Strippable Lignite Deposits, Wibaux Area, Montana and North Dakota

GEOLOGICAL SURVEY BULLETIN 995-G

A CONTRIBUTION TO ECONOMIC GEOLOGY

STRIPPABLE LIGNITE DEPOSITS IN THE WIBAUX AREA, MONTANA AND NORTH DAKOTA

By PAUL R. MAY

ABSTRACT

The Wibaux area, including about 1,200 square miles east of the Yellowstone River in Dawson, Richland, and Wibaux Counties, Mont., and an adjacent strip of Golden Valley County, N. Dak., contains large reserves of lignite in two deposits that can be extracted economically by strip mining. The smaller of the two deposits is north of Wibaux, has an average thickness of about 10 feet, and contains 91 million tons of lignite under less than 120 feet of overburden. The larger deposit is east and southeast of Wibaux, extending southeastward into North Dakota. It has an average thickness of about 20 feet and contains about 1.2 billion tons of lignite under less than 120 feet of overburden. In each deposit the area is mapped where the overburden is less than 120 feet, and reserves of lignite are calculated in the following overburden categories: Less than 60 feet, 60 to 90 feet, and 90 to 120 feet. Eight other localities where lignite might be profitably strip mined were noted, but these localities are inferior to the deposits described in detail.

INTRODUCTION

This report describes two large deposits of lignite near Wibaux, Mont., convenient to water and transportation and adaptable to large-scale strip-mining. It has been prepared as part of the Department of the Interior's program for the integrated development of the Missouri River Basin.

The most economical way in which the lignite resources of the Wibaux area can be fully exploited is by open pit, or strip mining. It is the purpose of this chapter to present and describe deposits where the lignite can be mined on a large scale by stripping methods.

Commercial strip mining of coal in the United States began about 1910. By 1942 strip mining accounted for 12 percent of the nation's total annual coal production; and by 1950, the latest year for which figures are available, strip-mined coal comprised 23.9 percent of the total (Bureau of Mines, 1951, p. 20). This rapid growth is due to the

comparative cheapness of strip mining. In Illinois, for example, the amounts of coal produced per man-day in 1950 were 8 tons by underground mining and 18.7 tons by stripping (Bureau of Mines, 1951, p. 20). Furthermore, strip mining recovers 80 to 90 percent of the coal in the ground (Koenig, 1950, p. 28), but underground mining recovers only about 50 percent, the remainder being left as roof, floor, and pillars (Averitt and Berryhill, 1950, p. 8).

At present the demand for coal in this region is very low. A few large mines supply coal for locomotive fuel, but this demand is decreasing as the railroads convert to diesel power. Many small local mines supply fuel for town power plants and homes, but this demand is being replaced by natural gas. When large industries come to the western part of the Missouri River Basin, the eventual demand for power will make it necessary to supplement the hydroelectric plants with steam-electric plants using the abundant coal resources of the region as fuel.

Manufacture of synthetic liquid fuels is another likely use for the lignite in the Wibaux area. The low-rank coals of this area are well suited to the chemical synthesis processes. These processes require large quantities of water, however, and the number of plants would be limited by the amount of water available in the Yellowstone River.

In view of the expected increase in the demand for industrial fuel in this region and expanding use of strip mining in exploiting coal resources, it is expected that the interest in undeveloped deposits of strippable coal will increase in the future.

LOCATION

The Wibaux area is in the Fort Union coal region, a vast area of coal-bearing rocks that includes the western half of North Dakota, the eastern part of Montana, and part of the plains of western Canada. The Wibaux area comprises approximately 1,200 square miles in those parts of Dawson and Richland Counties, Mont., east of the Yellowstone River; the central and northern parts of Wibaux County, Mont., and an adjacent strip of Golden Valley County, N. Dak. (See fig. 35.) The area is roughly triangular. It is bounded on the northwest by the Yellowstone River; on the southwest by a line that connects the towns of Glendive, Mont., and Golva, N. Dak.; and on the east by the Montana-North Dakota State line, except in the southern part where it extends for about 4 miles into North Dakota.

PREVIOUS GEOLOGIC WORK

The entire Wibaux area lies within the limits of lignite fields mapped and described in previous bulletins of the U. S. Geological Survey. The northern half of the area is in the Sidney lignite field

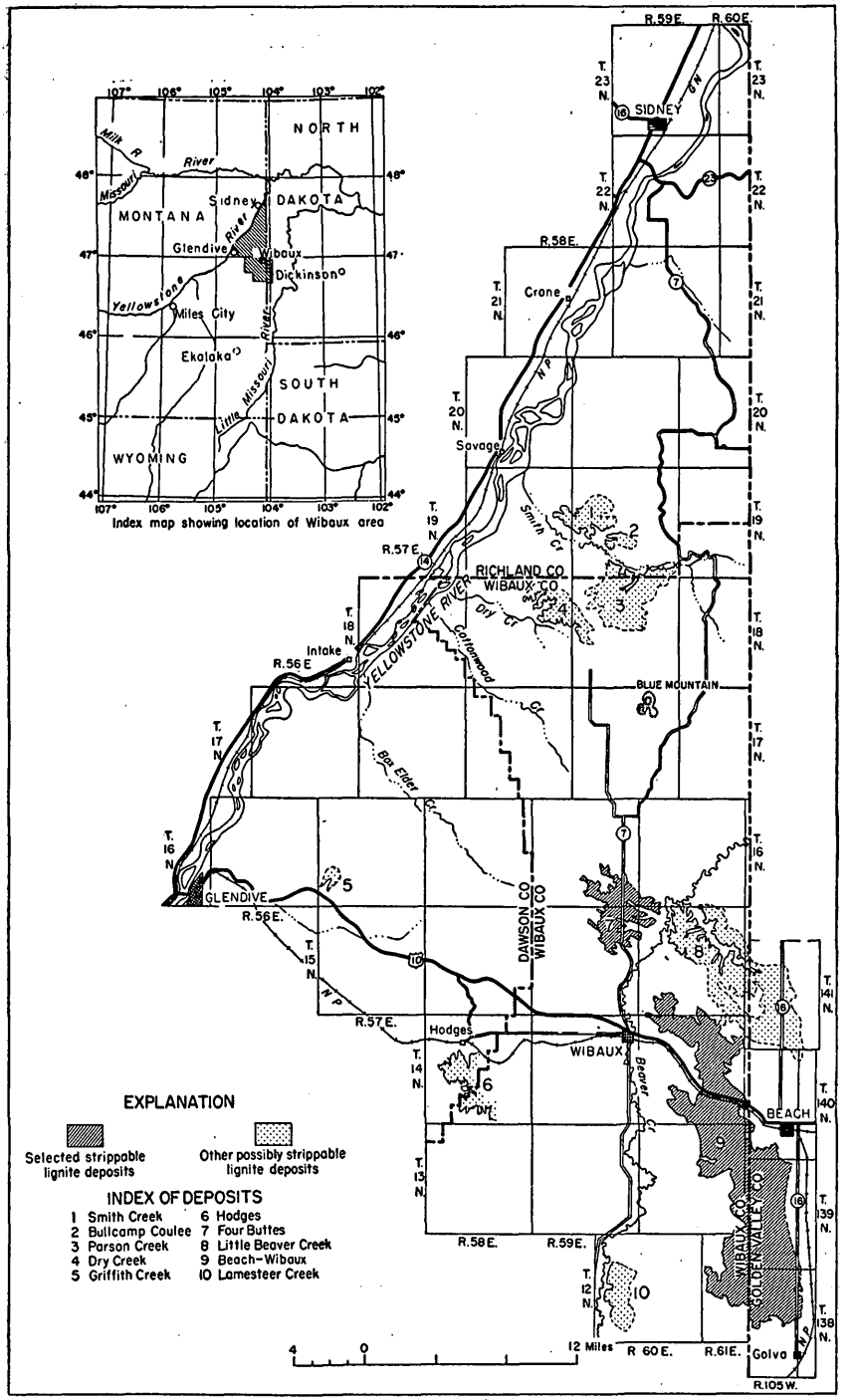

FIGURE 35. Map of Wibaux area, showing outline of strippable deposits, principal roads, and railroads.

(Stebinger, 1912). The southern half is in the Sentinel Butte lignite field (Leonard and Smith, 1909), the Glendive lignite field (Hance, 1912), and the Terry lignite field (Herald, 1912). T. 138 N., Rs. 105 and 106 W., N. Dak., are part of the Marmarth lignite field (Hares, 1928).

The northern three-fourths of the Wibaux area is part of the Glendive quadrangle, which was topographically mapped by the U. S. Geological Survey in 1909 at the scale of 1:250,000. The scale of this map is too small for use in mapping the lignite deposits.

ACKNOWLEDGEMENTS

The writer is very grateful for the help, consideration, and hospitality of the farmers and residents in the area. In particular, he wishes to acknowledge the contributions of Mr. Earl Baker, owner of the Black Diamond Mine; Mr. Joe Peplinski, who assisted the writer in taking a sample of the lignite from his mine; and Mr. Kenneth Thompson of Wibaux, who provided logs of a number of wells that he had drilled. The Petty Geophysical Engineering Company contributed a great deal to the value of this report by providing the the driller's logs and elevations of their shot holes. The staffs of the Soil Conservation Service, U. S. Department of Agriculture, at Glendive, Wibaux, and Beach generously provided the writer with the use of their office space and equipment.

SCOPE AND METHOD OF INVESTIGATION

The deposits of strippable lignite described in this report were selected with the object of describing areas suited to surface mining with heavy equipment and with sufficient reserves to be operated for several years. The standards used in evaluating and selecting the deposits, necessarily somewhat arbitrary, are based on present advanced strip-mining practices with an allowance for probable improvements in the future.

STANDARDS OF SELECTION OF STRIPPABLE DEPOSITS

The principal factors that determine the selection of strippable deposits are thickness and cleanness of lignite, thickness of overburden, stripping ratio, shape of the deposit, dip of the lignite beds, nature of the overburden and terrain, size of the deposit, and its nearness to transportation and water supply.

Thickness of lignite.—The minimum thickness of coal that can be strip mined profitably varies according to local conditions. In the East and Midwest, near the places of consumption, coal beds as thin as one foot have been strip mined. In North Dakota, where the rank of the coal is lignite, the minimum thickness now being stripped is

about 5 feet. The minimum thickness of lignite considered strippable in the Wibaux area is arbitrarily set at 5 feet, partly because of the North Dakota minimum and partly because of the accepted practice of using that figure as the dividing line between thin and intermediate beds of lignite and subbituminous coal. The average thicknesses of the selected deposits in the Wibaux area are well above this minimum, but along the margins of the deposits the lignite beds thin to less than 5 feet. In such cases, the border of the deposit is considered to lie at the point where the lignite is 5 feet thick.

Thickness of overburden.—The amount of cover that can be economically moved in a stripping operation depends largely on the type and capacity of the earth-moving equipment used. Most of such equipment now in use can move as much as 60 feet of overburden. In some parts of the country that figure is considered as a rough maximum for strip mining except under unusual conditions. At the Colstrip mine in Rosebud County, Mont., the average thickness of overburden moved in 1950 was 85 feet, and in small areas as much as 135 feet was stripped. For the purposes of this report the maximum thickness of overburden considered as strippable is placed at 120 feet, somewhat below the Colstrip maximum; and the overburden is broken down into three thickness categories—less than 60 feet, 60 to 90 feet, and 90 to 120 feet.

Stripping ratio.—In the eastern and midwestern states the maximum ratio of thickness of overburden to thickness of coal is commonly placed at 20 to 1. In the western states, particularly in the Fort Union and Powder River regions where the rank of the coal is low and sells at a lower price than eastern coal, a ratio of 10 to 1 is usually considered about the maximum for profitable mining. In this report the stripping ratio is expressed in cubic yards of overburden per ton of lignite; this ratio is equivalent to approximately nine-tenths of the thickness-to-thickness ratio. The stripping ratios of the selected deposits in the Wibaux area are well below the maximum for this region, the average ratio in the deposits being about 5 cubic yards per ton, with a maximum overburden of 120 feet.

Shape of the deposit.—Areas to be stripped should be relatively wide in proportion to their length so that a number of successive stripping cuts can be made in the deposit and a minimum of expensive opening cuts from ground level need be made. Although this requirement is not necessary in all cases, in general, long, narrow deposits are not desirable.

Dip of lignite beds.—As a general rule beds dipping more than 20 degrees cannot be strip mined. In the deposits described in this report the beds dip less than one degree.

279477—54——2

Nature of the overburden.—The ideal types of overburden for strip mining are shale and soft sandstone that can be loosened by light blasting, or possibly with no blasting at all. The rocks overlying the lignite in the Wibaux area are mostly shales, clays, and soft sandstones. The few thin limestone beds and most of the harder sandstone beds can be broken by light blasting.

Nature of the terrain.—Rough, hilly country is not suitable for stripping operations unless other factors, such as an exceptional thickness of lignite, offset the difficulty of working on steep slopes. A particular disadvantage of rough terrain is that the practical overburden limit is likely to be so close to the outcrop of the lignite bed that only a narrow strip can be mined. In general, areas are sought where the land is gently rolling or flat.

Total reserves.—The reserves in a strippable deposit as defined in this report should be sufficient to insure continuous operation for at least five years, as it is not economical to move heavy stripping equipment into an area for a shorter period. Based on the anticipated scale of future strip mining in eastern Montana and western North Dakota, the minimum reserve of lignite for a strip deposit as defined in this report is 15 million tons, of which 10 million tons should be under less than 60 feet of overburden.

Nearness to railroads.—The main line of the Northern Pacific Railway passes through the Wibaux area, and there are excellent deposits within a few miles of the railroad. These were mapped in preference to those in other parts of the area.

METHODS OF INVESTIGATION

The first phase of investigation of the Wibaux area was a study of the published bulletins on lignite fields to find those areas having lignite beds more than 5 feet thick. Following this an extensive reconnaissance tour of the area was made to: (1) Check the prospects noted on the published maps to see which might be suited for strip mining and (2) discover other lignite beds not previously mapped that might contain strippable deposits.

It became evident during the preliminary field reconnaissance that the Beach-Wibaux and Four Buttes deposits (nos. 7 and 9, fig. 35) are the most favorable for strip mining of the several prospects in the area. Hence, nearly all the field season of 1951 was devoted to mapping them in detail.

Geologic mapping.—The strippable bed in the Beach-Wibaux and Four Buttes deposits were previously mapped as part of the Sentinel Butte lignite field (Leonard and Smith, 1909), but the mapping was

on a reconnaissance scale and not in sufficient detail for the purposes of this project. The lignite bed was outlined only approximately on the map of the Glendive lignite field (Hance, 1912) in the area of the Beach-Wibaux deposit.

The outcrop and clinker of the strippable bed and other nearby lignite beds were mapped on the U. S. Department of Agriculture aerial photograph mosaic of Wibaux County at a scale of 1:31,680, or 2 inches to the mile. As the photo map has been adjusted to an accurate land control, surveying methods were not necessary. The Beach-Wibaux, Four Buttes, and Little Beaver Creek deposits were mapped in this manner.

Determination of thickness of lignite.—The estimates of the average thickness of the lignite in the selected strippable deposits are derived from: (1) Measured exposures, (2) logs of power-auger holes, (3) reports of the thickness in abandoned mines, by owners or former employees, (4) logs of water wells, given by the driller or the farmer, and (5) logs of seismograph shot holes.

The most accurate measurements are those taken at outcrops or in open mines. The power auger gives fair accuracy in holes less than about 50 feet deep; the thicknesses are generally accurate within one to two feet, although details, such as thin partings, usually cannot be distinguished in the cuttings. The accuracy of farm well reports is variable. As the main purpose of the driller and the farmer is to find water, the thickness and depth of the lignite beds is of incidental interest. Some such logs are fairly accurate; others, however, cannot be relied upon except as indicating the presence of the lignite and its approximate depth and thickness. The seismograph shot-hole logs used in this report were obtained from the Petty Geophysical Engineering Company. The drillers were extremely cooperative and made every effort to get accurate logs; and, therefore, most of the thicknesses recorded are probably reliable within a few feet.

Mapping of overburden.—The overburden lines on the maps (pls. 39 and 40) represent those lines along which the overburden is 60, 90, and 120 feet thick. These contours were drawn in the field on aerial photographs by reference to nearby points where the depth to the top of the lignite was known. The difference in elevation was measured with a surveying aneroid barometer or with an alidade and plane table. Where well reports or other drill holes that give the depth to the lignite were lacking, the overburden lines were located approximately by calculating the dip of the lignite bed and subtracting the inferred elevation of the lignite below the ground from the surface elevation at the same point.

TABLE 1.—*Original reserves of strippable lignite in the Four Buttes and Beach-Wibaux deposits, Wibaux County, Mont., and Golden Valley County, N. Dak. (in millions of short tons)*

Deposit	Average thickness (in feet)	Less than 60 feet overburden		60–90 feet overburden		90–120 feet overburden		Total	
		Acres	Reserves	Acres	Reserves	Acres	Reserves	Acres	Reserves
Four Buttes	10	3,480	61	1,450	25	[1] 250	[2] 5	5,180	91
Beach-Wibaux:									
Northern part	17	4,460	120	1,010	43	1,860	55	7,330	218
Central part	24	8,070	339	4,260	179	3,330	140	15,660	658
Southern part	16	9,080	254	1,960	55	680	19	11,720	328
Beach-Wibaux total	------	21,610	713	7,230	277	5,870	214	34,710	1,204
Total	------	25,090	774	8,680	302	6,120	219	39,890	1,295

[1] Includes 15 acres of overburden 120–135 feet thick.
[2] Includes less than 500,000 tons lying beneath 120–135 feet of overburden.

Calculation of reserves of strippable lignite.—Data on the thickness and areal extent of each deposit are spaced closely enough to permit a fairly accurate estimate of the reserves of strippable lignite in the deposits, although the accuracy necessarily varies considerably from place to place. As most of the measurements of the lignite are at or near the outcrop of the bed, the most accurate reserves are those in the category of less than 60 feet of overburden. In general, the strippable reserves of the selected deposits are considered to be commensurate with the "indicated" category of reliability as described by Averitt and Berryhill, (1950, p. 11).

In calculating reserves, the acreages between the outcrop of the lignite and the 60-, 90-, and 120-foot overburden lines were measured separately on each deposit map with a planimeter. The number of acres of less than 60, 60 to 90, and 90 to 120 feet of overburden were each then multiplied by the average thickness of the lignite, giving the volume of lignite in acre-feet under three maximum thicknesses of overburden. The approximate number of short tons per acre-foot of lignite is 1,750. Therefore, the product of this figure and the volume of lignite, in acre-feet, gives the reserves in short tons.

The strippable reserves of the two selected deposits are given in table 1, divided into three categories of overburden. The reserve figures are on the basis of original reserves in the ground. The amount of lignite removed in the few mines in the deposits is not large enough to make a significant difference in the total tonnages.

Stripping ratio.—In both of the selected deposits, an estimate is made of the average ratio of cubic yards of overburden per ton of lignite if either 60 or 120 feet of overburden is removed in strip mining. This type of ratio is equal to approximately nine-tenths of a

ratio of average thickness of overburden to average thickness of lignite. To derive the stripping ratio, the total volume of overburden is estimated from the area measurements and from the knowledge of the terrain over the deposit. Then the volume divided by the tonnage gives the average stripping ratio. These figures are necessarily approximate and are rounded off to the nearest cubic yard per ton.

GEOGRAPHY

The Wibaux area is a part of the northern Great Plains, a semiarid region devoted mainly to livestock raising and grain growing. The principal mineral resources of the region are coal and petroleum. The region is sparsely populated, towns being about 30 to 40 miles apart. As none of the rivers are navigable, all freight is carried by rail or by truck.

Climate.—The climate in the Wibaux area is semiarid, with a great range of temperature throughout the year. The average annual precipitation is about 15 inches, most of which falls as rain during the spring and summer months. The remainder falls principally as snow from late October into April.

The winters are particularly severe; the temperature may reach as low as 30° to 40° below zero, and frequent blizzards virtually paralyze rural areas. During the summer the temperature averages about 70°, but may exceed 100°.

Topography and drainage.—The Wibaux area is part of a dissected plateau, marked by hills and buttes, occasional badlands, and smooth upland surfaces. The principal streams are the Yellowstone River and Beaver Creek, a tributary to the Little Missouri River. The drainage areas of the Yellowstone and Beaver Creek contrast strongly in their general topographic aspect. The parts of the area drained by the Yellowstone River are rugged and hilly with many badlands. The valleys of some of the major creeks have broad, smooth slopes. In contrast, the drainage basin of Beaver Creek is characterized by low, rolling fields and meadows, broken in places by buttes capped by clinker or sandstone.

Settlement.—Slightly more than half the population of the Wibaux area is in Beach, N. Dak., population 1,461, and the larger towns of Glendive, Sidney, and Wibaux, Mont., which, according to the 1950 census, have populations of 5,254, 3,987, and 1,907 respectively. The rest live on farms, ranches, and in small rural communities such as Hodges, Mont., and Golva, N. Dak. The greatest concentration of rural population is in east-central Wibaux County and in that part of Golden Valley County, N. Dak., included in the area investigated.

Transportation.—The main line of the Northern Pacific Railway passes through Glendive, Hodges, Wibaux, and Beach, and connects the area with Miles City and Billings on the west and with Dickinson and Bismarck on the east. Sidney is connected to the main line of the Great Northern Railway by a spur and to Glendive by a line of the Northern Pacific. A spur of the Northern Pacific extends south from Beach through Golva, N. Dak., to Ollie and Carlyle, Mont.

U. S. Highway 10 and Montana Route 14 are first-class paved roads. The former passes through Glendive, Wibaux, and Beach; the latter connects Glendive and Sidney. Montana Route 7 and North Dakota Route 16 are good gravel-surfaced roads kept passable under most weather conditions. Montana Route 7 passes southward through Wibaux, and North Dakota Route 16 passes southward through Beach. In addition there are many dirt- and gravel-surfaced county roads that range from a quality equal to the State routes to mere trails. Density and average quality of the smaller roads vary according to the density of farms. In central Wibaux County near the State line and in the part of Golden Valley County included in the investigated area, there is a road on nearly every section line; but in southwestern Dawson County and many parts of northern Wibaux County, roads are very sparse.

Electric power.—Most of the electric power in the area is generated at the Fort Peck Dam in northeastern Montana and is delivered to Glendive over a 115-kilovolt transmission line. A 57-kilovolt line, owned by the Montana-Dakota Utilities Co., extends from Glendive through Wibaux to Beach. The local needs in the area around Wibaux and Beach are served by the Wibaux Rural Electric Association, which converts the 57 kilovolts to 7.2 kilovolts at a substation 3 miles west of Beach. A 57-kilovolt line follows the west side of the Yellowstone River from Glendive to Sidney. In addition, the Bureau of Reclamation has constructed a 115-kilovolt line that extends from Glendive to Sidney.

279477—54——3

TABLE 2.—*Monthly and annual discharge in 1,000 acre-feet of Yellowstone River near Sidney, Mont.*

Water year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
1935	294.2	249.6	192.6	169.6	245.9	322.7	324.8	600.1	2,473.0	1,491.0	345.0	199.0	6,907.5
1936	258.8	268.7	288.1	199.8	155.4	681.4	495.1	1,195.0	1,898.0	625.4	359.1	207.1	6,631.9
1937	321.2	327.6	213.7	128.3	158.5	417.7	404.7	805.3	2,369.0	1,381.0	229.6	201.8	6,958.4
1938	376.1	269.5	189.9	268.5	189.2	573.5	370.4	965.1	2,940.0	1,910.0	480.8	377.5	8,910.5
1939	399.7	388.1	253.8	296.5	166.8	737.7	423.8	1,066.0	1,613.0	702.6	284.8	192.6	6,525.4
1940	331.1	348.4	248.8	134.5	220.7	334.6	377.8	795.3	1,593.0	524.7	160.1	163.9	5,232.9
1941	582.4	293.0	327.5	213.8	239.9	361.7	411.4	1,033.0	1,656.0	604.3	599.9	952.1	7,275.0
1942	889.4	577.1	464.4	278.9	319.2	823.7	688.7	1,387.0	2,527.0	1,300.0	393.2	320.9	9,969.5
1943	450.6	455.8	284.1	270.5	791.6	1,221.0	1,092.0	1,157.0	3,461.0	2,854.0	821.5	477.1	13,336.2
1944	401.8	443.1	349.1	265.0	259.3	942.3	734.8	1,269.0	4,028.0	2,022.0	462.1	369.7	11,546.2
1945	431.6	413.6	243.3	327.4	304.9	722.0	429.4	790.5	2,409.0	2,132.0	650.7	508.6	9,363.0
1946	557.8	434.1	260.4	394.1	300.5	641.9	547.8	908.6	2,066.0	1,106.0	287.7	533.4	8,038.3
1947	620.5	480.8	367.3	230.7	294.3	1,130.0	714.4	1,748.0	2,460.0	1,956.0	623.9	394.5	11,020.4
1948	564.4	498.7	388.0	299.5	346.9	763.2	657.3	1,172.0	3,467.0	1,510.0	461.0	253.4	10,381.4
1949	403.3	422.4	195.1	200.1	231.7	717.4	625.0	1,166.0	2,133.0	913.1	238.2	313.1	7,558.4
1950	231.3	219.0	124.4	98.7	154.2	322.5	457.7	394.3	1,170.0	946.6	340.3	250.2	4,709.2
Total	7,114.2	6,089.5	4,390.5	3,775.9	4,379.0	10,713.3	8,755.1	16,452.2	38,263.0	21,978.7	6,737.9	5,714.9	134,364.2
Average	444.6	379.3	274.4	236.0	273.7	669.6	547.3	1,028.3	2,391.4	1,373.7	421.1	357.2	8,397.2

TABLE 3.—*Monthly and annual discharge in acre-feet of Beaver Creek at Wibaux, Mont.*

[Drainage area 240 square miles]

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1940	0	33	59	43	86	167	839	320	30	3	0	0	1,580
1941	3	7	17	10	34	231	264	92	398	46	153	106	1,360
1942	333	101	58	0	10	13,760	2,730	543	8,090	193	223	35	26,080
1943	86	71	50	308	13,360	14,260	1,650	141	4,300	425	76	47	34,770
1944	60	91	61	99	29	1,720	14,360	354	4,400	583	189	91	22,040
1945	121	260	31	27	535	11,300	675	616	1,590	180	23	3	15,360
1946	7	13	10	32	85	2,110	214	56	23	1,860	0	0	4,410
1947	22	23	20	12	329	14,570	9,300	399	2,610	1,570	426	57	29,340
Total	632	599	306	531	14,460	58,118	30,032	2,521	21,441	4,860	1,090	339	134,940
Mean	79	75	38	66	1,808	7,265	3.754	315	2,680	608	136	42	16,868

Water supply.—The Wibaux area is 30 miles southeast of the Yellowstone River, which is the only source of water in quantity. The annual rate of flow of the Yellowstone, measured at Sidney, is given in table 2. None of the other streams in the area supply enough water the year round for industrial use. Beaver Creek flows some water during all but the winter and the driest months, enough to serve certain engines such as test-drilling rigs. Its annual flow, measured at Wibaux, is given in table 3.

Ground water may be obtained at fairly shallow depths from sandstone and coal beds of the Tongue River member of the Fort Union formation. The available supply generally is inadequate for industrial demands and is too highly mineralized to be used in boilers. However, in the valley of the Yellowstone River, wells that tap the saturated alluvial fill may produce enough water for use in fuel or steam plants, provided it is treated to remove the high content of dissolved salts.

Land use.—About three-fourths of the area is grazing land; the rest is under cultivation, principally to spring wheat, as well as flax, feed corn, barley, and oats. The greatest concentration of cropland is east of Beaver Creek where, on the smooth upland, there is a belt of rich soil that supports a fairly high density of nonirrigated farms. The land west and north of Beaver Creek is used mostly for raising livestock; however, there are scattered plots of cropland on the more level areas. The price of cropland during 1951 ranged from 40 to 75 dollars an acre, and pasture land was from 5 to 8 dollars an acre.

Land ownership and mineral rights.—Ownership of the land in the investigated area is divided among private individuals, the Northern Pacific Railway, the States of Montana and North Dakota, and the Federal Government. Mineral rights are in some cases owned by the same party that owns the surface and in other cases are owned separately.

The Northern Pacific Railway was originally granted all odd-numbered sections in the area and rights to the coal. Much of its land

has since been sold or traded; but the railroad has, in most sections, retained the mineral rights. The States of Montana and North Dakota were given sections 16 and 36 of each township for use as school land. In most townships neither the surface nor mineral rights of state-owned sections have been sold.

Those Government sections in which agriculture is possible have been homesteaded or sold. The mineral rights, in particular coal rights, are held by the Government on most of its original land, but in a few cases these rights were sold to the landholder.

By 1951 the oil and gas rights in nearly the entire area were leased by private companies. About half of the leases include rights to all minerals, including coal. There has been a large amount of buying and selling of mineral rights for the value of the oil royalties since 1950, and many of these transfers have included the coal rights.

STRATIGRAPHY

The strata exposed in Dawson, Richland and Wibaux Counties, Mont., are of Cretaceous and Paleocene age. The formations are, in ascending order, the Pierre shale, the Fox Hills sandstone, the Hell Creek formation of Late Cretaceous age, and the Fort Union formation of Paleocene age. In the Wibaux area only rocks of the Fort Union formation are exposed.

FORT UNION FORMATION

The Fort Union formation is the surface rock of most of eastern Montana and western North Dakota and contains most of the lignite resources of the region. The formation is of nonmarine origin; its strata were deposited in lakes, swamps, and river flood plains. It is composed mostly of sandstone, shale, clay, and numerous beds of lignite. A conspicuous characteristic of the Fort Union formation is the reddish masses of clinker, or baked and fused rock, caused by widespread burning of the lignite beds. Clinker, locally called "scoria," strongly resists erosion and thus forms the cap-rock on ledges and flat-topped buttes. The Fort Union formation in this locality is divided into three members; the Ludlow, Tongue River, and Sentinel Butte members.

Ludlow member.—The Ludlow member, the lowest unit of the Fort Union formation, lies comformably on the Upper Cretaceous Hell Creek formation. In most of the older geologic reports the Ludlow member and Hell Creek formation, which are similar in character, were not distinguished from each other but were referred to as the Lance formation. The Ludlow member crops out only along the banks of the Yellowstone River in Dawson County, and on the southwestern edge of the area as far east as the vicinity of Hodges, Mont.

279477—54——3

The Ludlow member consists of lenticular beds of somber gray and brown sandstone and shale, and a few thin beds of lignite. In this area it is about 250 feet thick. At the top of the member the coloring of the sandstones and shales gradually changes to the light yellow and tan hues of the overlying Tongue River member.

Tongue River member.—The Tongue River member, which is exposed over nearly all the Wibaux area, is composed of light-yellow, tan, and gray sandstones and shales; thin lenses of limestone; and numerous beds of lignite, the thicker of which are generally marked by fringes of clinker. The major lignite resources of the region are in the Tongue River member, as are the strippable deposits described in this report. The maximum thickness of the Tongue River member is about 1,200 feet, as measured in the Sidney lignite field. However, in the Marmarth field, southeast of the investigated area, its thickness is only about 600 feet. In the older reports, the term Fort Union formation is restricted to the yellow strata herein referred to as the Tongue River member.

Sentinel Butte shale member.—About 200 feet of the Sentinel Butte shale member, the uppermost member of the Fort Union formation, is exposed at the top of Blue Mountain in northern Wibaux County. It is composed of gray and brown sandstone and shale and contains a few thin lignite beds and bears a striking resemblance to the Ludlow member. The contact of the Sentinel Butte shale member with the Tongue River member is marked in most places by a lignite bed, called bed K in the Sidney field, bed F in the Sentinel Butte field, and the HT Butte bed in the Marmarth field.

STRUCTURE

The Wibaux area lies on the southwestern side of the Williston Basin, directly northeast of the Cedar Creek anticline. The central part of the Williston Basin lies northeast of the investigated area south of the city of Williston, N. Dak. The Cedar Creek anticline is a long, linear uplift, which trends N. 30° E. from near Glendive to the northeast corner of South Dakota. Along the southwestern edge of the area, nearest the anticline, the strata dip northeastward about 200 feet per mile. The dip gradually decreases toward the central part of the basin; until, at the northern corner of the area, it is about 25 feet per mile. In addition to these major structures, there are a few small folds to be found in the area. One of these is a sharp monocline that can be observed along U. S. Highway 10 near Krug Creek (sec. 4, T. 15 N., R. 58 E.), where the strata dip southward about 30°.

Many minor undulations were noted in the attitude of the lignite beds in the strippable deposits, but there is no evidence that the lignite on the limbs of these small folds dips more than about 5°.

TABLE 4. *Analyses of samples of lignite from the Wibaux area and vicinity*

[Analyses by U. S. Bureau of Mines]

Lab. no.	Bed and location	Form of analysis [1]	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Air-dry loss	Heating value (Btu)
A–34180	Unnamed bed, Smith mine, T. 17 N., R. 55 E., 9 miles NE. of Glendive, Dawson County, Mont.	A	32. 6	24. 9	34. 0	8. 5	1. 3	10. 9	7, 380
		B	----------	37. 0	50. 4	12. 6	1. 9	----------	10, 950
		C	----------	42. 3	57. 7	----------	2. 2	----------	12, 520
11045	Unnamed bed, Snyder mine sec. 27, T. 17 N., R. 55 E., Dawson County, Mont.	A	32. 1	25. 6	34. 2	8. 1	1. 4	23. 4	7, 110
		B	----------	37. 7	50. 4	11. 9	2. 0	----------	10, 470
		C	----------	42. 7	57. 3	----------	2. 3	----------	11, 890
D–71162	Bed C, Stair mine, sec. 2, T. 15 N., R. 59 E., Wibaux County, Mont.	A	37. 9	26. 4	26. 1	9. 6	1. 0	28. 2	6, 140
		B	----------	42. 6	41. 9	15. 5	1. 6	----------	9, 890
		C	----------	50. 4	49. 6	----------	1. 9	----------	11, 700
D–71163	Bed C, Peplinksi mine sec. 9, T. 12 N., R. 61 E., Wibaux County, Mont.	A	41. 0	24. 8	26. 3	7. 9	0. 9	32. 3	6, 050
		B	----------	42. 0	44. 7	13. 3	1. 6	----------	10, 240
		C	----------	48. 5	51. 5	----------	1. 8	----------	11, 820

[1] The forms of analysis are: A—As received at the laboratory; B—Moisture-free; C—Moisture and ash (mineral matter)-free.

LIGNITE

PHYSICAL AND CHEMICAL CHARACTERISTICS

Lignite is coal which has a heating value of less than 8,300 Btu, determined on the moist, mineral-matter free basis (according to the standard specifications of the American Society for Testing Materials). All coal in the Wibaux area and its vicinity is lignite in rank. Proximate analyses of representative samples of the lignite are presented in table 4. Only two samples were obtained in the investigated area, one from the Four Buttes strippable deposit and the other from the southern part of the Beach-Wibaux deposit. The other two are from mines northwest of the Yellowstone River in the vicinity of Glendive, and are probably representative of the lignite in the western part of the area.

Unweathered lignite is hard and tough, black to brownish black, and has a dark-brown streak. When exposed to air, it loses moisture and slacks readily and may eventually ignite spontaneously and burn. Special care must be taken in storing it, several methods being used—immersing the stockpile in water, covering it with an airtight seal of tar or asphalt, or storing in closely compacted piles or pits.

The freshest natural exposures of lignite are those found on steep cutbanks of streams; however, even those are somewhat weathered. Exposures on slopes are usually fully slacked, and the lignite is brittle and crumbly. Such outcrops frequently show only as a dark smudge or "bloom" in the soil. Exposures of any sort are rather rare owing to extensive burning of the lignite along its outcrop. Heat from this burning, and the resultant emanations of hot gases, have produced the bricklike baked rock called clinker or "scoria" that marks the trace of nearly all the thicker lignite beds in the region.

By comparison with most of the lignite and subbituminous coal of eastern Montana, the ash and sulfur content of the lignite in the Wibaux area is average to somewhat high; but, by comparison with most of the coals of the United States, the percentage of impurities is low. In addition to the layers or clay and bone and the lenses and bands of pyrite and marcasite that are common to most coals, the lignites in the Wibaux area contain a few silicified tree stumps, gypsum crystals, and veinlets and small masses of jarosite, a yellow oxide of sulfur, iron, and potassium.

PRINCIPAL LIGNITE BEDS

Three lignite beds in the Wibaux area contain deposits that are minable by stripping methods. These are, beginning with the lowest, the unnamed "lowest minable bed" of the Glendive (Hance, 1912) and the Terry lignite fields (Herald, 1912); bed G of the Sidney lignite

field (Stebinger, 1912); and bed C of the Sentinel Butte lignite field (Leonard and Smith, 1909). Bed C contains the two strippable deposits that are mapped and described in detail. Possible strip areas in the two lower beds are described in the section headed "Possible deposits." The stratigraphic relations of the beds are shown in figure 36.

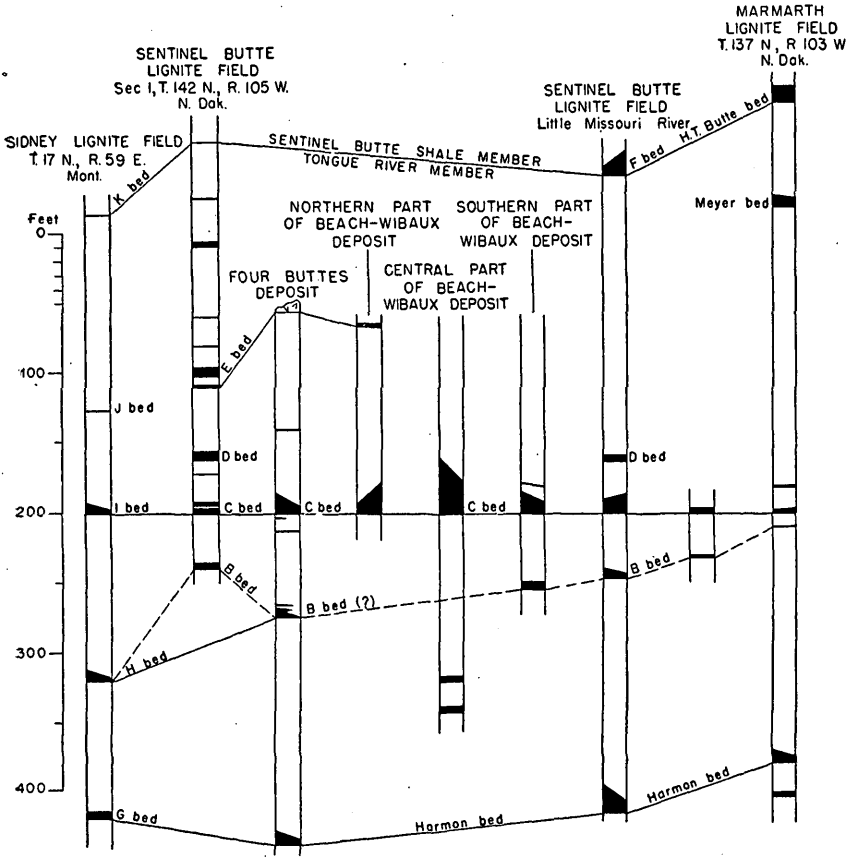

FIGURE 36. Generalized columnar sections showing correlations, intervals, and thicknesses of lignite beds in the vicinity of the Beach-Wibaux and Four Buttes strippable deposits.

Lowest bed.—This bed crops out almost continuously throughout the Glendive and Terry lignite fields in the southern half of the area. It is equivalent to bed A of the Sidney lignite field, which crops out only on the west side of the Yellowstone River. Two potential strip deposits were prospected in this bed, one at Griffith Creek and the other south of Hodges, Mont., both in the Glendive lignite field. The bed is at or near the contact of the Ludlow and Tongue River members of the Fort Union formation. It varies greatly in thickness within rather short distances and ranges from less than 2 feet to 24 feet. The possibilities for strip mining in the thicker portions of this bed are limited

by the fact that it crops out almost exclusively in a belt of high, rugged badlands.

Bed G of the Sidney field.—Bed G is the thickest and most continuous of the minable beds in the Sidney lignite field. Bed G contains four possible strip deposits in the rolling uplands near Smith and Dry Creeks in the northern part of the area where it ranges from 5 to 11 feet in thickness. Bed G is equivalent to the Harmon bed of the Sentinel Butte lignite field. The Harmon bed crops out near the level of Beaver Creek near the Four Buttes strippable deposit and lies at shallow depth beneath the town of Wibaux, where it is reported to be 12 feet thick. The Harmon bed is not identified with certainty along Beaver Creek south of Wibaux, but it may be that the deposit prospected for stripping at Lamesteer Creek in the extreme southern part of the area is in the Harmon bed.

Bed C of the Sentinel Butte field.—Bed C contains the Beach-Wibaux and Four Buttes strippable deposits and a possible deposit in the Little Beaver Creek area; this is the thickest of the beds in the investigated area. Bed C reaches a maximum thickness of 40 feet in the Beach-Wibaux deposit and maintains a thickness of more than 10 feet over most of the southeastern part of the area. It is probably equivalent to bed I of the Sidney field and to the equivalent Burkey and Garner Creek beds of the Marmath field to the southeast.

SELECTED STRIPPABLE DEPOSITS

Two deposits in the Wibaux area were mapped in detail—the Beach-Wibaux deposit and the Four Buttes deposit, both in bed C of the Sentinel Butte lignite field (Leonard and Smith, 1909). Both areas are well above the minimum standards for selection of strippable deposits with regard to the thickness of lignite and overburden, and the total reserves of each are sufficient to allow continuous stripmining operations for many years. An important advantage is that all parts of the deposits are within a short distance of the main line of the Northern Pacific Railway, which connects them directly with potential points of consumption.

FOUR BUTTES STRIPPABLE DEPOSIT

The Four Buttes strippable deposit (pl. 40) comprises about 8 square miles in the divide between the Yellowstone River and Beaver Creek, in central Wibaux County, Mont. State Route 7, a well-drained gravel road, connects the deposit with the town of Wibaux, five miles to the south; and, as U. S. Highway 10 and the main line of the Northern Pacific Railway pass through Wibaux, the deposit is readily accessible to the main routes of transportation. The strippable deposit is in secs. 1, 2, 3, 10, 11, 12, 13, and 14, T. 15 N., R 59 E.; secs. 6

and 7, T. 15 N., R. 60 E.; secs. 25, 26, 27, 28, 34, 35, and 36, T. 16 N., R. 59 E.; and secs. 31 and 32, T. 16 N., R. 60 E.

Topography and land use.—The deposit is in a moderately hilly upland, which slopes east and west from the divide between the Yellowstone River and Beaver Creek. The crest of the divide is less than 120 feet above the top of the strippable lignite except in sec. 35, T. 16 N., R. 59 E., where eight small clinker-capped hills rise to about 135 feet above the bed. A cluster of four of these hills in the northeast corner of the section is the Four Buttes, a distinctive local landmark.

The eastern slope of the divide is a smooth, gently rolling surface cut by several broad, shallow draws tributary to Beaver Creek. In the northeast corner of the deposit, however, the draws are steep and incised, and the relief exceeds 100 feet. The extreme eastern edge of the deposit underlies a small portion of a flat terrace of Beaver Creek.

The western slope is in general more rugged than the eastern, particularly along the narrow ridges that project northwestward from the main body of the deposit. The heads of the tributaries of the Yellowstone lie in deep valleys, the sides of which rise nearly 100 feet toward the uplands near the divide. The deposit is about 2,700 feet above sea level.

About 70 percent of the area over the deposit is under cultivation to wheat and feed corn. The remainder is occupied by pasture.

C lignite bed.—The strippable lignite of the Four Buttes deposit is in bed C of the Sentinel Butte field. The lignite ranges from 5 to possibly 20 feet in thickness and averages about 10 feet. The data are provided by 28 measured exposures, four power-auger logs, and seven seismograph shot-hole logs (pl. 41). The map of the deposit (pl. 40) includes lines showing the general thickness of the lignite as inferred from these measurements. In the NW¼ sec. 12, T. 15 N., R. 59 E. and in adjacent parts of secs. 1 and 11, the lignite is less than 5 feet thick and is not considered as being in the deposit.

A thin clay parting in the lower part of the bed was noted at locations 20 and 25, but no partings were found elsewhere. Three vertical sand partings, or "sand splits," were found in the Stair mine. They are 1 to 3 inches wide, spaced about 200 feet apart, and cut the bed from top to bottom. These "sand splits" apparently were formed shortly after the lignite bed was deposited as peat and a thin layer of sand and clay had spread over it. The ground surface sloped slightly, and the soft materials tended to slump downslope. The stresses exerted by the slumping tore fissures in the jellylike peat, and loose sand and clay were washed in. Now that the peat has hardened to lignite, the sand-filled fissures remain as dikes.

The proximate analysis of a channel sample of the lower 11 feet of the bed is given in table 4. The sample was taken from the innermost room of the Stair mine, about 600 feet north of the mine mouth. The analysis shows a medium heating value for lignite and a rather high ash and sulfur content. The high ash content is partly accountable to the one-inch parting in the lower part of the bed.

In accord with the regional structure, the beds dip about 30–40 feet per mile northeast. Owing to this dip and to the fact that the lignite is cut through by Beaver Creek east of the deposit, it is unlikely that any appreciable amount of ground water has accumulated in the bed.

Overburden and floor rock.—The overburden consists of lenticular beds of soft sandstone, siltstone, shale, and clay. A fairly persistent bed of lignite, one to two feet in thickness, lies about 50 feet above bed C. Small points of clinker cap the hills in sec. 35, T. 16 N., R. 59 E., where the overburden reaches its maximum thickness of 135 feet. In most localities the lignite rests on gray or carbonaceous clay, but at location 2 the power auger struck sand directly beneath the lignite.

Strippable reserves.—The total strippable reserves of the Four Buttes deposit are estimated at 91 million short tons of lignite beneath a maximum of 135 feet of overburden. (See table 1.) Of this amount, only about 250,000 tons are under more than 120 feet of overburden. If the entire tonnage were recovered by strip mining, it would be necessary to remove on the average 5 cubic yards of overburden per ton of lignite. The lignite beneath less than 60 feet of overburden could be mined at an average ratio of slightly less than 3 cubic yards per ton.

That lignite beneath the crests of the narrow ridges south of the NW¼ sec. 14, T. 15 N., R. 59 E. is not considered to be in the deposit. Northeast of Four Buttes, lack of exposures or of clinker indicated that the bed is probably thin, and the deposit, therefore, is not considered as extending into this area. Furthermore, exposures along Beaver Creek at location 31 and others farther northeast, show that the bed splits into several thin benches.

BEACH-WIBAUX STRIPPABLE DEPOSIT

The Beach-Wibaux strippable deposit (pl. 39) underlies about 55 square miles between Wibaux, Mont., and Beach and Golva, N. Dak. Bed C of the Sentinel Butte lignite field (Leonard and Smith, 1909) is the strippable bed. In about three-fourths of the area, bed C is more than 20 feet thick; and, in a large part in the central portion, its thickness exceeds 30 feet, with no partings. U. S. Highway 10 and the main line of the Northern Pacific Railway cross the deposit, and a railway spur skirts its eastern border. The town of Beach lies

on the east edge of the deposit as shown on plate 39; the town of Wibaux lies 5 miles northwest of the deposit and half a mile west of the west edge of the area shown on plate 39.

For convenience in description, the deposit is arbitrarily divided into three parts (see pl. 39): The northern part, the central part, and the southern part. The northern part includes all of the area north of U. S. Highway 10. The central part extends from Highway 10 southward to Duck Creek in the vicinity of the State line, and in North Dakota, includes the northernmost four tiers of sections in T. 139 N. The southern part lies south of Duck Creek in Montana and includes the southern two tiers of sections in T. 139 N. and the northern three tiers of T. 138 N. in North Dakota.

NORTHERN PART

The area lying north of the highway is distinguished from the central and southern parts by somewhat higher relief and a lower maximum thickness of lignite. The northern part is convenient to the main line of the Northern Pacific Railway, which follows the south side of U. S. Highway 10.

The northern part includes 7,330 acres in the following sections: sec. 32, T. 15 N., R. 60 E.; secs. 2, 3, 4, 5, 9, 10, 11, 12, 13; 14, 15, 22, 23, and parts of 24, 25, 26, and 27, T. 14 N., R. 60 E., Wibaux County, Mont.

Topography and land use.—The terrain is moderately hilly and characterized by gentle, grassy slopes of 50–80 feet of relief. Hay Creek, which drains the central and northern portions of this area, and an unnamed creek near the highway and railroad contain water throughout most of the year.

Nearly all the area is under cultivation for wheat, feed corn, and flax. Some small plots on hilltops and slopes are used for pasture. Roads, most of which are graded and drained, follow all the section lines. The elevation of the area is around 2,700 feet above sea level.

C lignite bed.—The C lignite bed in the northern part of the Beach-Wibaux deposit ranges from 5 to at least 20 feet in thickness and averages about 17 feet thick. Thickness measurements were taken from five power-auger logs, one well report, and one seismograph shot hole log (pl. 42). In addition, two seismograph shot holes and a mine a few hundred feet south of the highway provided data on the thickness along the southern edge of the area.

The lignite probably exceeds 20 feet in thickness along the southern border near Highway 10, and in a narrow band in secs. 2, 3, 9, and 10, T. 14 N., R. 60 E. (see pl. 39). In the broad central portion available information indicates that the bed is between 10 and 20 feet thick. In the northern tier of sections in T. 14 N. and in the southern

tier in T. 15 N., the bed thins gradually to less than 5 feet. North and east of this part of the deposit, bed C is more than 5 feet thick and may be strippable in parts of the Little Beaver Creek area, which is described in the section, "Other possible deposits."

No samples of the lignite were obtained for analysis from this part of the deposit, but it is presumably similar in rank and quality to the samples taken in the southern part and in the Four Buttes deposit. (See table 4.)

The beds dip generally northeastward about 30 feet per mile. Throughout most of the deposit, the lignite is saturated with ground water. In the western part of the area, Hay Creek may provide an outlet for this water from stripping pits, but in the parts where the lignite lies below the level of the stream channel, pumping will probably be necessary.

Overburden and floor rock.—The overburden up to 120 feet above the lignite consists of fine-grained sandstone and siltstone, interbedded with shale and clay. Directly beneath the lignite is a soft, gray underclay.

Strippable reserves.—The total estimated reserves of lignite under less than 120 feet of overburden in the northern part of the Beach-Wibaux deposit are 218 million tons. (See table 1.) Slightly more than half, 120 million tons, lies beneath less than 60 feet of overburden and can be mined at an average stripping ratio of 2 cubic yards of overburden per ton of lignite. If 120 feet of overburden were removed, the ratio would be between 3 and 4 cubic yards per ton.

CENTRAL PART

The central part consists of 15,660 acres in the following sections: favorable prospect for strip mining of all the areas described in this report. In its northern portion there are about 4 square miles in which bed C ranges from 25 to 40 feet in thickness and, except for a few low hills, lies beneath less than 60 feet of overburden. The surrounding areas are scarcely less favorable, and there is indication that the lignite maintains a thickness of more than 20 feet throughout most of this part of the deposit.

The main line of the Northern Pacific Railway marks the northern boundary of the area, and the spur line connecting Beach and Golva, N. Dak., is within a mile of the eastern boundary.

The central part consists of 15,660 acres in the following sections: Secs. 25, 26, 27, 28, 29, 33, 34, 35, and 36, T. 14 N., R. 60 E.; secs. 1, 2, 3, 10, 11, 12, 13, 14, 15, 24, and 25, T. 13 N., R. 60 E., and the quarter mile wide strip of T. 13 N., R. 61 E., Wibaux County, Mont.; and

secs. 34 and 35, T. 140 N., R. 106 W.; secs. 1, 2, 3, 10, 11, 12, 13, 14, 15, 22, 23, and 24, T. 139 N., R. 106 W., Golden Valley County, N. Dak.

Topography and land use.—The surface over the central part of the deposit is part of a smooth, rolling plain that stretches from the clinker fringe at the western edge of the deposit eastward into North Dakota. The relief between the low rises and the broad hollows is about 50 feet, although in some places the slopes are so gradual that the land appears to be nearly level. The elevation of the area is between 2,800 and 2,900 feet above sea level.

The area is nearly 100 percent under cultivation, as it is considered to contain some of the best wheat growing land in the region. Almost every section contains two or three farms.

C lignite bed.—The C lignite bed in the central part of the Beach-Wibaux deposit ranges from 13 to 40 feet in thickness and averages about 24 feet thick. Data on the thickness are provided by 6 power-auger logs, 17 seismograph shot-hole logs, 3 water well reports, and 4 reports of abandoned mines (pl. 42). A maximum thickness of 40 feet was reported at the Black Diamond Mine (location 19) near the southeast corner of sec. 10, T. 13 N., R. 60 E., Mont. As shown on the map (pl. 39), the thickest part of the deposit lies in the north-central sections of T. 13 N., R. 60 E., and in sec. 34 of the township to the north. Within a mile east of the thick area, the bed becomes as thin as 16 feet in sec. 2, T. 13 N., R. 60 E., and 13 feet in the SE. corner of sec. 12 of the same township. The wells at Beach, N. Dak., (location 39) in which 36–38 feet of lignite were recorded, indicate that the bed is at least 20 feet thick along the northeastern margin of the deposit. No partings were observed or reported in the bed except at location 23 in sec. 13, T. 13 N., R. 60 E. Very little information on the thickness of the lignite was obtained on the North Dakota side of the deposit, though a few water well reports from farms within two miles east of the State line indicate the presence of lignite probably more than 20 feet thick as far east as about 3 miles east of the State line. As the amount of available information on the lignite progressively decreases eastward, mapping was not continued more than about 1¾ miles farther than the easternmost point of reliable information on the depth to the lignite. Beyond this, the depth and thickness of the bed could not be inferred with accuracy consistent with that maintained elsewhere.

The thickness of 14 feet at location 15 G is probably not representative of the surrounding parts of the bed. This location is not far from a long tongue of clinker that cuts into the deposit, and the lignite at this point has probably been partly affected by burning. The other

nearby measurements show that within a short distance of 15 G the bed is 30 or more feet thick.

In secs. 27, 28, and 33, T. 14 N., R. 60 E., the lignite is missing along a strip about half a mile wide. No lignite was found in an auger hole at the SE. corner of sec. 28, and no clinker or bloom was found along the slope in sec. 33, on the opposite side of the hill. On either side of these localities, the thick clinker stops abruptly and thus marks the probable outline of the area in which the lignite is missing. It is likely that this area represents part of the course of an ancient stream that removed the lignite by erosion.

In the 4 quarter-sections about the common corners of secs. 13, 14, 23, and 24, T. 13 N., R. 60 E., a wedge of weathered lignite lies below the level of several patches of clinker and is not included in the deposit. The position of the clinker indicates that only that part of the bed that lay above the water table was burned. The lignite that underlies the area between the clinker and the outcrop trace of the base of the lignite bed is directly beneath a veneer of soil and is thoroughly weathered.

No analyses of the lignite were obtained in this part of the deposit, but it is likely that it is nearly identical in rank and quality with the sample taken at the Peplinski mine in the southern part of the deposit. (See table 3.)

The bed dips generally 40–50 feet per mile northeast, modified in many places by minor warps and low folds.

Throughout most of the area, the lignite is probably saturated with ground water. The abandoned mines are now flooded and many of the local farm wells tap bed C for water. As the dip of the bed is for the most part opposed to the slope of the ground, stripping pits will probably have to be drained by pumping.

Overburden and floor rock.—The overburden consists mostly of shale and dense, blue-gray clay, interbedded with siltstone and thick lenses of sandstone. Some of the sandstone beds are quite hard and may require blasting to remove. Blocks of this hard sandstone may be seen near location 22 in the SE¼ sec. 11, T. 13 N., R. 60 E., at the site of a small strip mine that was abandoned because the miners were unable to remove the hard overburden with a bulldozer. Beneath the lignite is a soft, gray underclay.

Strippable reserves.—The central part of the Beach-Wibaux deposit contains 658 million tons of lignite; which, except for two small hills, lies under less than 120 feet of overburden. (See table 1.) Slightly more than half the total, or 339 million tons, lies under less than 60 feet of overburden and can be stripped at an average ratio of one to two cubic yards of overburden per ton of lignite. If 120 feet

of overburden is removed, the ratio would be two to three cubic yards per ton.

Further exploratory drilling on the North Dakota side of the area may considerably revise the above estimate of reserves, and it may be possible to extend the strippable deposit farther to the east than the arbitrary limit set in this report.

SOUTHERN PART

Although the southern part of the Beach-Wibaux deposit has the lowest average thickness of lignite (16 feet) of the three parts of the deposit, three-fourths of it lies beneath less than 60 feet of overburden. Within this part there are several indications that the lignite has been removed along the course of buried stream channels.

The southern part of the deposit is 5½ miles south of Beach, N. Dak., and is also convenient to the Northern Pacific Railway spur that connects Beach and Golva. This line lies within the westernmost tier of sections of T. 105 W., N. Dak.

This part of the deposit includes 11,720 acres in the following sections: in Wibaux County, Mont., sec. 36, T. 13 N., R. 60 E.; sec. 31, T. 13 N., R. 61 E.; secs. 4, 5, 8, 9, 16, 17, 18, 19, 20, and 21, T. 12 N., R. 61 E.; and in Golden Valley County, N. Dak., secs. 25, 26, 27, 34, 35, and 36, T. 139 N., R. 106 W.; secs. 1, 2, 3, 10, 11, 12, 13, 14, 15, 22, and 24, T. 138 N., R. 106 W.; and an adjacent narrow strip of T. 138 N., R. 105 W.

Topography and land use.—Similar to the central part, this area is part of a broad, rolling plain. Relief is somewhat higher, however, as some of the hills rise gradually to about 100 feet above the surrounding lowlands. Most of the area is drained by Duck Creek and other tributaries of Beaver Creek. The southeastern portion drains into Bullion Creek, which flows east into the Little Missouri River.

The southern part of the Beach-Wibaux deposit is nearly all under cultivation for wheat. In general its productive capacity appears slightly less than that of the central part. The elevation is 2,800–2,900 feet above sea level.

C lignite bed.—The C lignite bed in the southern part of the Beach-Wibaux deposit ranges from 9 to 24 feet in thickness, where it has not been thinned by channel erosion, and averages about 16 feet thick. East of Duck Creek information is very sparse on the depth and thickness of the lignite; and, as in the central part, mapping was not carried out more than 1¾ miles farther than the easternmost point of reliable information.

Complete sections of the bed were obtained from six power-auger logs, four abandoned mine reports, and one water-well report (fig. 37). Additional well reports on the North Dakota side gave fairly

reliable estimates of the depth to the lignite but were not considered reliable as sources of data on thickness.

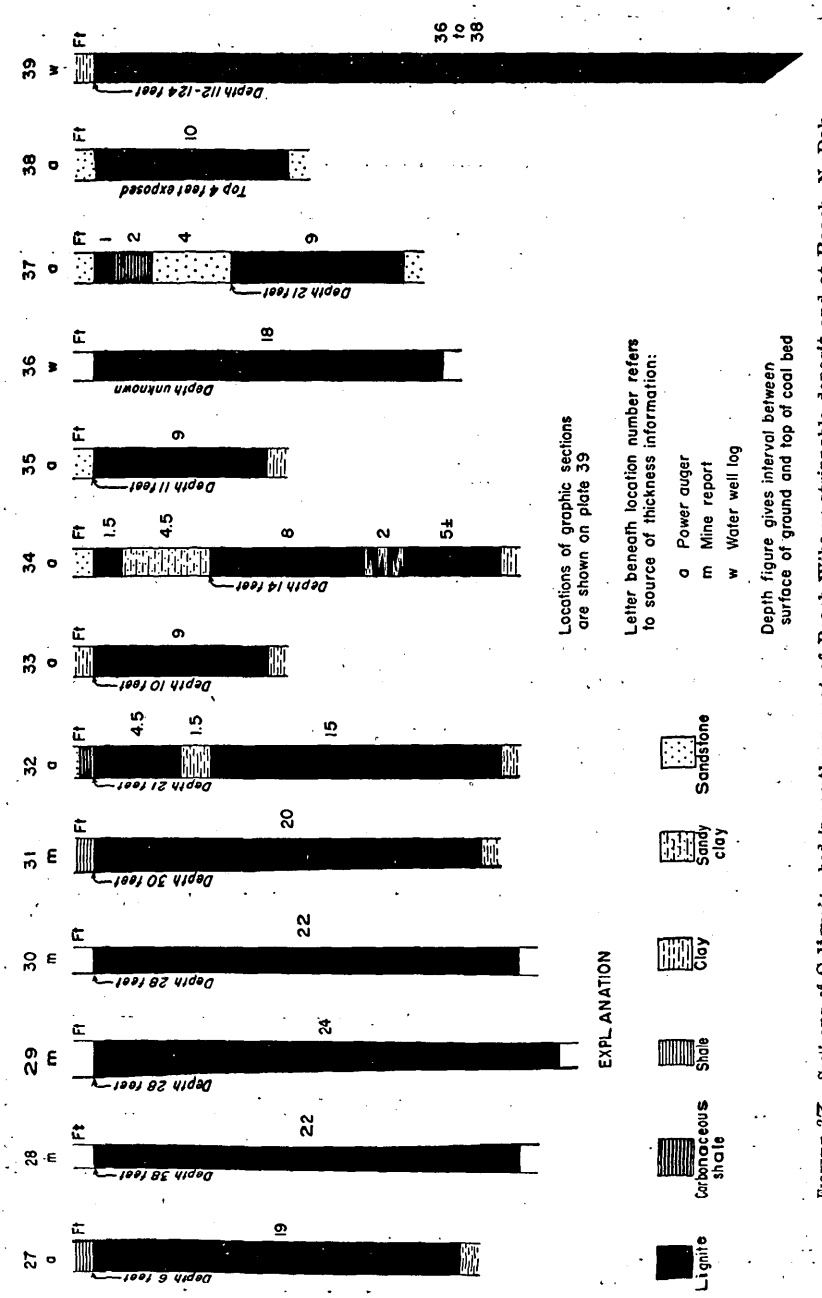

FIGURE 37. Sections of C lignite bed in southern part of Beach-Wibaux strippable deposit and at Beach, N. Dak.

Bed C crops out in in an area of about 2 square miles near the head of Duck Creek, approximately in the center of the Southern Part, where its outcrop trace is marked by scattered occurrences of clinker.

It dips downstream below the level of the creek in sec. 3, T. 138 N., R. 106 W., N. Dak., and reappears as clinker a mile northeast in sec. 35, T. 139 N., R. 106 W. The outcrop trace winds over about 3 square miles to the northwest of the latter point, and the bed dips again under the level of Duck Creek in sec. 27 of the same township. It then reappears about a mile to the northwest, just over the Montana line, where its outcrop is part of the main clinker-fringed border of the deposit.

Power-auger drilling at location 27, in the bed of Duck Creek, shows that the lignite, lying 6 feet below the surface, is thoroughly weathered. Thus, it is likely that the bed is similarly weathered and not minable at shallow depths beneath the course of Duck Creek. Accordingly, the lignite under the stream bed is not considered as being in the deposit.

The bed is 20 to 25 feet thick in the northern half of the area but thins gradually southward to less than 10 feet along its southern and western edges.

At six places in and near the North Dakota side of southern part, there are indications that the lignite has been removed along the courses of buried stream channels. Points where the lignite was found to be missing in power-auger holes or in farm wells are marked on the map (pl. 39) by small circles. In addition to the marked localities, a channel cutting the lignite was reported at the mine at location 29. In power-auger holes in the NE¼ sec. 11, T. 138 N., R. 106 W. and the NW¼ sec. 35, T. 139 N., R. 106 W.; 1 to 2 feet of lignite was found, overlain by a fine sand; and, at the farm near the center of sec. 2, 138 N., R. 106 W., the deepest of three wells did not strike lignite, whereas the other two encountered the C bed at a depth of 24 feet. At the SW. corner of sec. 18, T. 138 N., R. 105 W., the power auger found only sand at the level where the lignite bed was expected. South of this latter point, ancient erosion of lignite is probably extensive; hence, the deposit was not considered as extending into the southern three tiers of sections of the township. At location 38 (fig. 37) in the SW¼ sec. 19 of the same township, half a mile south of the south limit of the map (pl. 39), the manner in which lignite is eroded is shown in a farm silage pit. Here the bank of the stream channel is exposed. The lignite, 10 feet thick at this point, abuts directly against a mass of fine sand along an irregular, near-vertical face, and a thin layer of shale at the top of the lignite hangs over the edge. This channel is probably the same one that was penetrated in the SW. corner of sec. 18. Beyond the points marked on the map and the inferences drawn from them, nothing is known of the extent of these buried channels, and their full distribution can be revealed only by intensive exploratory drilling.

Partings in bed C were observed at locations 32 and 34, both on the Montana side of the area. At location 34, the power auger re-

vealed a zone of partings about 2 feet thick, but the individual layers were not discernible in drilling. No partings were observed at the other locations.

Of the four mines in this area, only the Peplinski Mine (location 31) in sec. 9, T. 12 N., R. 61 E., Mont., is still operating. The lower 12 to 15 feet of the 20-foot bed is exposed in the mine. A channel sample taken 150 feet north of the shaft entry and given in table 1 shows a medium grade of lignite.

Overburden and floor rock.—The overburden consists of interbedded sandstone, shale, and clay, with a few thin streaks of lignite. Beneath bed C is a soft, gray clay.

Strippable reserves.—The estimated strippable reserves of the southern part of the Beach-Wibaux deposit total 328 million tons of lignite under less than 120 feet of overburden. (See table 1.) The indefinite eastern boundary and the unknown extent of channel erosion in this area constitute possible sources of error in the tonnage estimates, which can be corrected only after the deposit has been intensively explored by drilling. About three-fourths of the total tonnage, 254 million tons, lies under less than 60 feet of overburden and can be strip mined at an average stripping ratio of 2 cubic yards of overburden per ton of lignite. Owing to the small amount of overburden more than 60 feet thick, the entire southern part of the Beach-Wibaux deposit could be mined at an average stripping ratio of 2 to 3 cubic yards per ton.

POSSIBLE STRIPPABLE DEPOSITS

In addition to the selected deposits in the Beach-Wibaux and Four Buttes areas, eight other economically strippable deposits were investigated. All of these deposits were at least checked briefly in the field to note the nature of the overlying land surface, to take measurements of the lignite, and to get a general idea of their extent and relative value according to the criteria of strippable deposits used in this report. These deposits plus the mapped deposits do not by any means exhaust the resources of strippable lignite in the Wibaux area but represent only the areas discovered in reconnaissance or described in bulletins of the U. S. Geological Survey.

The deposits are outlined roughly on the map (fig. 35), bounded by the approximate location of the line of 120 feet of overburden. These marginal deposits are scattered widely. Four are closely grouped in the northern part of the investigated area around Smith and Dry Creeks; two are in the hilly belt in the western half of the area, and the other two are fairly close to the Beach-Wibaux deposit in the southeastern part of the area. The salient features of each deposit are discussed briefly below, and where practical, an estimate

of their tonnage is made. The deposits in the vicinity of Smith and Dry Creeks are described as a single group.

DEPOSITS IN THE VICINITY OF SMITH AND DRY CREEKS

The deposits in the vicinity of Smith and Dry Creeks are in the Sidney lignite field (Stebinger, 1912) and are a part of bed G of that field. The outcrop trace of bed G is mapped in detail in the report on the Sidney field, and a fairly adequate number of exposures have been measured. The deposits are separated from each other by scattered areas of rough topography and high relief and by divides that rise to more than 120 feet above bed G. This area is about 30 miles from both Sidney and Wibaux and may be reached by way of Montana Route 7 from either town. Route 7 is dirt and gravel surfaced, and the few other roads around the area are small rural roads and trails, a few of which are graded.

Smith Creek deposit.—The Smith Creek deposit (no. 1, fig. 35) is on the north side of the valley of Smith Creek, and includes about 3 square miles in sec. 13, T. 19 N., R. 58 E., and secs. 17, 18, 19, and 20, T. 19 N., R. 59 E. It underlies a broad, smooth hill bounded on the north and east by badlands. Five measurements in the deposit show that bed G ranges in thickness from 6 feet 8 inches near the center of the deposit to 9 feet 7 inches near its eastern end. About a mile north, in the badlands, bed G reaches a thickness of 15 feet 2 inches. No partings were observed in the bed. Assuming an average thickness of 8 feet, the deposit probably contains about 25 million tons of lignite under less than 120 feet of overburden.

Bullcamp Coulee deposit.—The Bullcamp Coulee deposit (no. 2, fig. 35) occupies about 1 square mile in a valley between Bullcamp Coulee and Smith Creek. This deposit lies in secs. 21, 27, and 28, T. 19 N.; R. 59 E. and is separated from the Smith Creek deposit by a steep-walled coulee bordered by narrow badlands. The deposit is centered on a locally thick lens in bed G. The only exposure in the deposit measures 11 feet, without partings. The bed thins to about 6 feet at the northern and southern borders. Assuming an average thickness of 10 feet, the deposit may contain 10 million tons of lignite under less than 120 feet of overburden.

Parson Creek deposit.—The Parson Creek deposit (no. 3, fig. 35) is fairly large, occupying about 10 square miles, in most of the valley of Parson Creek, a tributary of Smith Creek. It lies in the north-central part of T. 18 N., R. 59 E. The land surface is rather hilly. In the middle of the deposit, one exposure of bed G measures 6 feet 2 inches; and, on the northeastern side, another shows 5 feet, 2 inches. Measurements in the badlands within a mile west of the deposit show that bed G thickens westward to about 10 feet. Assuming an average

thickness of 7 feet, the Parson Creek deposit probably contains as much as 70 million tons of lignite under less than 120 feet of cover.

Dry Creek deposit.—The Dry Creek deposit (no. 4, fig. 35) includes about 4 square miles in secs. 1, 2, 3, 11, 12, 13, and 14, T. 18 N., R. 58 E.; and secs. 18 and 19, T. 18 N., R. 59 E. It underlies smooth slopes on the north side of the valley of Dry Creek. The only exposure of bed G in the deposit is in sec. 13, T. 18 N., R. 58 E., where it is 7 feet 6 inches thick and without partings. The bed thickens to the north; and, in the badlands about a mile north of the deposit, it is 11–12 feet thick. Assuming an average thickness of 9 feet, the Dry Creek deposit may contain about 40 million tons under less than 120 feet of overburden. Further exploration may prove an extension of this deposit on the south side of Dry Creek, where one exposure of bed G measures 7 feet 6 inches.

GRIFFITH CREEK DEPOSIT

The lowest minable bed of the Glendive lignite field (Hance, 1910) crops out along Griffith Creek near U. S. Highway 10 about 9 miles east of Glendive. At this point, in NW¼ sec. 31, T. 16 N., R. 57 E., the bed shows the following section:

	Feet	*Inches*
Shale.		
Lignite	2	6
Clay	2	0
Lignite	7	0
Bone	0	6
Lignite	4	0
Clay	1	6
Lignite	1	0
Sandstone.		

If the 6-inch bone parting is disregarded, the thickest bed of lignite in this section is 11½ feet thick. From this point the bed dips northeast about 1 or 2 degrees and underlies most of the valley of Griffith Creek. The valley sides are gently sloping, and the bed may be strippable in an area about half a mile to a mile wide and perhaps nearly a mile up the valley of the creek (no. 5, fig. 35). If the lignite maintains a thickness of 10 or more feet, the deposit may contain about 10 million tons.

HODGES DEPOSIT

The Hodges deposit (no. 6, fig. 35) lies in the central part of T. 14 N., R. 58 E., in the belt of badlands formed in the outcrop zone of the Ludlow member of the Fort Union formation. South of Hodges, Mont., the lignite bed that lies at the contact of the Ludlow and Tongue River members of the Fort Union formation thickens locally. The area underlain by thick lignite is part of a high, dissected divide. The crest of the divide lies on the narrow remains of a smooth, upland surface;

and on either side of the crest, the land slopes away sharply into deep canyons. Along the precipitous sides and in the bottoms of these canyons, the lignite crops out about 100–150 feet below the upland surface. Hence, the strip of lignite under less than 120 feet of overburden is probably about a quarter of a mile wide, and the overburden less than 60 feet thick is mostly confined to the steep sides of the canyons. A deposit in such rugged country would not ordinarily be considered for strip mining, but this area is 2–3 miles south of the main line of the Northern Pacific Railway.

Most of the sections of the lignite in this area given in the report on the Glendive lignite field (Hance, 1912) are incomplete. One complete section at the SW. corner of sec. 21 shows the following measurements:

Glendive lignite field, location 29:

Shale.	*Feet*	*Inches*
Lignite, impure	3	4
Parting	0	1
Lignite	3	6
Parting	0	1
Lignite	1	9
Parting	0	1
Lignite	2	3
Shale, carbonaceous	1	0
Lignite	3	6
Shale	0	6
Lignite	2	8

Disregarding the 1-inch partings, the thickest bed of lignite in this section is 7½ feet. An exposure in a deep coulee near the center of sec. 16 shows the following approximate measurement:

Sandstone.	*Feet*
Lignite	9
Clay	1
Lignite	7
Clay	7½
Lignite	3½
Clay	1
Lignite	13

In the NE¼ sec. 28, another exposure shows 19 feet 7 inches of clean lignite.

To the north and east of the community of Hodges, the bed appears to be thin; and, near the south border of T. 14 N., R. 58 E., it is also too thin to justify strip mining.

LITTLE BEAVER CREEK DEPOSIT

The Little Beaver Creek deposit (no. 8, fig. 35) may be considered as a northern extension of the Beach-Wibaux deposit. It represents

those areas underlain by bed C of the Sentinel Butte lignite field (Leonard and Smith, 1909) that were not included in the Beach-Wibaux deposit because of thin lignite, rough topography, and scarcity of information. The deposit lies in the northeast half of T. 15 N., R. 60 E., the narrow strip of T. 15 N., R. 61 E., and the northeast corner of T. 14 N., R. 60 and 61 E., Wibaux County, Mont., and the west half of T. 141 N., R. 105 W., Golden Valley County, N. Dak. It is about 6 miles north of Beach, N. Dak., by way of North Dakota Route 16. Its outline is illustrated in plate 43.

The outcrop of bed C is mapped in detail, and a number of measurements of the lignite are noted. The 120-foot overburden line was determined by mapping the base of the clinker of bed E., which lies 120 to 125 feet above bed C. On the North Dakota side bed E is, in most places, not visible; hence, the 120-foot line has been approximated.

The land surface on the Montana side is hilly and mostly pasture land. However, the hills do not rise to more than 120 feet above bed C except on the clinker-capped ridges in the southern and central parts of the area and on one pointed butte in sec. 9, T. 15 N., R. 60 E. In the valley of Little Beaver Creek in North Dakota, the land is a smooth, nearly flat plain.

Locations where the depth or thickness of bed C was measured are numbered on the map (pl. 43). Those exposures numbered 32 to 36 are in the sections of bed C in the Four Buttes deposit (pl. 41). The other exposures and well logs in the deposit, numbered 1 to 14 on the map, are given in sections below. Three additional well reports in T. 140 N., R. 106 W., N. Dak., which give the thickness and depth of the lignite where the overburden is more than 120 feet thick, are also given:

Sections of locations in bed C

	Feet	Inches
Location 1:		
Sandstone.		
Lignite	6	4
Sandstone, with much carbonaceous matter	2	3
Lignite	5	2
Location 2:		
Shale.		
Bone	0	8
Lignite	4	10
Clay.		
Location 3:		
Shale.		
Lignite	3	9
Clay.		

Sections of locations in bed C—Continued

About 20 feet south of location 3:

	Feet	Inches
Shale.		
Lignite	3	2
Clay, brown	0	1
Lignite	0	3½
Clay.		

Location 4:

Sandstone.		
Lignite	10	0
Shale.		

Location 5:

Shale.		
Lignite	7	0
Clay,		

Location 6:

Shale.		
Bone	0	12
Lignite	0	8
Clay.		

Location 7:

Shale.		
Bony lignite	0	8
Lignite	4	7
Shale, carbonaceous.		

Location 8: (Three exposures about 50 feet apart on either side of the State line.)

(a) About 50 feet west of State line:

Shale.		
Bony lignite	0	1
Breccia, clay fragments in matrix of bone	0	7
Lignite	6	9
Clay, carbonaceuos.		

(b) On State line:

Shale.		
Lignite	5	10
Shale.		

(c) About 50 feet east of State line:

Shale.		
Lignite	6	3
Shale.		

Location 9: (Seismograph shot-hole log)

Lignite	9	0

Reports of farm well logs

	Thickness (feet)	Depth (feet)
Location 10:		
Lignite	25	111
Location 11:		
West well:		
Lignite	24+	55
East well:		
Lignite	2+	60
Location 12:		
Lignite, top was struck at	Unknown	70
Location 13:		
Lignite	50	100
Location 14:		
North well:		
Lignite	40	108
South well:		
Lignite	40	128
SW¼NW¼ sec. 12, T. 140 N., R. 106 W.		
Lignite	40	180
NE¼NW¼ sec. 14, T. 140 N., R. 106 W.		
Lignite	7	35
Interval	121	42
Lignite	47	163
SW¼NW¼ sec. 24, T. 140 N., R. 106 W.		
Lignite	47	unknown

The total tonnage of lignite under less than 120 feet of overburden in the Little Beaver Creek deposit cannot be estimated accurately owing to the lack of reliable information on the thickness of the lignite on the North Dakota side. If one assumes an average thickness of 10 feet, the deposit contains about 250 million tons. But assuming that the reports of very thick lignite in the wells are correct, the average thickness is 15 feet or more; and the total tonnage of lignite is 300 to 400 million tons.

LAMESTEER CREEK DEPOSIT

The Lamesteer Creek deposit (no. 10, fig. 35) lies on the east side of Beaver Creek between Lamesteer and Lone Tree Creeks (secs. 7, 8, 16, 17, 18, 19, 20, 21 and 29, T. 12 N., R. 60 E.) and may include 3 to 4 square miles. The only measurement of the lignite is in the SE¼NE¼ sec. 18, where two benches of lignite (possibly the Harmon bed) are exposed on a cutbank of Beaver Creek. The upper bench is approximately 10 feet thick with a thin parting in the middle. The lower bench is 8 feet thick and separated from the upper bench by about 5 feet of clay. The bed is represented by a thick sequence of

carbonaceous shale and thin streaks of lignite north of Lamesteer Creek in sec. 6 and apparently becomes thin near the southern edge of the township. Further exploration may reveal that the bed maintains a minable thickness to the east. The deposit underlies a moderately hilly surface of low relief. Assuming an average thickness of about 10 feet of lignite over an area of 3 to 4 square miles, the Lamesteer Creek deposit contains 30 to 40 million tons of lignite in both benches, all beneath less than 120 feet of overburden.

SELECTED BIBLIOGRAPHY

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

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

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

Corps of Engineers, U. S. Army, Dec., 1948, Report to the U. S. Bureau of Mines on the survey of southeastern Montana for areas suitable for synthetic liquid fuel plants : Office, Chief of Engineers, Washington, D. C.

Hance, J. H., 1912, The Glendive lignite field, Dawson County, Mont.: U. S. Geol. Survey Bull. 471–D, p. 271–283.

Hares, C. J., 1928, Geology and lignite resources of the Marmarth field, southwestern North Dakota ; U. S. Geol. Survey Bull. 775.

Herald, F. A., 1912, The Terry lignite field, Custer County, Mont.: U. S. Geol. Survey Bull. 471–D, p. 227–270.

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

Leonard, A. G., and Smith, C. D., 1909, The Sentinel Butte lignite field, North Dakota and Montana: U. S. Geol. Survey Bull. 341–A, p. 15–35.

Stebinger, Eugene, 1912, The Sidney lignite field, Dawson County, Mont.: U. S. Geol. Survey Bull. 471–D, p. 284–318.

U. S. Bureau of Mines, 1932, Analyses of Montana coals: Tech. Paper 529.

U. S. Bureau of Mines, November 1951, Bituminous coal and lignite in 1950: Mineral Market Report 2032.

U. S. Geological Survey Water Supply Papers, 1935 to 1950 incl., Surface water supply of the United States, part 6, Missouri River Basin.