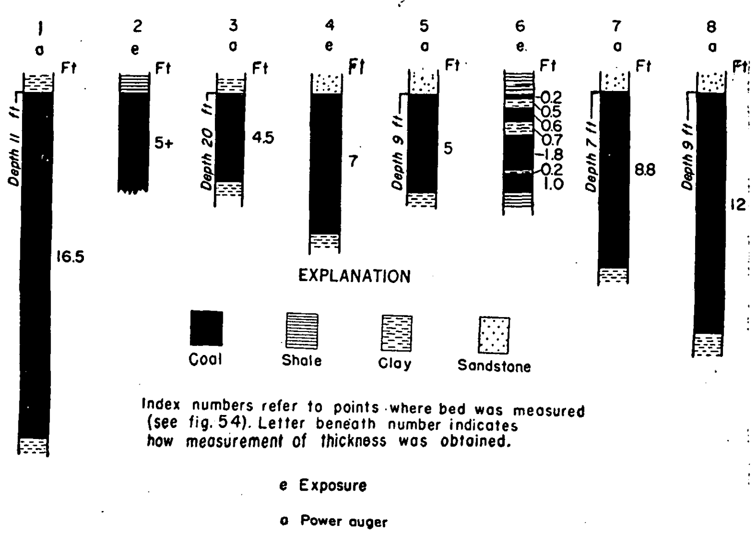

FIGURE 55.—Sections of Terret coal bed in and near Sweeney Creek strippable deposit.

Terret coal bed.—The Terret coal bed in the Sweeney Creek deposit ranges from 5 feet to 16.5 feet thick and averages about 9 feet, as determined from 3 measured exposures and 5 drill holes. (See fig. 55.) These data indicate that the thickness of the coal and the amount of partings in the bed vary considerably within fairly short distances. North of the mapped area the bed becomes too thin to be minable; and southward along the divide, although it maintains a thickness of 10 to 15 feet, it is overlain by 100 to 200 feet of cover. The coal in this area was not sampled for analysis, but analysis no. A-42289 (table 3) made from a sample taken from the Terret bed in the Holt mine near Ashland indicates that the rank of the coal is probably at least as high as subbituminous C.

The coal dips northward about 20 feet per mile. Because the deposit is well above the surrounding country, strip pits could be drained without serious difficulty.

Overburden and floor rock.—The overburden consists mainly of gray to yellow-brown silty and sandy shale and very fine friable sandstone. At least two dense fresh-water limestone beds and one thin coal bed lie within 120 feet above the Terret bed, and ferruginous concretions are also abundant at as many as four horizons.

Gray clay or silty shale immediately underlies the Terret coal bed.

Strippable reserves.—The estimated reserves of strippable coal in this deposit total 25.2 million short tons. (See table 1.) The amount of overburden averages about 5½ cubic yards per ton of coal. The reserves in the most favorable category, those beneath less than 60 feet of overburden, total 14.5 million tons.

Not included in the strippable reserves is the coal that underlies the areas totaling about 15 acres immediately surrounding locations 3 and 6 (fig. 53), where the coal is less than 5 feet thick. These areas are indicated on the map in figure 53 by an absence of overburden pattern.

SNYDER CREEK DEPOSIT

The Snyder Creek deposit (fig. 56) lies in the Rosebud coal field (Pierce, 1936, p. 102–103) in secs. 25 and 36, T. 2 N., R. 43 E., and secs. 29, 30, 31, and 32, T. 2 N., R. 44 E., Rosebud County, Mont. The nearest railroad, at Colstrip, is only about 12 miles by air to the southwest, but it is twice as far by way of existing roads. These roads include two county roads and State Route 45, all of which are well-drained and gravel-surfaced. The Tongue River is only 6 miles east of the eastern edge of the deposit. The Yellowstone River near Rosebud, Mont., is 35 road-miles to the north by way of State Route 45. Miles City, the largest town in eastern Montana, is 66 miles north of the deposit by way of the gravel surfaced road paralleling the Tongue River.

Topography and land use.—The deposit underlies the headlands of Snyder Creek, a northward-flowing tributary to Rosebud Creek. These uplands consist of prominent northward-trending, pine-covered ridges, and valleys as much as half a mile wide. The valleys have gently sloping grass-covered sides that steepen near the tops of the ridges. The valley floors are in places channeled as deep as 25 feet. The maximum relief is about 200 feet, and the average altitude is about 3,120 feet above sea level. The area is given over entirely to the grazing of livestock.

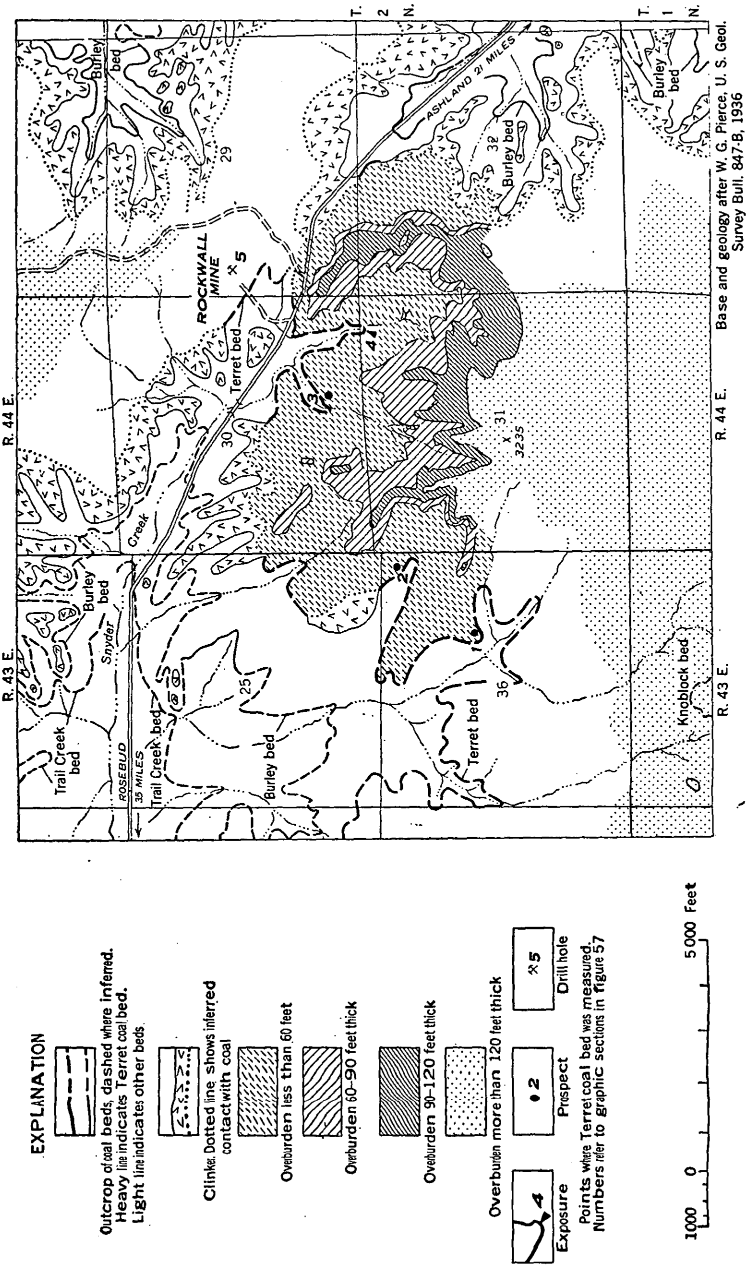

FIGURE 56.—Map of Snyder Creek strippable deposit in Terret coal bed, Rosebud County, Mont.

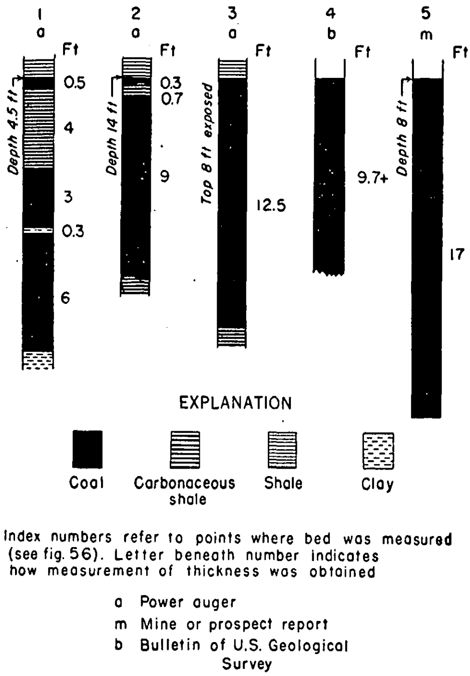

FIGURE 57.—Sections of Terret coal bed in and near Snyder Creek strippable deposit.

Terret coal bed.—In the Terret bed, thickness data (fig. 57) from three power-auger holes, one report from a closed mine and a report of previous geologic explorations (Pierce, 1936), indicate that the thickness of the coal ranges from 9 to 17 feet, and except for a single thin parting found at location 1, the coal is clean.

The coal bed dips southwestward about 20 feet per mile. No water was found in the coal in any of the prospect holes drilled in the area, but should strip-pit drainage prove to be necessary, it could probably be accomplished without pumping, for the coal bed is everywhere higher than the channels of the streams that border the deposit.

Overburden and floor rock.—The 30 to 40 feet of overburden immediately above the coal consists chiefly of gray shale and clay. The higher rock is mainly a friable yellow-brown sandstone, which, from 50 to 80 feet above the coal, is more massive and somewhat harder than the strata above or below it. This massive sandstone forms benches with nearly vertical walls and odd-shaped erosion remnants.

The floor rock is mainly gray silty clay, but immediately beneath the coal in several places is carbonaceous shale.

Strippable reserves.—The total reserves of strippable coal contained in this deposit are 16.2 million tons. (See table 1.) The recovery of this amount would require the removal of about 4½ cubic yards of overburden for each ton of coal. The Snyder Creek deposit contains

10.1 million tons of coal lying beneath no more than 60 feet of overburden.

GREENLEAF CREEK DEPOSIT

The Greenleaf Creek deposit is in secs. 9, 10, 15, 16, 20, 21, 22 and 29, T. 1 S., R. 43 E., Rosebud County, Mont. (See fig. 49). This area is in the Ashland coal field (Bass, 1932, p. 66–67). The northeastern edge of the deposit is 19 miles southeast of Colstrip by way of improved county roads and 16 miles northwest of Ashland by way of the Tongue River road. The strippable coal is the Knoblock bed, which, in this deposit, averages 12 feet in thickness.

Topography and land use.—Most of the deposit underlies an asymmetric ridge that forms the divide between northwestward-flowing Greenleaf Creek on the east and northward-flowing Miller Creek on the west. Both of these streams are intermittent tributaries to Rosebud Creek. The crest of the ridge is dominated by a few hills, which rise to about 200 feet above the coal bed and which are capped by the clinker of the Sawyer bed. The western side of the ridge rises abruptly from the coal outcrop to the crest, but on the eastern side, the surface is a broad rolling gravel-covered terrace, dissected by V-shaped valleys 30 to 50 feet deep. The line that marks the eastern extent of the Knoblock coal bed on the map (pl. 49) also approximates the eastern limit of the terrace gravel deposits. To the southwest, the main deposit of coal swings across the flat bottom of the steep-sided Greenleaf Creek valley. A narrow neck in which no coal is present separates an outlier of strippable coal in the south half of sec. 22. This outlier is about one-tenth the size of the main deposit, and occupies the low ridge between Greenleaf Creek and Lay Creek.

Although some hay and small grains are grown in the valley bottoms, most of the area is used for cattle grazing. The average altitude is about 3,300 feet; the maximum topographic relief, as measured from the road to the crest of the main divide, is about 320 feet.

Knoblock coal bed.—The average thickness of the coal in the Knoblock bed, as determined from 4 measured sections, 2 reported thicknesses, and 5 drill holes, is 12 feet. (See graphic sections, fig. 58.) The maximum thickness, 21 feet, was measured at a drill hole at location 9; the minimum thickness, 7.5 feet, at location 8, less than a mile away. A variation of this magnitude within a mile indicates that the thickness of the coal may be extremely variable throughout the deposit. Sections measured at locations 4 and 5 (pl. 49) show that the coal has been eroded at the top, possibly during the deposition of the gravel. This erosion, however, seems to be restricted to the marginal parts of the deposit. The coal shows no partings except at locations 2 and 9, and in those locations the partings were restricted to the uppermost part of the bed.

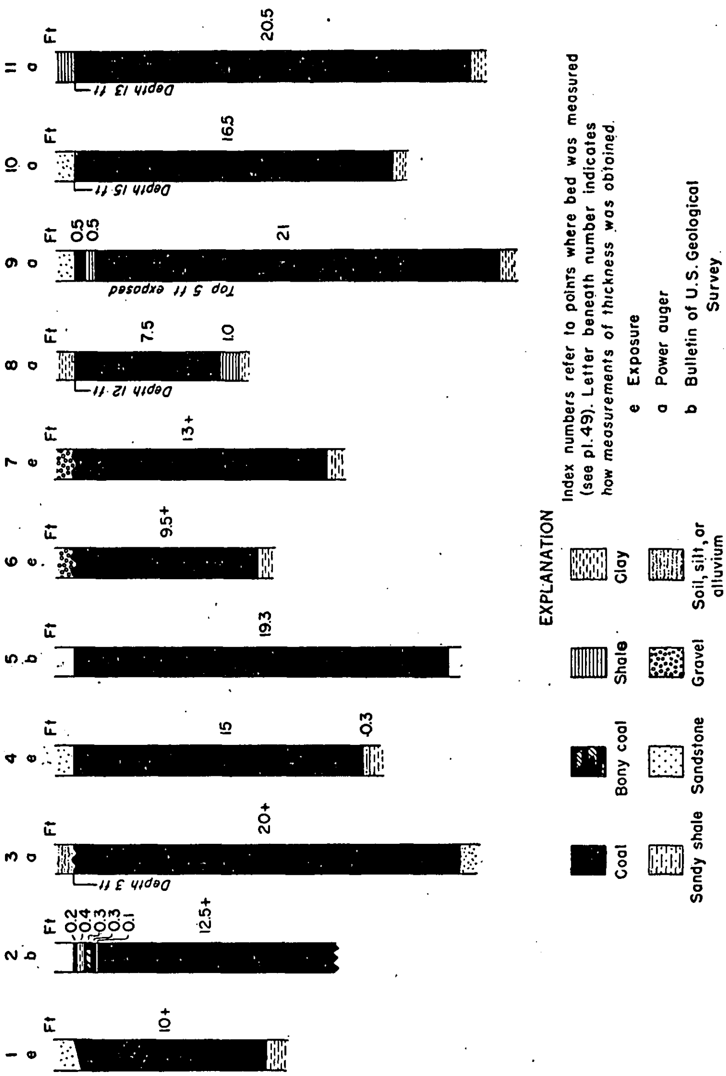

FIGURE 58.—Sections of Knoblock coal bed in and near the Greenleaf Creek strippable deposit.

The coal dips northeastward about 20 feet per mile from a line drawn diagonally northwestward through the center of sec. 16. Southwest of this line the coal dips southwestward at approximately the same rate. Except in the southwestern part of the deposit, the dip will not hinder the construction of self-draining strip pits, for most of the coal lies well above the valley. In the southwestern part of the deposit, however, pumping might be necessary. The average altitude of the coal is about 3,225 feet.

Overburden and floor rock.—Near location 2 the coal is overlain by 90 feet of gray to yellow-brown friable, massive sandstone that contains some ferruginous concretions and a few shaly layers, and locally forms steep escarpments 50 to 70 feet high. From 90 to 120 feet above the coal, the overburden is chiefly gray sandy shale and friable sandstone. Terrace gravel deposits as much as 25 feet thick cover about 90 percent of the area underlain by coal in the 0–60 foot overburden category in secs. 3, 9, 10, 15, 16 and 21.

Strippable reserves.—The original reserves of strippable coal in the Greenleaf Creek deposit total 56.3 million short tons. Of this amount 33.1 million short tons, or about 70 percent of the total, lies beneath less than 60 feet of overburden. An average of 4 cubic yards of overburden would be moved for each ton of coal.

MILLER CREEK DEPOSITS

Three small strippable areas, each within 3 miles of another, constitute the Miller Creek deposits. (See map, pl. 50.) Two of these, the North and the East deposits, are in the Rosebud coal bed; the other, the South deposit, is in the Knoblock coal bed. All three deposits are in the Ashland coal field (Bass, 1932, p. 63–67).

The East deposit underlies secs. 8 and 17, T. 1 S., R. 43 E., and adjoins the Greenleaf Creek deposit (pl. 49) on the west. It is about 23 road-miles southeast of Colstrip, by way of 18.6 miles of clinker-surfaced road and about 5 miles of prairie trails. These trails extend southeastward across Miller Creek from a point on State Route 45 about 4 miles south of the junction of the highway and the road extending southeastward from Colstrip.

The North deposit is mainly in secs. 14 and 15, T. 1 S., R. 42 E. It is 14 road-miles from Colstrip, 13 miles of which are by way of the Colstrip road and State Route 45, and 1 mile of which is by way of a prairie trail.

The South deposit is in secs. 25, 26, and 36, T. 1. S., R. 42 E., about 3 miles farther up the trail that passes through the North deposit. Of the three deposits, the South deposit is the only one that contains sufficient reserves to warrant investigation according to the criteria used in this report. The three deposits are described together because they could probably be stripped as a unit.

Topography and land use.—The East deposit lies beneath the gentle western slopes of the clinker-rimmed Greenleaf Creek-Miller Creek divide. The North deposit lies beneath a low ridge that separates the Miller Creek drainage basin from a smaller tributary to Rosebud Creek on the west. The South deposit is beneath the headlands of Miller Creek. The creeks head in areas in which the Sawyer and Knoblock coal beds have burned to clinker. There they have cut steep-walled canyons whose sides and rims are lightly forested with pine and juniper. The areas underlain by strippable coal are generally rolling. They are given over almost entirely to grass and low brush, and are utilized mainly as pasture for livestock. The relief of the area exceeds 300 feet, though locally it seldom exceeds 100 feet.

Rosebud coal bed.—The Rosebud coal bed was observed at 2 outcrops, and 3 drill holes, and reported at 4 outcrops in the North deposit, and at 1 exposure and 4 drill holes in the East deposit. These measurements (fig. 59) indicate that the thickness of the bed here is less uniform than it is on the west side of Rosebud Creek, and that the average thickness of the coal in the 2 strippable deposits is about 9 feet and ranges from 4.1 to as much as 11 feet within a relatively small area. These deposits are fairly thick lenses, surrounded by much thinner coal. The altitude of the Rosebud bed is about 3,140 feet.

Knoblock coal bed.—The Knoblock bed is 90 to 105 feet above the Rosebud bed and about 3,230 feet above sea level. The Knoblock coal in the South deposit averages about 16 feet in thickness, according to 2 sections measured by Bass (1932) and 3 drill holes. (See fig. 59.) The maximum thickness, 19 feet, was observed at 2 drill holes in sec. 25, T. 1 S., R. 42 E. The bed thins to the north, east, and west of the deposit to such an extent that economical strip mining is probably not feasible. A spring issues from the coal at an outcrop near location 14 and water was found in holes drilled at locations 15 and 16. The regional dip within the Miller Creek area is southeastward about 10 feet per mile. This dip is not great enough to prevent the construction of self-draining strip pits, and pumping, if at all necessary, will probably be required only in the strip pits that will occupy the valley bottoms, where the coal lies beneath the present level of the streams.

Overburden and floor rock.—The overburden of the Rosebud bed in the North and East deposits consists of 30 feet of shale overlain by a white friable fine-grained massive sandstone, which weathers into prominent ledges or grotesque erosion forms. A gravel terrace overlies the Rosebud bed on the west side of Miller Creek about 100 to 130 feet above stream level. This deposit is about 10 to 15 feet thick and contains pebbles and cobbles, as well as a few large angular

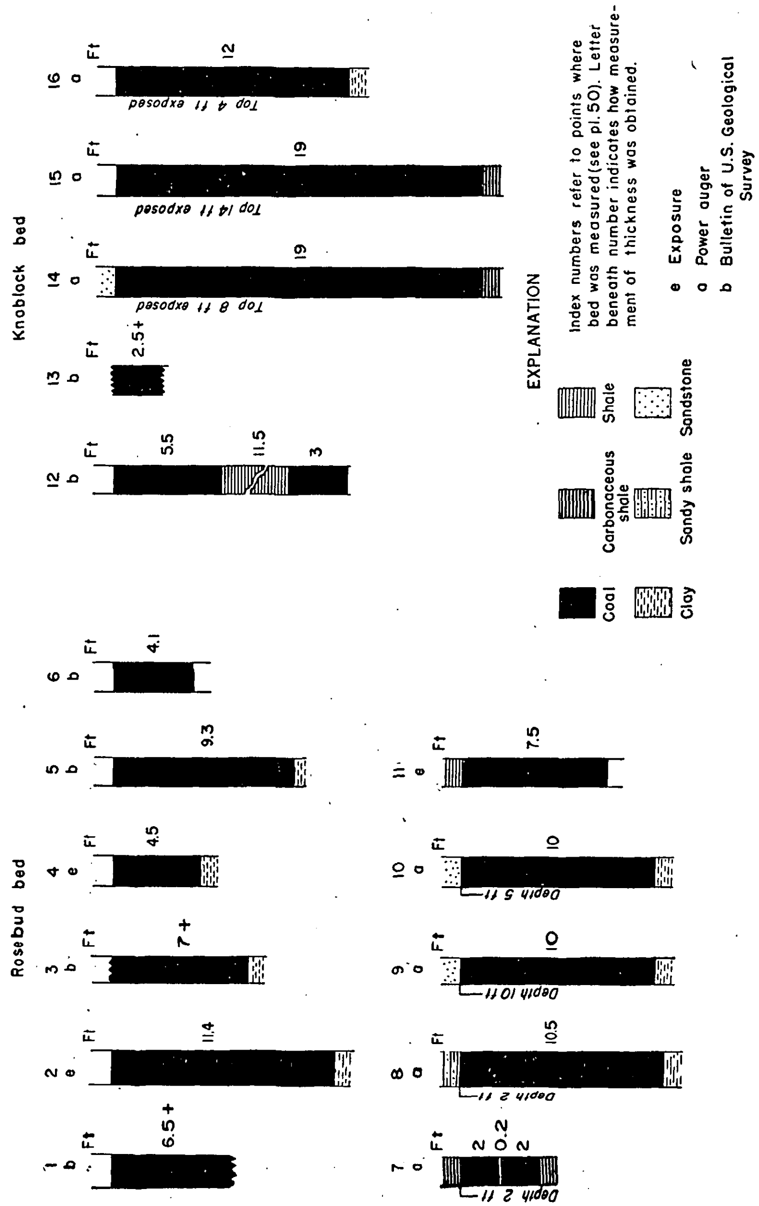

FIGURE 59.—Sections of Rosebud and Knoblock coal beds in and near Miller Creek strippable deposits.

fragments of clinker as much as 4 feet in diameter. The lower 3½ feet of this deposit has been cemented with limy material into a loose conglomerate.

The floor rock of the Rosebud bed is gray clayey shale.

The overburden of the Knoblock coal bed in the South deposit is predominantly sandstone interbedded with shale. Most of the shale, however, lies within less than 30 feet above the top of the coal. Clinker from the Sawyer bed supports high bluffs from which jut ridges of massive sandstone that rise nearly 150 feet above the coal. Scattered at several horizons through the shale and sandstone of the overburden are lenses of iron-stained concretions and pyritic nodules.

The floor rock of the Knoblock bed is carbonaceous clay, which grades downward to hard and dry gray underclay.

Strippable reserves.—The original strippable coal reserves of the three Miller Creek deposits total 56.1 million short tons. Nearly half of the total reserves, or 27.9 million tons, are under less than 60 feet of overburden; and 42.8 million tons, or slightly more than three-fourths of the total, are under less than 90 feet of overburden.

The average stripping ratio in the East deposit is about 6 to 1; in the North deposit the stripping ratio is about 4½ to 1, and in the South deposit about 3½ to 1.

SOUTH COAL BANK COULEE DEPOSIT

The South Coal Bank Coulee deposit is in the Rosebud bed in secs. 15 and 22, T. 1 N., R. 41 E., Rosebud County, Mont. (See map, fig. 60.) The deposit is in the southeastern part of the Forsyth coal field (Dobbin, 1929, p. 54–55), and comprises the smallest acreage but contains the greatest average thickness of coal of any deposit in the area investigated. (See table 1.) It is 9 road-miles south of Colstrip, by way of 7 miles of good graded road and 2 miles of prairie trails.

Topography and land use.—The deposit underlies the eastern flank of a high fingerlike ridge that extends southward from the clinker-capped Miller Coulee-East Fork Armells Creek divide. The top of this ridge is about 160 feet above the coal bed, but the sides drop abruptly to gentle slopes and thus provide—on the eastern side of the ridge—an area of about 500 acres which is less than 120 feet above the coal. The northern part of this surface is dissected by South Coal Bank Coulee, but the remainder is slightly rolling. If this high ridge were removed or bypassed, additional reserves of thick coal could probably be recovered by stripping farther up Miller Coulee to the west.

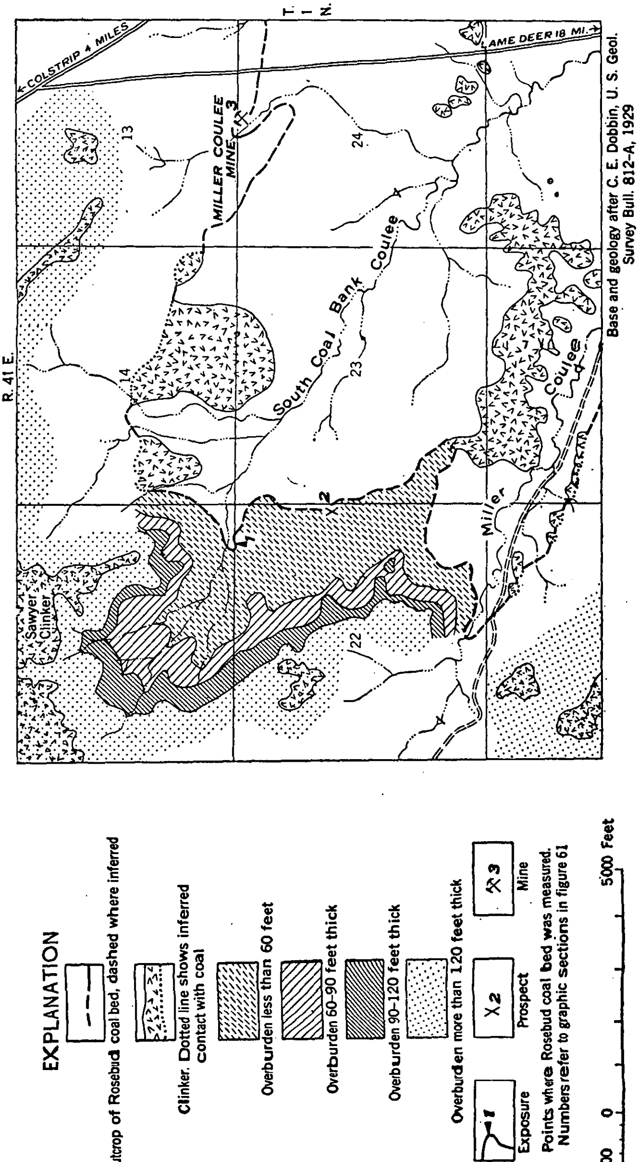

FIGURE 60.—Map of South Coal Bank Coulee strippable deposit in Rosebud coal bed, Rosebud County, Mont.

Most of the area is grass-covered and is given over to grazing. Some of the high clinkered ridges are sparsely timbered by scrub pine and juniper.

Rosebud coal bed.—The strippable coal in the Rosebud bed is subbituminous B in rank (table 3). The only exposure within the deposit reveals a thickness of about 25½ feet of coal, separated by about 11½ feet of shale and clay from the underlying McKay coal bed, which here is about 9 feet thick. (See graphic sections, fig. 61). At this exposure the Rosebud bed contains an unusual concentration of selenite as fracture filling along a definite band about 6 feet above the base of the bed. This band ranges from a few inches to more than a foot in thickness, and, if it is fairly widespread in this deposit, may seriously detract from the value of the coal. The only other information concerning the thickness of the Rosebud coal bed in this deposit—a prospect report (loc. 2)—indicates that the bed probably averages about 24 feet in thickness. At the Miller Coulee mine the coal is about 28 feet thick, though it contains 2 bone partings, each about 2 inches thick. The McKay coal bed is about 10 feet thick at the mine, and is about 7½ feet below the Rosebud bed.

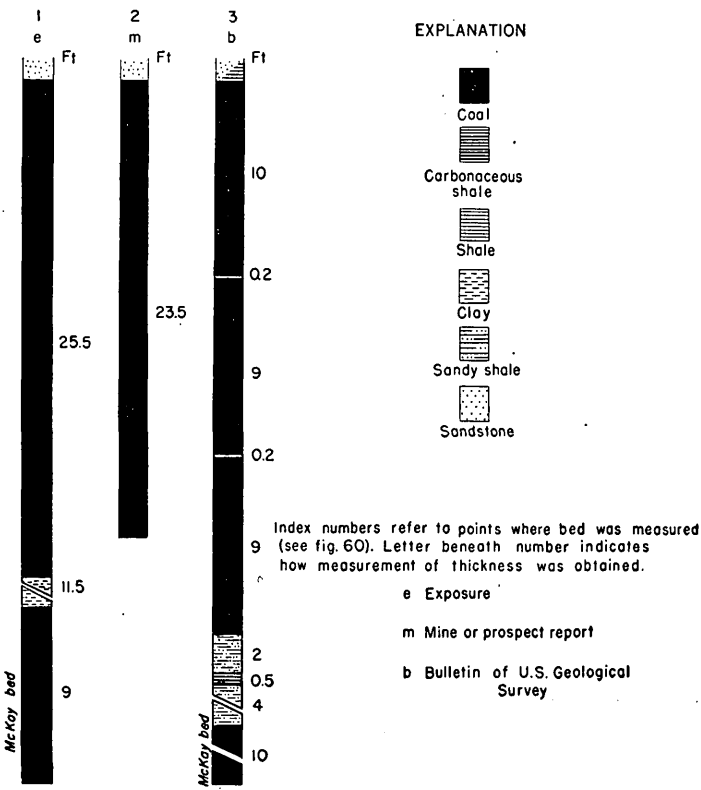

FIGURE 61.—Sections of Rosebud coal bed in and near the South Coal Bank Coulee strippable deposit.

The coal dips eastward about 25 feet per mile throughout the deposit except at location 1, where it dips westward at nearly 2°. Though self-draining strip pits would be feasible throughout most of the area, pits near location 1, where the dip of the strata is opposite to the direction of the stream drainage, would probably require some pumping. The altitude of the coal bed throughout the deposit averages about 3,200 feet.

Overburden and floor rock.—A massive sandstone that is locally cliff-forming comprises most of the overburden within 140 feet above the coal, though locally clay or clayey shale replaces this sandstone immediately above the coal. The relationship between the porosity of the overburden and the degree to which a coal bed weathers when it lies beneath fairly shallow overburden was observed at the Miller Coulee mine: On a fresh surface beneath 6 to 10 feet of a porous sandstone overburden, the coal was weathered to a depth of 3 to 4 feet below the top of the bed; nearby along the same exposure, where the sandstone grades laterally into clayey shale, the coal is not visibly weathered.

The floor rock of the deposit consists of gray sandy shale.

Strippable reserves.—The reserves of strippable coal in the deposit total 21.9 million short tons (table 1), which would require the removal of about 2 cubic yards of overburden for each ton of coal. Of the total reserves, those beneath less than 60 feet of overburden are 12.1 million short tons, and those beneath less than 120 feet of overburden total 21.9 million tons. Should the underlying McKay coal bed also prove to be strippable, the reserves would be increased by about 7 million tons, assuming an average thickness of 8 feet of coal beneath the same area in which the Rosebud bed is outlined as strippable.

CASTLE ROCK DEPOSIT

The Castle Rock deposit (pl. 51) contains the largest reserve of strippable coal and the greatest areal extent of any of the deposits described in this report. Colstrip, the nearest railhead and source of electric power, is less than 1 mile east of the area, and Forsyth, the nearest town with a large available water supply, is 39 road miles to the north. The average thickness of the strippable coal is 22 feet, second only to that of the South Coal Bank Coulee deposit.

The deposit is in the Rosebud coal bed in sec. 1, T. 1 N., R. 39 E.; secs. 28, 29 and 31 through 33, T. 2 N., R. 40 E.; secs. 1 through 6 and 8 through 17, T. 1 N., R. 40 E.; secs. 32 and 33, T. 2 N., R. 41 E.; and secs. 4 through 9 and 17 and 18, T. 1 N., R. 41 E., Rosebud County, Mont. This area is part of the Forsyth coal field (Dobbin, 1929).

The continuity of the deposit is broken in SW¼ sec. 6, T. 1 N., R. 41 E., where the coal has burned under a low divide. As this area of burned coal is only about one-fourth mile wide, the strippable reserves east of the burned area are considered to be continuous with the main part of the deposit.

The western part of the Castle Rock deposit includes a tract of about 2,150 acres that was set aside on June 6, 1929, as a reserve for a synthetic liquid-fuels program. The tract comprises all of secs. 4, 5, and 6, T. 1 N., R. 40 E.; lots 3 and 4, the E½SW¼, and the SE¼ sec. 31, and all of sec. 32, T. 2 N., R. 40 E.

Topography and land use.—The most conspicuous features of the area are the broad eastward-trending valleys of the East Fork of Armells Creek and its tributary to the north, Stocker Creek, and the high ridge that extends eastward between the two valleys from the Wolf Mountains. On the south side of the area another high, eastward-trending ridge separates the East Fork Armells Creek valley from Lee and Miller Coulees to the south; and in the northwestern corner of the area is the divide between Stocker Creek and the West Fork of Armells Creek. The profiles of the main valleys are generally U-shaped. The ridges that form the divides have irregular outlines owing to dissection by gullies and narrow, V-shaped stream valleys 5 to 50 feet deep. A ledge of massive sandstone forms a conspicuous bench near the base of the ridges, and in many places the sandstone has been eroded into steep cliffs or grotesque forms. Castle Rock, an isolated remnant of this sandstone, stands about 60 feet above the valley floor of Stocker Creek near the western edge of the deposit.

Most of the strippable coal underlies the sides of the valleys in the lower parts of the two main streams; a lesser amount underlies the valley bottoms in the headward parts of the streams, and some underlies the lower parts of the divide between the main valleys. The deposit is bounded on the west by the West Fork of Armells Creek, where the course of the creek follows a box canyon 30 to 50 feet deep. This canyon effectively separates the deposit from the adjoining West Fork Armells Creek deposit (pl. 53). The eastern boundary of the deposit is arbitrary; the mapping was not extended nearer than 1 mile to the strip mine at Colstrip in order to avoid duplication of mapping done by the Northwestern Improvement Company. Northward from the southwest corner of sec. 31, T. 2 N., R. 40 E., and near the center of the W½ sec. 32 of the same township and in the NW¼ sec. 6, T. 1 N., R. 41 E., the reserves are small, owing to the roughness and high relief of the terrain; northward from the center of the S½ sec. 29, T. 2 N., R. 40 E., most of the reserves have been removed by erosion and burning.

Most of the land is used for cattle grazing, although about 70 percent of the valley bottoms are farmed by dry-farming methods, the principal crops being corn, alfalfa, and small grains. A few pine trees grow in this area, principally on clinker or sandstone exposures. The total relief is about 55 feet, and average altitude is about 3,400 feet.

Rosebud coal bed.—Analyses (table 2) of samples from the Rosebud bed at the Northwestern Improvement Company's mine at Colstrip show that the coal is subbituminous B in rank. The thickness of the bed in the deposit, as determined from 3 measured exposures, 3 water-well logs, 15 power-auger holes, and 1 prospect report, ranges from at least 11 feet to as much as 29 feet and probably averages about 22 feet. (See graphic sections, pl. 52.) The character of the coal can best be observed at the working face of the Colstrip mine, for none of the three exposures within the deposit shows either an unweathered surface or a complete thickness of the bed. The maximum measured thickness is 25.5 feet at location 12, in sec. 2, T. 1 N., R. 40 E., but 7½ feet of this interval is covered by debris, as is the lowest 2.6 feet of the exposure at location 1. Except for a few thin partings at locations 6, 14, and 16 (pl. 51) the coal throughout the deposit is clean. Water saturates the bottom 2 to 9 feet of the bed at locations 15, 19, and 23; and it issues from the bed at the exposure at location 12. This indicates that, though the bed may be dry over much of the area, it may contain a considerable amount of water in the valleys.

The general dip of the coal is east to southeastward; in the western two-thirds of the deposit the dip is about 15 feet per mile, but in the eastern third it increases to as much as 75 feet per mile. The general dip is modified by local doming in sec. 12, T. 1 N., R. 40 E. Of this dome, Dobbin (1929, p. 48) says,

> The position of this dome is outlined by the outcrop of the Rosebud coal bed, which rises above the level of the East Fork of Armells Creek in the NE¼ sec. 7, T. 1 N., R. 41 E., and dips beneath the creek again in the SW¼ sec. 11, T. 1 N., R. 40 E.

Overburden and floor rock.—The overburden of the Rosebud coal bed consists of about 90 feet of a massive, loosely cemented, fine-grained, yellowish-gray sandstone, above which lies extremely friable sandstone, interbedded with silty clay, shale, 1 or 2 yellow-brown fresh-water limestone beds about 1 foot thick, and a few scattered concretions. The high divides in the area are generally capped by gray to yellow-brown shale and soft sandstone.

The floor rock is chiefly a dense grayish-white clayey or silty sandstone, but at several locations the first 2 or 3 feet directly beneath the coal is a typical gray underclay. (See graphic sections, pl. 52.)

Strippable reserves.—The original reserves of strippable coal in the Castle Rock deposit total 303.3 million short tons. (See table 1.) Of this amount, 53 percent, or 161.3 million tons, is under less than 60 feet of overburden, and nearly 70 million tons are contained in the

Government's coal reserve. The average stripping ratio throughout the deposit is about 2½ to 1.

Not included in the deposit is an area in the valley of East Fork Armells Creek beneath which the coal bed has been eroded or weathered to such an extent that it probably is not profitably minable. This is indicated on the map (pl. 51) as a patternless area between the 60 feet of overburden contour and the coal bed outcrop.

WEST FORK ARMELLS CREEK DEPOSIT

The West Fork Armells Creek deposit (pl. 53) is adjacent to the western edge of the Castle Rock deposit (pl. 51). Although both deposits are in the Rosebud coal bed, they are described separately, not only because the canyon of West Fork Armells Creek separates the two deposits, but also because the West Fork Armells Creek deposit has a narrower, more sinuous outline as a result of its rugged terrain, and because its average thickness of coal, 18 feet, is less than that of the Castle Rock deposit. The reserves of the West Fork Armells Creek deposit are larger than those of any of the other deposits described in this report.

The deposit is west of West Fork Armells Creek, in the northeastern flank of the Wolf Mountains, in secs. 13, 14, 23, 24, and 25, T. 2 N., R. 38 E., Treasure County, Mont., and in secs. 19, and 26 through 35, T. 2 N., R. 39 E., and secs. 1 through 5, T. 1 N., R. 39 E., Rosebud County, Mont. The area is in the Forsyth coal field (Dobbin, 1929, p. 38, 41, and 43). The eastern edge of the deposit is 11.5 road-miles west of the railroad at Colstrip, and is 39 miles south of Forsyth, by way of the road along West Fork Armells Creek.

Topography and land use.—The deposit underlies the upper reaches of valleys formed by northward-trending West Fork Armells Creek and its tributaries, the North and South Forks of Donley Creek. In general, the topography has moderate relief near the coal outcrop, but a short distance back from the outcrop the relief becomes much greater and the surface is broken by a succession of ridges and valleys. The main valleys are generally U-shaped, having floors less than half a mile wide. The headward parts of the main valleys, as well as all the small tributary valleys, are V-shaped and have sides that rise steeply to the tops of narrow, fingerlike ridges.

The Wolf Mountains, which are south of the strippable deposit in T. 1 N., R. 39 E., are 1,300 feet above the Rosebud coal bed at their highest point. The high ridges that extend eastward and northward from these mountains rise sharply above the southern and western limits of the deposit. The north-trending ridge bordering the deposit on the west forms the divide between Sarpy Creek and

West Fork Armells Creek; at its lowest point, this divide is 160 feet above the Rosebud coal bed.

The average altitude of the area is about 3,525 feet; the maximum relief is about 400 feet. Most of the area is grass-covered pasture land, and the high slopes of the Wolf Mountains, the north sides of many of the hills, and the coulees are forested with brush and evergreens. About 15 percent of the strippable area is farmed; the main crops are wheat and alfalfa.

Rosebud coal bed.—The Rosebud bed can best be observed at the Northwestern Improvement Company's strip mine at Colstrip, 12 miles east of the deposit. Analyses (table 3) of coal samples taken from this mine show that the coal is subbituminous B in rank. The thickness of the coal ranges from 20 to 23 feet throughout most of the deposit, although in the northwestern part, partings near the top of the bed reduce the minable thickness to about 15 feet, so that the average thickness of strippable coal is about 18 feet. (See graphic sections, fig. 62.)

Aerial photographs indicate that the coal bed may be faulted in the northwestern part of the deposit, although no direct proof of faulting could be found in a cursory field examination of the area. The average altitude of the coal is about 3,450 feet. The true dip of the coal bed was not determined; however, measurements indicate that, in the western two-thirds of the deposit, it dips southeastward at 20 to 40 feet per mile, and in the eastern one-third it dips northwestward at nearly 50 feet per mile.

Water was found in the bottom 3 feet of the coal bed in holes drilled at location 5, sec. 30, T. 2 N., R. 39 E., and location 6, sec. 29 of the same township. This indicates that the coal bed may contain a fairly large amount of water where it underlies the main valley bottoms, but that elsewhere in the deposit it may be relatively dry.

Overburden and floor rock.—The overburden throughout the deposit consists chiefly of massive, poorly indurated sandstone. Dobbin (1929, p. 18–19) includes the following measurements in his description of the part of the Tongue River member of the Fort Union formation that lies directly over the Rosebud coal bed in secs. 34 and 35, T. 2 N., R. 39 E.:

	Feet
Sandstone, yellow	24
Sandstone, gray, massive, concretionary; weathers into fantastic erosion forms	96
Sandstone, gray, well-stratified	11
Clay, blue	6
	137

Coal, Rosebud.

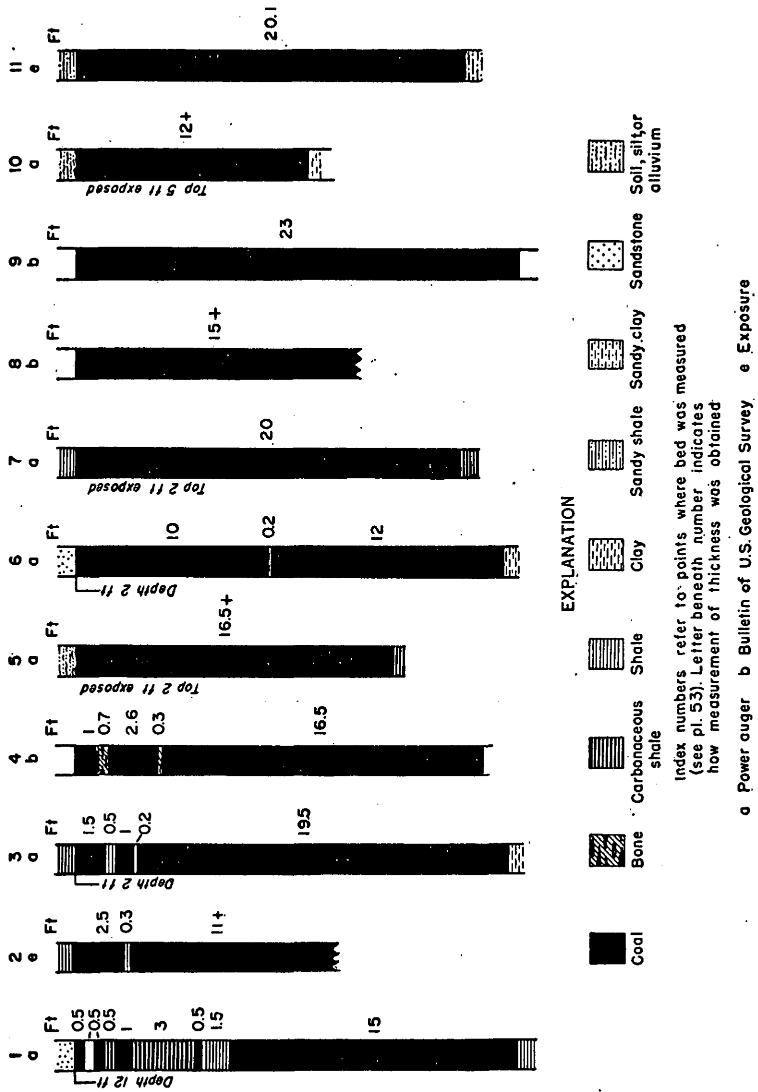

FIGURE 62.—Sections of Rosebud coal bed in West Fork Armells Creek strippable deposit.

The floor rock in some localities is a gray sandy shale; in others, it is a typical gray underclay. (See graphic sections, fig. 62.)

Strippable reserves.—The original reserves of strippable coal in the Rosebud bed in this deposit total 125.0 million short tons. Of this amount, slightly more than two-fifths, or 53.4 million short tons, are under less than 60 feet of overburden, and 70 percent of the total, or 87.9 million tons, are under less than 90 feet of overburden. The average stripping ratio of the deposit is about 3½ cubic yards of overburden to each ton of coal under less than 120 feet of cover.

REFERENCES

Alden, W. H., 1932, Physiography and glacial geology of eastern Montana and adjacent areas: U. S. Geol. Survey Prof. Paper 174.

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

Andrews, D. A., Lambert, G. S., and Stose, G. W., 1944, Geologic map of Montana, scale 1:500,000: U. S. Geol. Survey Oil and Gas Inv. Prelim. map 25.

Averitt, Paul, and Berryhill, L. R., 1950, Coal resources of the United States: U. S. Geol. Survey Circ. 94.

Bass, N. W., 1932, The Ashland coal field, Rosebud, Powder River, and Custer Counties, Montana: U. S. Geol. Survey Bull. 831–B.

Brown, Andrew, and others, 1954, Selected deposits of strippable coal in southern Custer and northern Powder River Counties, Mont.: U. S. Geol. Survey Bull. 995–E.

Combo, J. X., Brown, D. M., Pulver, H. F., and Taylor, D. A., 1949, Coal resources of Montana: U. S. Geol. Survey Circ. 53.

Combo, J. X., Holmes, C. N., and Christner, H. R., 1950, Coal resources of Montana: U. S. Geol. Survey Coal Inv. map C 2.

Culbertson, W. C., 1954, Strippable lignite deposits west of the Yellowstone River in southern Richland and northern Dawson Counties, Montana: U. S. Geol. Survey Bull. 995–H.

Dobbin, C. E., 1929, The Forsyth coal field, Rosebud, Treasure, and Big Horn Counties, Montana: U. S. Geol. Survey Bull. 812–A.

Fisher, C. H., and others, 1924, Hydrogenation and liquefaction of coal, part 2.—Effect of petrographic composition and rank of coal: U. S. Bur. Mines Tech. Paper 642.

Koenig, R. P., 1950, Economics and techniques of strip coal mining: Colorado School of Mines Quart., v. 45, no. 28.

May, P. R., 1954, Selected strippable lignite deposits in the Wibaux area, Richland, Dawson, and Wibaux Counties, Montana, and Golden Valley County, North Dakota: U. S. Geol. Survey Bull. 995–G.

Pierce, W. G., 1936, The Rosebud coal field, Rosebud and Custer Counties, Montana: U. S. Geol. Survey Bull. 847–B.

Renick, B. C., 1929, Geology and ground-water resources of central and southern Rosebud County, Montana: U. S. Geol. Survey Water-Supply Paper 600.

U. S. Bureau of Mines, 1951, Mineral Industry Surveys, Bituminous coal and lignite in 1950: Mineral Market Report no. 2032.

——— 1932, Analyses of Montana coals: Tech. Paper 529.

U. S. Geol. Survey Water-Supply Papers, Surface water supply of the United States, part 6, Missouri River basin: nos. 896 (1940), 926 (1941), 956 (1942), 976 (1943), 1006 (1944), 1036 (1945), 1056 (1946), 1086 (1947).
——— 1943, Summary of records of surface waters of Missouri St. Mary and River basins in Montana, 1881–1938: no. 917.