CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1929

PART II. MINERAL FUELS

THE FORSYTH COAL FIELD, ROSEBUD, TREASURE, AND BIG HORN COUNTIES, MONTANA

By C. E. DOBBIN

INTRODUCTION

Location and relations of the field.—The Forsyth coal field embraces an area of about 800 square miles in southern Montana, south of Yellowstone River and east of the 107th meridian, and includes parts of Rosebud, Treasure, and Big Horn Counties. (See pl. 1.) The Forsyth field is only a fractional part of the great coal field which extends from the Big Horn and Musselshell Rivers eastward into the Dakotas and southward into the Powder River Basin, Wyo. The coal of this broad region ranges in grade from lignite, which occurs in the Dakotas and the extreme eastern part of Montana, to subbituminous coal in the Forsyth, Tullock Creek, Sheridan, and Bull Mountain fields.

Interest in the Forsyth field has been stimulated recently by the construction of a branch line of the Northern Pacific Railway 30 miles long up Armells Creek and the East Fork of Armells Creek to one of the thick Fort Union coal beds long known to occur in the region. The field is of present importance because it contains a large tonnage of coal that can be recovered by strip mining.

Field work and acknowledgments.—The Forsyth field was examined to collect data upon which to classify the public land included in it with regard to its value as coal land. The geologic mapping was done with the plane table and telescopic alidade, and all locations were tied to land corners. Altitudes are based on the United States Coast and Geodetic Survey bench mark at Finch railroad station and upon precise levels established by the engineers of the

Northern Pacific Railway and the Northwestern Improvement Co. The field work was done in the summer of 1923, and the writer was assisted by Prof. C. R. Fettke, C. M. Clark, and D. S. Mossom. The examination was made under the supervision of W. T. Thom, jr., and the writer feels indebted to him for suggestions both in the office and in the field. Acknowledgments are due to Mr. S. P. Sawyer, resident engineer of the Northwestern Improvement Co., and his associates for their unfailing courtesy and kindness in furnishing altitudes and other data necessary to properly carry on the work. Thanks are also due to the residents in the field for the many favors they showed. Finally, the writer takes this means of publicly thanking his assistants for their efficient work during the field examination.

Land surveys.—The earliest land surveys in the Forsyth field were made in the Yellowstone Valley in the years 1878 and 1879 and embraced T. 6 N., Rs. 38–41 E. In 1885 land surveys were made along Armells Creek in Tps. 2 and 3 N., Rs. 40 and 41 E., T. 4 N., R. 40 E., and T. 5 N., R. 39 E. In 1886 T. 1 S., R. 41 E., was surveyed. Except T. 5 N., R. 38 E., and T. 1 S., R. 40 E., surveyed in 1903 and 1908, respectively, all other townships in the field were surveyed in the period 1909–1916.

Many land-corner marks in Yellowstone Valley and along Rosebud and Armells Creeks are missing. In the upland areas practically all corner marks searched for were found, and to them all geologic mapping was tied. The corners of all townships surveyed before 1911 were marked by stones many of which have been so much weathered that all identification marks have been obliterated.

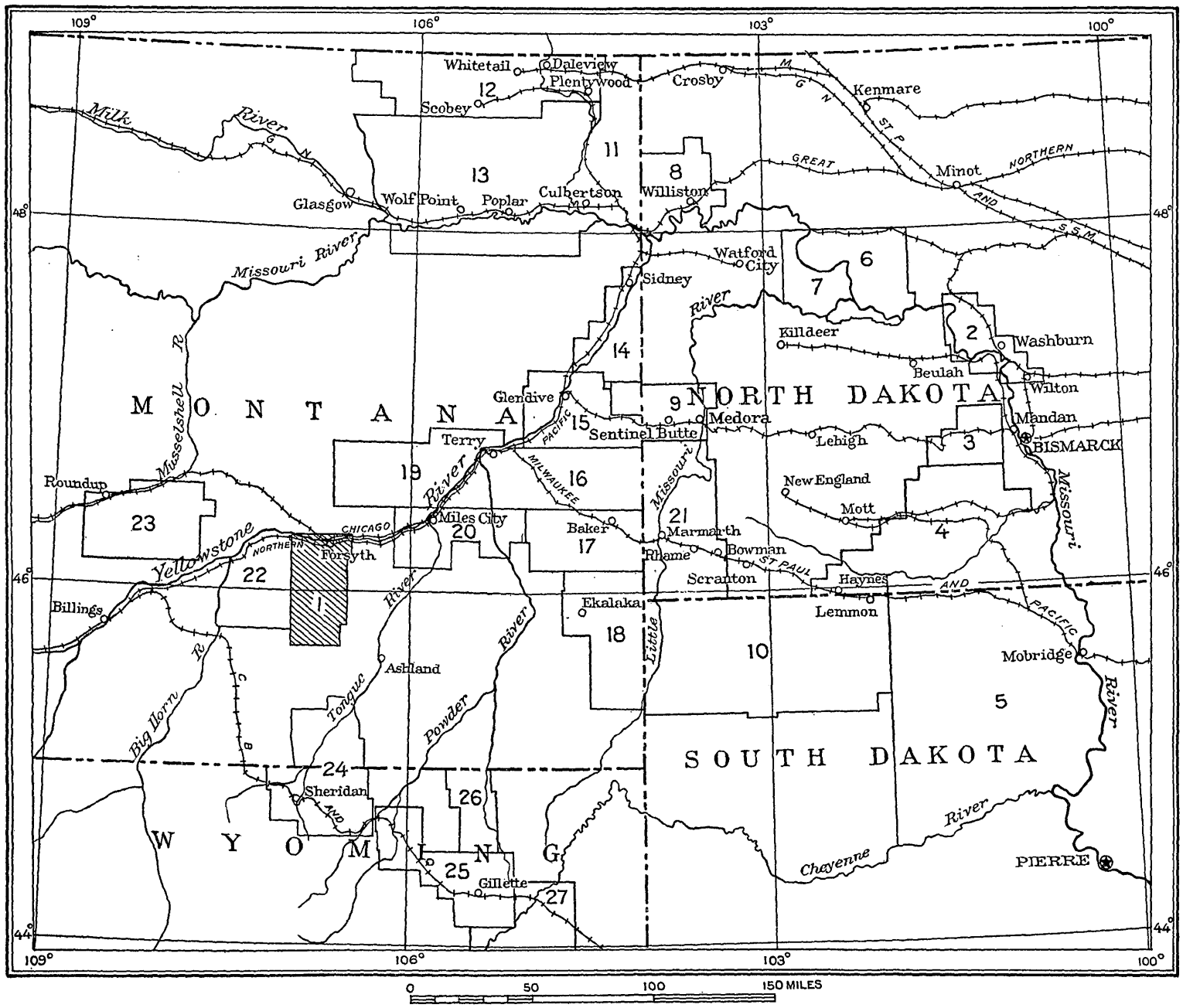
Previous work.—The general geology along the Yellowstone Valley has been described by Campbell[1] and that north of the Forsyth field and beyond the Yellowstone River by Bowen.[2] In 1920 C. E. Dobbin and W. T. Thom, jr., made a reconnaissance study of the principal geologic features of the coal-bearing area of southeastern Montana, the results of which were released in a press notice.[3] The Tullock Creek coal field, which adjoins the Forsyth field on the west, has been described by Rogers and Lee.[4] The location of other coal fields in the region surrounding the Forsyth field that have been

[1] Campbell, M. R., Guidebook of the western United States, Part A, The Northern Pacific Route: U. S. Geol. Survey Bull. 611, 1915.

[2] Bowen, C. F., Possibilities of oil in the Porcupine dome, Rosebud County, Mont.: U. S. Geol. Survey Bull. 621, pp. 61–70, 1915.

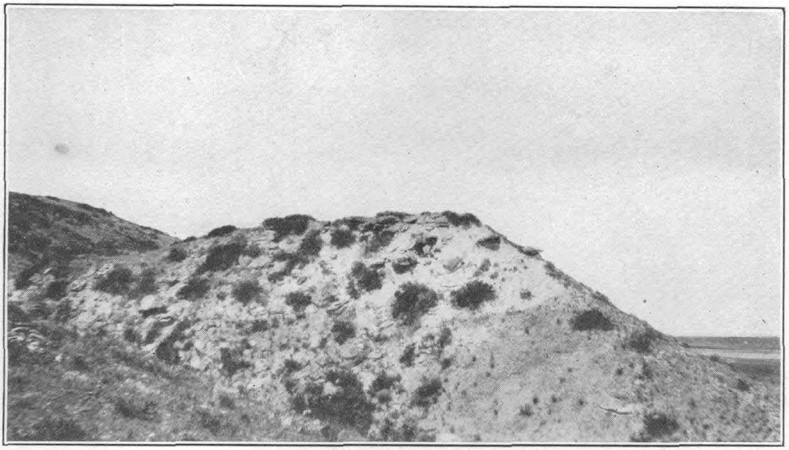
[3] Oil possibilities in southeastern Montana: U. S. Geol. Survey Press Notice 14846, 1921.

[4] Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek coal field, Rosebud and Big Horn Counties, Mont.: U. S. Geol. Survey Bull. 749, 1923.

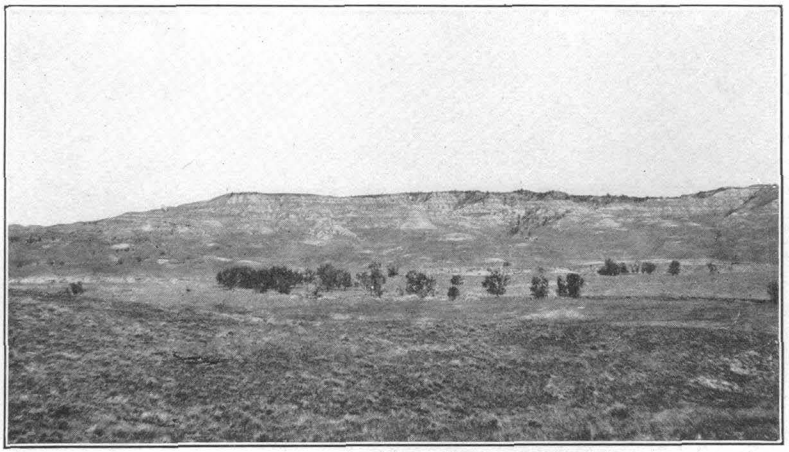


INDEX MAP SHOWING LOCATION OF FORSYTH COAL FIELD, MONTANA

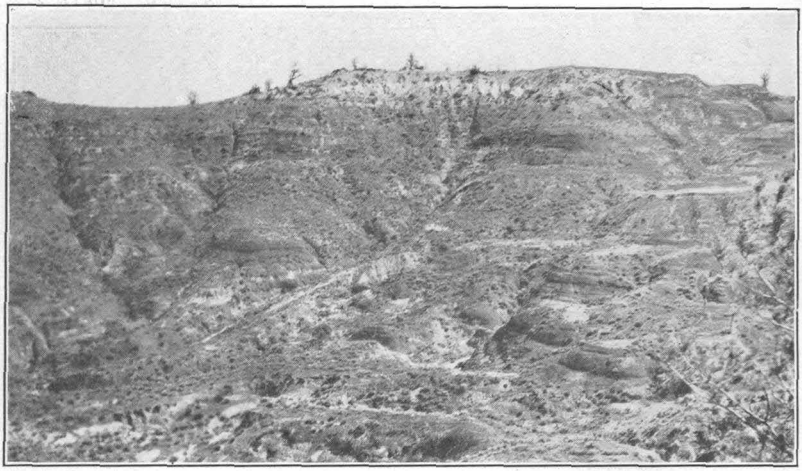
See page 1



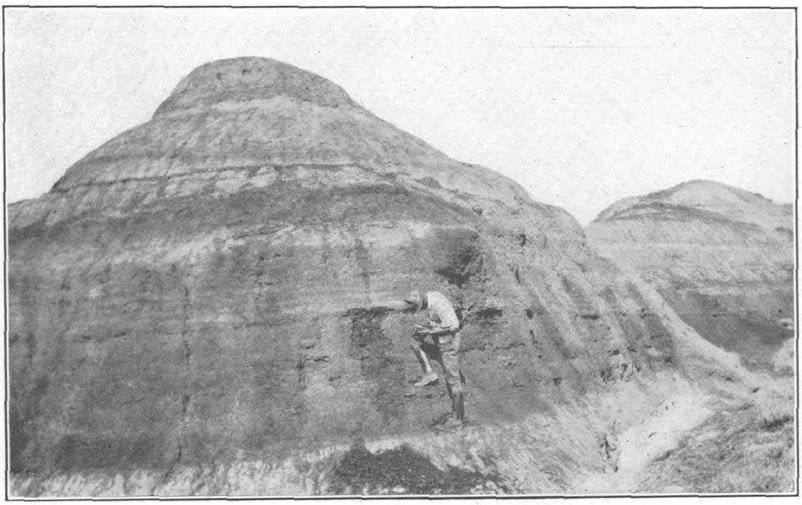
A. LIGHT-COLORED SANDSTONE AND BROWN SANDY SHALE AT THE TOP OF THE JUDITH RIVER FORMATION, NEAR FINCH, MONT.



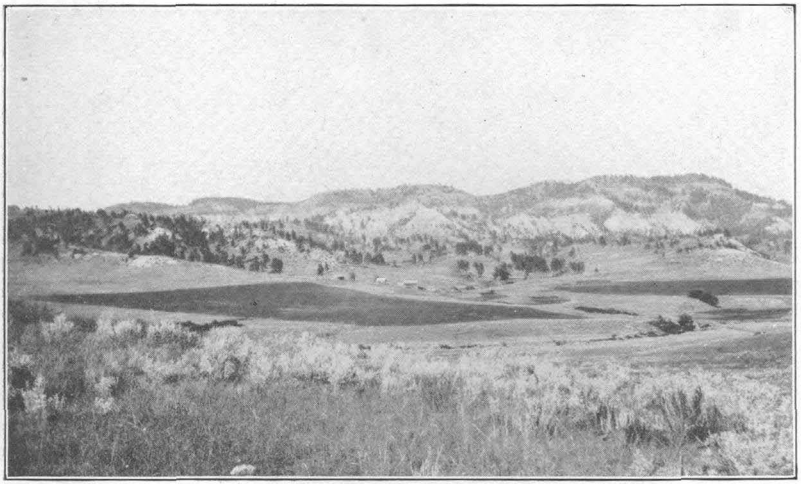
B. ESCARPMENT OF THE TULLOCK MEMBER OF THE LANCE FORMATION ON ARMELLS CREEK, T. 5 N., R. 40 E., MONTANA



A. LEBO SHALE MEMBER OF THE FORT UNION FORMATION OVERLAIN BY THE TONGUE RIVER MEMBER, SEC. 31, T. 5 N., R. 41 E., MONTANA

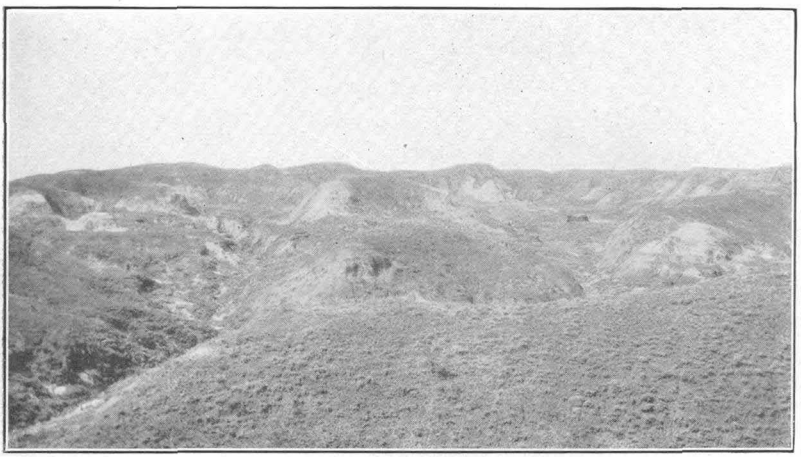


B. BIG DIRTY COAL BED AT THE BASE OF THE LEBO SHALE MEMBER OF THE FORT UNION FORMATION, SW. ¼ SEC. 31, T. 3 N., R. 41 E., MONTANA



A. WEST SIDE OF THE WOLF MOUNTAINS FROM THE EAST QUARTER CORNER OF SEC. 25, T. 1 N., R. 38 E., MONTANA

Showing the character of the topography where the Tongue River member of the Fort Union formation crops out



B. VIEW IN SEC. 13, T. 3 N., R. 40 E., MONTANA

Showing type of topography characteristic of areas where the Lebo shale member of the Fort Union formation crops out

described by the Geological Survey is shown on Plate 1. The names of the fields designated by numbers on the map and references to the Geological Survey publications in which they have been described are as follows:

Coal fields whose locations are shown in Plate 1

No.	Field	Bulletin	No.	Field	Bulletin
1	Forsyth	812-A.	14	Sidney	471-D.
2	Washburn	381-A.	15	Glendive	471-D.
3	New Salem	726-A.	16	Terry	471-D.
4	Cannonball River	541-G.	17	Baker	471-D.
5	Standing Rock and Cheyenne River.	575.	18	Ekalaka	751-F.
			19	Little Sheep Mountain	531-F.
6	Fort Berthold	381-A and 471-C.	20	Miles City	341-A.
			21	Marmarth	775.
7	do	726-D.	22	Tullock Creek	749.
8	Williston	531-E.	23	Bull Mountain	647.
9	Sentinel Butte	341-A.	24	Sheridan	341-B and 806-B.
10	Northwestern South Dakota	627.			
11	Culbertson	471-D.	25	Powder River	381-B.
12	Scobey	751-E.	26	Little Powder River	471-A.
13	Fort Peck	381-A.	27	Gillette	796-A.

GEOGRAPHY

Land forms.—The Forsyth field lies in the Great Plains province and is a much dissected plateau across which the Yellowstone River and its tributaries have cut their valleys. To a large extent the topography of the field is determined by the nature of the underlying rocks. Where the surface strata are soft and incoherent clay and shale the upland areas have a subdued, rolling, and barren appearance, becoming rougher and minutely dissected in parts subject to stream erosion. These types of topography are characteristic of areas where the Bearpaw shale and the Lebo shale member of the Fort Union formation crop out. (See pl. 4, *B*.) In those areas where the rocks of the Lance formation are the surface strata the land is rough; the divides are long and narrow and the intermittent streams flow in narrow and deep valleys and invariably have their sources in narrow ravines trenching the edge of an escarpment several hundred feet high which is capped by a resistant sandstone. (See pl. 2, *B*.) Such an escarpment is a prominent topographic feature on the east side of Armells Creek. Although some rather broad and nearly flat lying areas have been developed in parts of the field where the Tongue River member of the Fort Union formation crops out, these parts are generally characterized by isolated buttes, mesalike hills, and long, narrow divides. These eminences usually have a cap rock of slag or clinker formed by the burning of one of the several thick coal beds of the member. The rocks between successive beds of clinker, except certain massive sandstones to be described later,

are much less resistant than the clinker and weather into steep and bare light-colored slopes.

The divide between Armells and Sarpy Creeks in T. 1 N., R. 39 E., and adjoining townships rises rather abruptly several hundred feet above the surrounding country. (See pl. 4, *A*.) This divide is less than a quarter of a mile wide and is capped with a coal clinker 50 feet or more thick. The top of the ridge is about 4,780 feet above sea level and is the highest point in the Forsyth field. The point of lowest altitude is 2,511 feet above sea level and is on the Northern Pacific Railway at the east line of T. 6 N., R. 41 E. The range of relief in the field is thus about 2,269 feet.

East of Armells Creek the flood plain of the Yellowstone River has a maximum width of slightly less than 1 mile at Forsyth, and in some places it has been obliterated by the river undercutting its banks. West of Armells Creek the flood plain attains a maximum width of about 2 miles near Howard and is extensively cultivated. South of the flood plain are rolling areas of Bearpaw shale and terrace gravel, which extend southward 8 miles from the river in Tps. 5 and 6 N., R. 38 E.

On the divide between Sarpy and Armells Creeks, in Tps. 3 and 4 N., Rs. 38 and 39 E., is a fairly extensive deposit of terrace gravel capping an escarpment at an altitude of 3,650 feet, or a little more than 1,000 feet above the level of the Yellowstone River, which corresponds to the highest gravel terrace of the Tullock Creek field.[6] Several hills and ridges in the northern part of T. 4 N., R. 41 E., capped by the same gravel are prominent landmarks. The most extensive gravel terrace is that which occurs in T. 6 N., R. 41 E., east of Forsyth, at a height of 200 feet above the Yellowstone River.

The flood plain of Rosebud Creek is about a quarter of a mile wide and is bordered on both sides by steep bare bluffs several hundred feet high capped by clinker. Viewed from any high point the tributaries of Rosebud Creek in this field appear to run in U-shaped valleys cut in a plateau of clinker, remnants of which make the cap rock on prominent and persistent escarpments rimming the valleys. The valley bottoms are broad and fairly level. Toward the headwaters of these streams the land becomes increasingly rough and, save for a few poor trails, is accessible by saddle horse only.

Drainage and water supply.—The northern part of the field is skirted by the Yellowstone River, which receives all the drainage of the field either directly or by its tributaries, the largest of which are Sarpy, Armells, and Rosebud Creeks. West of Armells Creek the Yellowstone meanders along the north side of its flood plain and

[6] Rogers, G. S., and Lee, Wallace, op. cit., pp. 44–47, 1923.

has a border of alluvium averaging 1½ miles wide. Hay and Reservation Creeks cross its flood plain and enter the river near Finch and Howard post offices, respectively. Reservation Creek is about 16 miles long and contains little water during the dry months. East of Armells Creek the Yellowstone flows near the south side of its flood plain, and has undercut its banks and obliterated nearly all of its flood plain along that side except a tract nearly a mile wide on which the town of Forsyth stands. Armells Creek is about 12 miles long and forks in sec. 21, T. 4 N., R. 40 E. Its West Fork extends southwestward about 18 miles and its East Fork southeastward about 16 miles and thence westward about 14 miles. The main creek and both forks contain flowing water the year round. Several short dry streams are tributary to Armells Creek; the largest is Cottonwood Creek, which drains eastward along the south line of T. 5 N., R. 39 E. In T. 2 N., R. 39 E., the larger tributaries of West Fork of Armells Creek are Trail and Donley Creeks, each about 7 miles long and having a north and a south fork. Sheep, Sevenmile, Corral, and Stocker Creeks are the larger tributaries of the East Fork of Armells Creek and except the flow from a few springs in their bottoms contain no water during the dry season. The western border of the field is drained by tributaries of Sarpy Creek. The East Fork of Sarpy Creek in this field is about 7 miles long and is a perennial stream. East Bear, East Beaver, and Horse Creeks, tributaries to Sarpy Creek in order from north to south, are not over 5 miles long and are usually dry. Rosebud Creek, which drains the southern part of the field, is a perennial stream. Its flood plain ranges in width from a few hundred feet to half a mile and locally is irrigated. The larger tributaries of Rosebud Creek from the west are, in order from north to south, Miller Coulee, Lee Coulee, Richard Coulee, Slough Grass Creek, Little Cottonwood Creek, Big Cottonwood Creek, and Lynch Coulee. Rye Grass Creek is the only notable stream which enters it from the east. Practically all these streams have shallow pools of water here and there along their courses in the dry season, and for short distances there may be a slight surface flow of water.

Many springs occur in the field, but water for domestic use and for stock is obtained chiefly from dug or drilled wells. Fair water in small amounts can be obtained from seepages in the terrace gravel along the Yellowstone River. No springs were observed in that part of the field where the Bearpaw shale is the surface formation. Good water issues from the sandstones near the base and at the top of the Lance formation in several places. The spring most used and most easily accessible is on the Yellowstone trail between Forsyth and

Armells Creek. This spring is protected by a concrete cover and furnishes a steady supply of drinking water. Another spring which yields satisfactory drinking water is on Sevenmile Creek near the southeast corner of sec. 1, T. 3 N., R. 40 E. The water issues from the base of the massive sandstone at the top of the Lance formation and is the supply used by stockmen and sheep herders for miles around. Springs can also be found in most of the deep and narrow coulees in the middle of the Lance formation, but the water in some of them is highly mineralized. No springs were observed in the Lebo shale anywhere in the field, and sandstones, which might yield water, are usually absent from the Lebo or if present are extremely lenticular and discontinuous.

Springs issue from nearly all the coal beds in the upper part of the Fort Union. This is especially true of the Rosebud bed where it crops out in bottoms of streams. The quantity of water supplied by such springs differs greatly. In some places there may be only enough water to make small pools in the bed of the stream; in others, as along the outcrop of the Rosebud bed in T. 2 N., R. 39 E., and in Miller Coulee, T. 1 N., R. 41 E., a number of springs may contribute enough water to make a small but steady flow even during the summer. Several drilled wells have obtained an abundant supply of water from the sandstones overlying the Rosebud coal bed. One of the best of these wells is at the Hafer place in sec. 12, T. 1 N., R. 41 E. The ground-water resources in the part of this field in Rosebud County have been discussed by Renick,[7] and the ground-water conditions in Treasure and Big Horn Counties were studied by Hall.[8]

Railroads, settlements, and roads.—The Northern Pacific Railway follows the south bank of the Yellowstone River across the northern edge of the field, and a branch line 30 miles long has been constructed up Armells Creek and its East Fork to Colstrip, a coal-mining camp of about 100 people in sec. 34, T. 2 N., R. 41 E. The Chicago, Milwaukee, St. Paul & Pacific Railway follows the north bank of the Yellowstone as far west as Forsyth where it swings northwestward and crosses over into the basin of Musselshell River. The projected North & South Railway will follow the valley of Tongue River east of this field and will connect with the Northern Pacific and Chicago,

[7] Renick, B. C., Base exchange in ground water by silicates as illustrated in Montana: U. S. Geol. Survey Water-Supply Paper 520, pp. 53–72, 1924; Some geochemical relations of ground water and associated natural gas in the Lance formation: Jour. Geology, vol. 32, pp. 668–684, 1924. Renick, B. C., and Riffenburg, H. B., Geology and ground-water resources of central and southern Rosebud County, Mont.; U. S. Geol. Survey Water-Supply Paper 600, 1929.

[8] Hall, G. M., and Howard, C. S., Ground water in Yellowstone and Treasure Counties, Mont.; U. S. Geol. Survey Water-Supply Paper 599, 1929. Hall, G. M., Ground water in Big Horn County, Mont.: U. S. Geol. Survey Water-Supply Paper — (in preparation).

Milwaukee, St. Paul & Pacific railways at Miles City, and with the Chicago, Burlington & Quincy Railroad at Sheridan, Wyo.

Forsyth, the county seat of Rosebud County, with a population of about 1,850, is the largest town in the field and is the chief shipping and trading center. The small stations, Howard and Finch, west of Forsyth on the Northern Pacific Railway, serve as shipping points for cattle and farm products.

The Yellowstone Trail crosses the central part of T. 6 N., R. 41 E., on the gravel bench and descends to the flood plain of the Yellowstone River at Forsyth. West of Forsyth it roughly parallels the Northern Pacific Railway to the western limit of the field. The Electric Trail, which follows approximately the Chicago, Milwaukee, St. Paul & Pacific Railway, starts at Forsyth and leads northwestward to Vananda, Ingomar, Sumatra, Roundup, and other towns in the Musselshell Valley. A graded county road follows Armells Creek and its West Fork to the northwest corner of T. 1 N., R. 40 E., where it connects with ungraded roads traversing the central part of the field. A graded road follows the East Fork of Armells Creek to Colstrip and leads thence to the Hafer ranch in sec. 12, T. 1 N., R. 41 E., from which two graded roads lead to Rosebud Creek. The graded road between Forsyth and points along Rosebud Creek and the Tongue River leaves the Yellowstone Trail 4½ miles east of Forsyth and runs southeastward into the valley of Rosebud Creek.

The road following Rosebud Creek in this field leads southwestward to Lame Deer, Busby, and Sheridan. On the geologic map are shown practically all the roads in the field. (See pl. 7.) These roads can be traversed by automobiles, though driving may be difficult in places where the roads cross the drainage lines at right angles.

Sarpy post office, in sec. 36, T. 1 N., R. 38 E., receives mail twice a week from Hysham on the Northern Pacific Railway about 12 miles west of this field. All other post offices in the Forsyth field not on the railroad receive their mail by stage from Forsyth.

GEOLOGY

The Forsyth field contains exposed rocks of Upper Cretaceous, Tertiary, and Quaternary ages, comprising the Judith River formation, Bearpaw shale, Lance and Fort Union formations, Oligocene or Miocene (?) terrace gravel, terrace gravel of Pleistocene age, and Recent alluvium. Exposures of the rocks are good throughout the field, and it was possible to obtain many detailed stratigraphic sections, some of which are given in the following pages. The pub-

lished sections were selected with the purpose of showing in detail the character of all the rocks in the field above the Bearpaw shale.

Geological section in the Forsyth coal field

System and series	Group and formation	Character	Thickness (feet)
Quaternary.		Recent alluvium and Pleistocene terrace gravel.	0–50
Tertiary (Oligocene or Miocene series).		Terrace gravel cemented into a conglomerate; largely made up of andesitic porphyry. Crops out 1,000 to 1,100 feet above Yellowstone River.	60
Tertiary (Eocene series).	Fort Union formation.	Tongue River member. Prevailingly light-colored sandstone and sandy shale; several of the sandstones thick and massive and weathered into many varied shapes; contains several thick coal beds which have burned along their outcrops and have fused the overlying rock into a slag or clinker.	1,686
		Lebo shale member. Soft incoherent dark gray to black shale, clay, and sandy shale with abundant ferruginous concretions; weathers into gentle treeless slopes and diminutive badlands. Big Dirty coal bed at base.	105–170
Tertiary (Eocene ? series).	Lance formation.	Tullock member. Light-yellow calcareous sandstone and sandy shale closely resembling the strata of the Tongue River member of the Fort Union; sandstones well stratified and rarely massive; usually crops out in a prominent escarpment; contains many thin coal beds, few of which are burned.	240–270
		Hell Creek member. Massive, thick sandstones in the lower part grading upward into greenish-gray and grayish-yellow sandy shale and clay; contains no workable coal in the Forsyth field. Basal sandstone may correspond to the Colgate sandstone member of the Fox Hills sandstone of eastern Montana.	630–675
Cretaceous (Upper Cretaceous series).	Montana group. Bearpaw shale.	Dark-gray fissile marine shale with abundant fossiliferous calcareous concretions. Transition zone, 40 to 60 feet thick, at top may correspond to lower part of Fox Hills sandstone of eastern Montana.	1,000±
	Montana group. Judith River formation.	Upper member composed of grayish-white massive sandstone succeeded below by brown marine shale. Not all of formation exposed in this field.	95+

CRETACEOUS SYSTEM

MONTANA GROUP

Judith River formation.—The rocks of the Judith River formation are the oldest rocks exposed in the Forsyth field and were brought to the surface by the Porcupine uplift. They crop out in the bluffs about a quarter of a mile south of the Northern Pacific Railway between Reservation Creek and the western limit of the field. The

top of the formation consists of a very hard, heavily bedded, grayish-white sandstone about 20 feet thick, which makes a prominent bench protruding through terrace gravel. (See pl. 2, *A*.) Its marine origin is shown by the fairly abundant but rather fragmentary remains of *Baculites* and other marine invertebrates. Beneath this sandstone there is 75 feet of brown sandy shale exposed at irregular intervals in the gravel-covered slopes above the level of the alluvium. No fossils were found in the shaly part of the formation.

Bearpaw shale.—Here as elsewhere throughout its outcrop in eastern Montana the Bearpaw is made up almost entirely of dark-gray fissile marine shale containing an abundance of light-brown calcareous concretions. These concretions are rounded and of various sizes, and some contain numerous marine invertebrate fossils of many kinds. At the top of the Bearpaw is a transition zone of thin-bedded sandstone and sandy shale, 40 to 60 feet thick, below the massive sandstones of the overlying Lance formation. This sandy zone represents the final stage of the last marine invasion in Montana and may be of the same age as the lower part of the marine Fox Hills sandstone of the Dakotas.

The Bearpaw, like the Judith River, has been brought to the surface in the northwestern part of the field by the Porcupine uplift and dips about 3° S. It crops out in low rounded hills covered by a mantle of terrace gravel, so that good exposures of the shale occur only in the stream valleys. No direct measurements of its thickness can be made in this field. Measurements made by the writer in the steep bluffs of the Musselshell River in western Garfield County showed that its average thickness for this general region is about 950 feet.

TERTIARY (?) SYSTEM

LANCE FORMATION

In the Forsyth field the lithologic difference between the upper and lower parts of the Lance formation warrants the separation of the formation as mapped into the Hell Creek[9] and Tullock[10] members.

In the opinion of the writer it is probable that more refined study of the lower part of the Hell Creek member would demonstrate the equivalence of its massive basal sandstone as here mapped with the upper or Colgate sandstone member of the Fox Hills sandstone of eastern Montana[9] and would lead to its combination with the sandy

[9] Thom, W. T., jr., and Dobbin, C. E., Stratigraphy of the Cretaceous-Eocene transition beds in eastern Montana: Geol. Soc. America Bull., vol. 35, pp. 481–506, 1924.

[10] Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek coal field, Rosebud and Big Horn Counties, Mont.: U. S. Geol. Survey Bull. 749, 1923.

strata which are here provisionally included in the upper part of the Bearpaw, but which, it is thought, correspond to the lower part of the Fox Hills. The most striking differences between the Hell Creek and Tullock members of the Lance in this field are the contrast in their topographic expression and the absence of coal in the Hell Creek member. Further details regarding their lithologic differences are given below.

HELL CREEK MEMBER

The Hell Creek member of the Lance formation as here mapped rests conformably on the sandy transition zone at the top of the Bearpaw shale, and no hard and fast line can be drawn between them. The basal part of the member is made up of grayish-brown cross-bedded sandstone, probably corresponding to the Colgate sandstone member of the Fox Hills sandstone of eastern Montana, and crops out west of Armells Creek in a pine-clad escarpment south of the rolling, treeless areas of Bearpaw shale. Sandstones slightly higher in the member crop out along the Yellowstone Trail between Armells Creek and Forsyth, and some are more than 50 feet thick.

Although the Hell Creek member in this field does not contain very great thicknesses of somber-colored clay and shale, such as are characteristic of the member at its type locality on Hell Creek, northern Garfield County, yet by far the greater part of the shale has a greenish-yellow tint that is decidedly different from the more yellow sandy shale of the Tullock member. The top of the member was consistently drawn at the base of the Wright coal bed, which is a persistent bed, though in many places it may be less than a foot thick or may consist entirely of carbonaceous shale.

The areas where the Hell Creek member crops out are, unless modified by terrace gravel, very rough and in many places almost inaccessible even to saddle horses. Badlands in the Hell Creek member occur on Armells Creek up to its forks and on Smith and Reservation Creeks. Throughout the field the lower 450 feet of the member is made up chiefly of gray and brown sandstone with alternating beds of very light gray and greenish-yellow shale. The sandstones are commonly as much as 50 feet thick, and many of them are cross-bedded and full of clay balls. One sandstone contained clay balls as much as 9 inches in diameter. Most of the thick beds have a brown sandstone cap rock which is much harder than the lower part of the bed and projects as a shelf. The action of the wind on the softer material beneath the cap rock has produced many fantastic erosion forms. The presence of cross-bedded conglomerate layers, some of which contain pebbles an inch or more in diameter, and the lack of distinctive bedding planes in the lower part of the member suggest that the rocks are of fluviatile origin and were deposited in stronger currents

than those flowing when the upper part of the member was laid down. The lenticularity of the massive sandstones in the lower part of the Hell Creek is very striking here as elsewhere in Montana where the member crops out. A sandstone may persist for several miles as a rather prominent ledge and be replaced by sandy shale within a few hundred feet.

The upper 175 feet of the Hell Creek member is made up almost invariably of light-colored sandy shale containing lenses of gray and brown ledge-making concretionary sandstone. Locally on Armells Creek the upper part of the Hell Creek member is made up of typical "somber beds" containing ferruginous concretionary layers and soft, incoherent cross-bedded sandstone. In these places the contrast in color and composition between the Hell Creek and Tullock members is very striking. In most places, however, the one grades insensibly into the other, and were the Wright coal bed absent there would be no definite horizon to mark their limits.

In the railroad cut at the mouth of Armells Creek the basal sandstone of the Hell Creek member contains thin partings of plant-bearing clay at a horizon probably not more than 50 feet above the Bearpaw. The material is very soft, friable sandy shale and clay and contains no perfect leaves. The following determinations of fragmentary material from this horizon were made by F. H. Knowlton:

7656. From sec. 23, T. 6 N., R. 39 E.:
Populus sp.
Zizyphus? sp.
Populus cuneata Newberry.
Fragments of several dicotyledons.

The *Populus* identified with a fair degree of certainty is a Fort Union species, according to Knowlton.

The following section measured from the mouth of Armells Creek, in sec. 23, T. 6 N., R. 39 E., eastward along the Yellowstone Trail to Smith Creek, thence southward up Smith Creek to sec. 12, T. 5 N., R. 40 E., illustrates the nature of the Hell Creek member of the Lance formation in the Forsyth field:

Section from Armells Creek to Smith Creek and up Smith Creek

Base of Tullock member.	Feet
Shale, light colored, sandy	9½
Shale, carbonaceous	1
Shale, light colored, sandy	42
Shale, gray, sandy, and gray concretionary sandstone	110
Sandstone, brown	60
Shale, greenish	26
Sandstone, gray, concretionary	27
Sandstone, dark brown; makes a cap rock	4
Sandstone, light brown	24

	Feet
Shale, brown, sandy	13
Shale, light colored, sandy	42
Sandstone, brown; contains clay balls with a maximum diameter of 9 inches	52
Shale, greenish, sandy	9
Sandstone, light gray	34
Sandstone, gray, cross-bedded	28
Shale, dark, soft	9
Shale, sandy, concretionary layers at base and top	14
Shale, gray and yellow, sandy	59
Sandstone, orange-brown, cross-bedded; contains several lenses with wavy top	58
Clay, dark	4
Sandstone, light brown, cross-bedded; contains thin partings of plant-bearing clay; probably corresponds to the Colgate sandstone member of the Fox Hills sandstone of eastern Montana	11+
Interval to Bearpaw shale about 50 feet.	
	636+

TULLOCK MEMBER

The Tullock member of the Lance formation is made up of light-colored sandstone, sandy shale, and several thin but fairly persistent coal beds. The base of the member is drawn at the base of the Wright coal bed and its top at the base of the Big Dirty coal bed. Its thickness is fairly uniform throughout the field and ranges from 240 to 270 feet. Along Armells and Smith Creeks the Tullock crops out in a steep escarpment (see pl. 2, *B*), which in some places may be obscured by a mantle of river gravel. The top of the Tullock is marked by a very resistant calcareous sandstone rim rock 2 to 15 feet thick, which may be underlain by either a much softer sandstone or a sandy shale. The sandstone rim rock is overlain by the Lebo shale, which crops out in gentle slopes slightly back of the edge of the Tullock escarpment, producing a striking physiographic contrast. The sandstones of the Tullock are light yellow, evenly bedded, calcareous, and rarely massive, unlike the sandstones of the Tongue River member of the Fort Union formation.

Only two coal beds were mapped in the Tullock—the Wright bed at its base and the Hamre bed about 35 feet below its top. These beds, in common with all other coal beds in the Tullock member, are usually persistent but only locally contain coal. Several sections measured on the west side of Armells Creek and the east side of Reservation Creek failed to show any coal more than a foot thick in the member.

Section of the Tullock member of the Lance formation in sec. 30, T. 5 N., R. 40 E.

Base of Lebo shale member.	Ft.	in.
Sandstone, brown, concretionary; makes cap rock on conspicuous escarpment	2	
Sandstone, yellow, soft	34	
Coal and carbonaceous sandstone } Hamre bed		10
Coal } Hamre bed		4
Carbonaceous sandstone } Hamre bed		1
Coal, dirty } Hamre bed	3	5
Sandstone, yellow, soft	48	
Sandstone, brown, ledge maker	4	
Clay		7
Sandstone, whitish, soft, conspicuous bed	23	
Coal	1	4
Shale, gray, sandy	56	
Coal		5
Clay		7
Coal		10
Clay, gray, sandy	16	
Sandstone, yellow	6	
Coal		10
Sandstone and sandy shale, yellow	18	
Coal	2	1
Clay	1	3
Shale	1	0
Coal	1	10
Clay, gray	5	
Clay, brown, sandy	17	
Coal; Wright bed	3	5
	247	10

Section of the Tullock member of the Lance formation in secs. 12 and 13, T. 5 N., R. 40 E.

Base of Lebo shale member.	Ft.	in.
Sandstone, yellow; makes prominent rim rock	10	
Shale, light colored, sandy, and concretionary sandstone	51	
Shale, light colored, sandy	17	
Shale, carbonaceous bed at top	15	
Sandstone, yellow	26	
Shale, light colored, sandy	23	
Sandstone, and sandy shale, yellow	20	6
Sandstone, brown, concretionary	2	
Sandstone and sandy shale, yellow	12	
Shale, slightly carbonaceous	2	
Sandstone, cream colored, very soft	7	
Coal and carbonaceous shale	1	3
Shale, light colored, sandy	11	
Sandstone, yellow, with thin rim rock of brown sandstone	18	
Clay, purple	3	
Sandstone, light yellow, very soft	9	

	Ft.	in.
Sandstone, yellow, shaly	3	
Clay		4
Shale, carbonaceous		3
Shale, light colored, sandy	22	
Carbonaceous shale		8
Coal	1	
Shale, light colored, sandy	7	
Shale, carbonaceous		8
Sandstone, yellow, shaly	2	
Shale, carbonaceous; Wright bed	4	6
	269	2

TERTIARY SYSTEM

FORT UNION FORMATION

The Fort Union formation in the Forsyth field is readily separable on lithologic grounds into two members, a lower one, the Lebo shale, and an upper one, consisting of yellow sandstone, sandy shale, and coal beds, called the Tongue River member.

LEBO SHALE MEMBER

The Lebo shale member of the Fort Union formation is made up of dark-gray to black clay and shale, largely of volcanic origin. By its somber aspect it is readily distinguished from the underlying Tullock member of the Lance formation and the overlying Tongue River member of the Fort Union. (See pl. 3, *A*.) It contains beds of soft, gray cross-bedded sandstone, some of which may be as much as 10 feet thick, but none are persistent for more than a few hundred feet. Ironstone concretions occur in the Lebo in great numbers and usually collect in piles where they have been washed out of small bare buttes or slopes. Some of the ferruginous concretionary layers are not more than 6 inches thick and are fairly persistent horizon markers.

The base of the Lebo is drawn at the base of the Big Dirty coal bed, which rests directly on the rim rock making the top of the Tullock member of the Lance formation. The top of the member is drawn at the point where there is a change from somber-colored clay to yellow sandstone and sandy shale. The thickness of the Lebo ranges from 105 to 170 feet and is least in the western part of the field.

Because of its infertile character the Lebo supports only a little vegetation, chiefly sagebrush. On the divides the Lebo forms a broad zone of rolling, treeless country between the escarpment-forming sandstones of the Tullock member of the Lance and the Tongue River member of the Fort Union. In the stream valleys,

however, because of its softness and thinness, it erodes readily into a narrow zone of badlands most intricately dissected and almost worthless for any use. Representative sections of the Lebo in the Forsyth field are given below.

Section of the Lebo shale member of the Fort Union formation in the NE. ¼ sec. 25, T. 3 N., R. 39 E.

Base of Tongue River member.		Ft.	in.
Shale, light gray		10	8
Shale, dark gray		6	6
Shale, carbonaceous			9
Shale, dark gray		7	8
Shale, greenish yellow, with clay-ironstone concretions		5	4
Shale, yellowish green, with sandstone lentils		3	10
Shale, yellowish green, tuffaceous		23	2
Shale. dark gray, with clay-ironstone concretions		6	4
Shale, yellowish green, sandy		39	4
Shale, brownish gray		3	2
Carbonaceous shale	Big Dirty bed		5
Coal, bony		4	7
Bone			2½
Coal		1	1
Shale			½
Coal		1	8½
Shale			1
Coal		1	9
Carbonaceous shale			2½
Clay		1	1
		117	11

Section of the Lebo shale member of the Fort Union formation in sec. 24, T. 5 N., R. 40 E.

Base of Tongue River member.	Ft.	in.
Clay, dark blue, bentonitic	7	
Shale, gray	21	
Clay, gray bentonitic	24	
Concretionary layer		6
Clay, gray, bentonitic	2	
Coal, impure	1	
Clay, bentonitic	3	
Sandstone, rusty		6
Clay, gray, sandy	13	
Calcareous concretionary layer	2	
Clay, gray, bentonitic; contains many ferruginous and carbonaceous layers	63	
Clay, dark, with ironstone concretions	13	
Fire clay	1	
Clay, greenish		8

		Ft.	in.
Bone	Big Dirty bed		11
Coal, impure, and bone		1	11
Bone			9
Coal, fair		1	1
Coal, impure, and carbonaceous sandstone			11
Bone, coal, and carbonaceous sandstone		1	
		158	3

Section of the Lebo shale member of the Fort Union formation in the SE. ¼ sec. 30, T. 4 N., R. 41 E.

	Ft.	in.
Shale, gray and blue, with thin carbonaceous layers	48	
Clay, containing many ferruginous concretions	48	
Coal		6
Clay, grayish blue	17	
Clay, grayish blue, containing many ferruginous concretions	1	
Clay, gray	28	4
Shale, carbonaceous	1	
Clay, grayish white	22	8
Shale, carbonaceous, with streaks of bony coal, Big Dirty bed	3	
	169	6

TONGUE RIVER MEMBER

The Lebo shale grades upward through a transition zone of sandy shale into a group of beds of light-colored sandstone, sandy shale, carbonaceous shale, and coal, which constitute the Tongue River member of the Fort Union formation. There is 1,686 feet of the member in the Forsyth field, included between the top of the Lebo shale and the clinker that makes the cap rock on Wolf Mountain. The rocks in this member are much more resistant than the Lebo clays and usually crop out in steep bluffs above Lebo lowlands or badlands. The lower 125 feet contains no workable coal. The succeeding 600 feet, however, contains eight coal beds ranging in thickness from 3 to 30 feet. These beds constitute the principal coal deposits of the field. The thick coal beds in this interval have burned along their outcrops and baked the overlying strata to various shades of red and brown. The slag or clinker thus formed is a distinctive feature of this part of the section, not only in the Forsyth field but elsewhere in Montana, and serves to distinguish the coals from those of the Tullock member, which occur in strata similar in color and lithology but are rarely burned. The clinker is much more resistant than the underlying rocks, and where it has been cut through by narrow stream gorges it makes a protective cap rock above steep and bare slopes. Where a thick coal bed has been burned over a considerable area remnants of its clinker form the summits of the divides, which may be less than half a mile wide and more than 5 miles long.

On the accompanying map (pl. 7) the areas thus covered by clinker are designated by a special pattern. The principal use for clinker at the present time is for road metal or railroad ballast.

The most prominent sandstone in the Tongue River member is that which commonly occurs above the Rosebud coal bed. (See pl. 5, *A*.) In places this sandstone is 150 feet thick and crops out as a persistent and easily recognized ledge at the base of a yellow bluff of softer sandstone and shale. It is especially well developed near Castle Rock, in Miller Coulee, and along Rosebud Creek and its tributaries. In the Rosebud Creek area it is split into two benches separated by the Lee coal bed. It is grayish-yellow, fine grained, usually massive, and arkosic. Castle Rock, in sec. 31, T. 2 N., R. 40 E., is an outlier of this sandstone about 60 feet high. Other similar but larger outliers of this sandstone occur in Richard Coulee, in T. 1 S., R. 41 E.

The Sawyer coal bed, which occurs about 725 feet above the base of the member, is the uppermost of the thick coal beds of considerable economic value in the section. Above the Sawyer bed is about 1,000 feet of sandstone, sandy shale, and thin but persistent coal beds. In the Wolf Mountain area (see p. 43) the sandstone and sandy shale are normally yellow. The sandstones, however, are usually well bedded, in contrast to those in the lower part of the member. Somber-colored clay occurs in many places in the Wolf Mountain section but nowhere through an interval greater than 30 feet.

The following fossils from the Tongue River member are Fort Union forms, according to F. H. Knowlton:

7657. From a sandstone above the Proctor coal bed, sec. 18, T. 1 N., R. 40 E.:
Onoclea sensibilis fossilis Newberry.
Sapindus grandifolius Ward.
Celastrus curvinervis? Ward.

7658. From a sandstone 350 feet above the Popham coal bed, sec. 9, T. 1 N., R. 39 E.:
Equisetum sp.
Populus acerifolia Newberry.
Viburnum newberryanum Ward.
Dicotyledon, new?
Sapindus sp. cf. S. grandifolius Ward.

7659. Horizon of Sawyer coal bed, SE. ¼ sec. 7, T. 1 N., R. 40 E.:
Populus amblyrhyncha Ward.
Populus acerifolia Newberry.

7660. From a sandstone 100 feet above the Sawyer coal bed, SW. ¼ sec. 19, T. 1 N., R. 40 E.:
Viburnum newberryanum Ward.

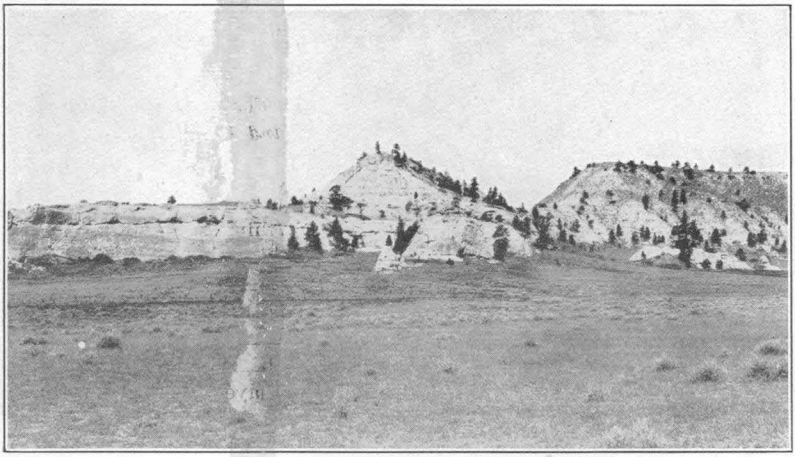
7661. From sandstone below Rosebud coal bed, SW. ¼ sec. 27, T. 2 N., R. 40 E.
Populus amblyrhyncha Ward.
Viburnum asperum Newberry.
Populus sp.

7662. From sandstone at horizon of Richard coal bed, SE. ¼ sec. 36, T. 1 N., R. 39 E.:

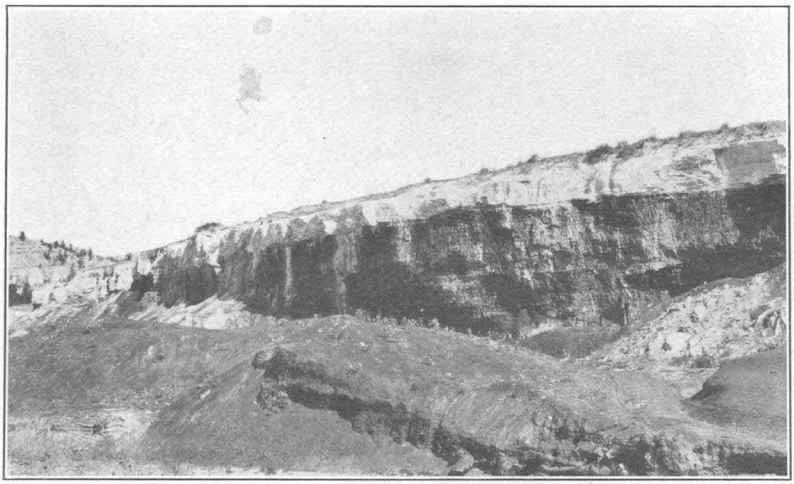
Thuya interrupta Newberry.
Viburnum sp.
Populus sp.
Oreodaphne sp.

Section of part of the Tongue River member of the Fort Union formation in secs. 34 and 35, T. 2 N., R. 39 E., and secs. 3, 8, 9, and 10, T. 1 N., R. 39 E.

	Ft.	in.
Clinker; makes cap rock on Wolf Mountain	28	
Sandstone and sandy shale, yellow; contains thin and nonpersistent coal beds	306	
Coal	4	
Sandstone, brown, concretionary; makes a bench	17	
Sandstone, yellow, massive	34	
Sandstone, brown, concretionary; makes a bench	6	
Sandstone, yellow; contains many carbonaceous l[illegible]rs	40	
Sandstone, brown, calcareous	17	
Shale and clay, grayish black	28	
Sandstone, yellow, well stratified	67	
Coal	4	
Sandstone, grayish white	23	
Sandstone, brown; makes a prominent bench	28	
Shale, sandy; contains many thin burned coal beds	68	
Sandstone and sandy shale, grayish white and yellow; containing many concretionary lenses and thin carbonaceous beds	110	
Shale, carbonaceous		8
Coal — Richard bed	1	
Shale, carbonaceous	1	
Sandstone, yellowish white	11	
Shale, somber colored	30	
Sandstone, brown	17	
Shale, carbonaceous	2	
Coal		6
Clay, carbonaceous	2	
Sandstone, grayish white	5	
Coal, dirty, and carbonaceous shale		10
Coal	3	
Sandstone, yellowish brown	32	
Coal, Proctor bed	3	
Shale, yellow, sandy	10	
Coal	1	
Sandstone, yellowish brown	80	
Sandstone, yellow, concretionary	40	
Shale, carbonaceous	3	
Clay, sandy	8	
Carbonaceous shale	7	
Coal	2	
Bone — Popham bed		1
Coal	2	

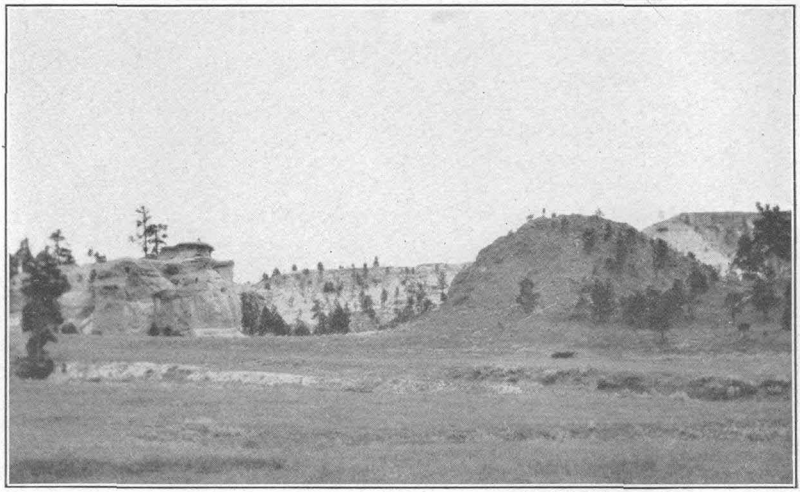


A. MASSIVE SANDSTONE ABOVE THE ROSEBUD COAL BED, SEC. 13, T. 1 N., R. 41 E., MONTANA



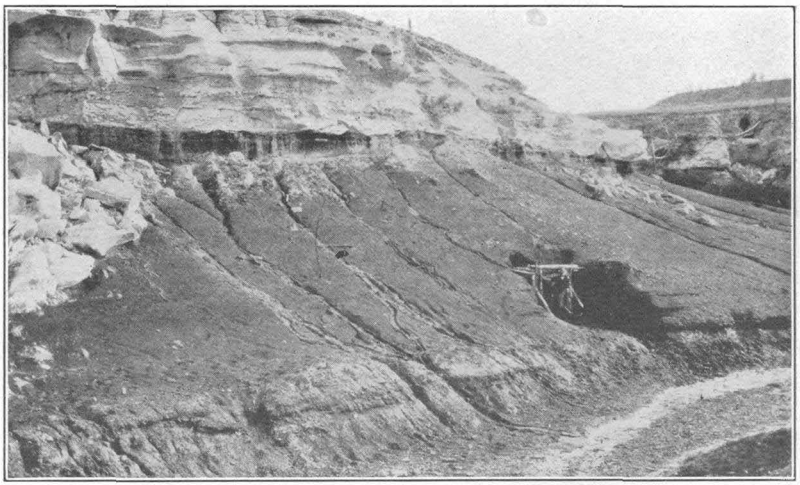
B. OUTCROP OF THE ROSEBUD COAL BED IN THE NORTH COAL BANK COULEE, SEC. 24, T. 1 N., R. 41 E., MONTANA

Thickness of coal bed about 28 feet



A. VIEW IN SEC. 31, T. 2 N., R. 40 E., MONTANA

At the right the massive sandstone has been fused and baked by the burning of the Rosebud coal bed



B. PROSPECT ON OUTCROP OF THE ROSEBUD COAL BED IN SOUTH COAL BANK COULEE, SE. ¼ SEC. 15, T. 1 N., R. 41 E., MONTANA

Amount of coal exposed about 28 feet

	Ft.	in.
Sandstone, yellow, massive	23	
Coal, dirty, and carbonaceous shale	1	
Sandstone, grayish yellow	17	
Shale, greenish	28	
Carbonaceous shale	2	
Coal, dirty	2	
Carbonaceous shale	4	
Clay, yellow, sandy; contains several ferruginous concretionary layers	11	
Sandstone, gray, massive, makes a prominent rim rock	45	
Clay carbonaceous	1	6
Sandstone, yellow	24	
Sandstone, gray, massive, concretionary; weathers into fantastic erosion forms	96	
Sandstone, gray, well stratified	11	
Clay, blue	6	
Coal; Rosebud bed.		
	1,313	7

Section of part of the Tongue River member of the Fort Union formation in N. ½ sec. 24 and S. ½ sec. 13, T. 1 N., R. 41 E.

Sawyer clinker.	Ft.	in.
Clay, greenish, sandy	11	
Sandstone, light gray; makes prominent ledge	3	
Shale, greenish, sandy	22	
Sandstone, brown, concretionary	5	
Shale, gray, greenish, and olive-colored	35	
Sandstone, yellow, soft, platy	12	
Clay, drab, gypsiferous	12	
Sandstone, yellow, very soft	6	
Sandstone, yellowish brown, concretionary	6	
Sandstone, grayish, very soft	11	
Coal and carbonaceous shale	1	
Sandstone, yellow, soft; contains many harder brown concretionary masses	34	
Sandstone, yellow, cross-bedded in places, usually massive; contains clay balls; fine grained, pitted; a very prominent ledge maker in this general area	134	
Sandstone, yellow, and light-colored sandy shale	17	
Sandstone, yellow, massive	17	
Clay, light gray, sandy	12	
Coal	10	
Bone		2
Coal — Rosebud bed	9	
Bone		2
Coal	9	
Shale, gray, sandy	2	
Shale, purple, carbonaceous		6
Clay, gray, sandy	4	
Coal; McKay bed	10	
	382	10

Section of part of the Tongue River member of the Fort Union formation in sec. 34, T. 3 N., R. 38 E.

	Ft.	in.
Shale, brown, sandy.		
Coal, Clay, Coal } Rosebud bed	11	7
Shale, gray	13	
Coal		10
Sandstone, light yellow	9	10
Coal; McKay bed	3	
Shale, gray, with thin lenses of sandstone	21	8
Shale, carbonaceous		6
Shale, gray, sandy	9	10
Coal; Stocker Creek bed	2	10
Shale, gray, sandy	35	10
Coal	1	5
Clay, gray		4
Coal		5
Shale, carbonaceous		3
Clay, gray		5
Sandstone, light gray, massive	61	6
Coal	1	8
Shale, carbonaceous		6
Coal		8
Shale, gray	26	4
Coal	1	1
Clay Robinson bed		3
Coal	5	4
Clay, gray	21	8
Sandstone, yellow, massive	21	8
Coal; Burley bed	2	8
	255	5

Section of part of the Tongue River member of the Fort Union formation in the SW. ¼ sec. 6, T. 4 N., R. 41 E.

	Feet
Sandstone, yellow, well stratified	57
Sandstone, grayish yellow	1
Coal; Burley bed	1
Sandstone, yellow, massive	58
Shale, carbonaceous	2
Sandstone, yellow, massive	12
Coal	1
Sandstone, yellow	34
Sandstone, yellow, concretionary	2
Sandstone, yellow, shaly	40
Lebo shale member.	
	208

OLIGOCENE OR MIOCENE (?) GRAVEL

The oldest gravel deposit in the field caps a plateau on the divide between Armells and Sarpy Creeks in the northwest corner of T. 3 N. and the southwest corner of T. 4 N., R. 39 E. (See pl. 7.)

Gravel occurs at the same level on the tops of the highest hills and ridges in the northern part of T. 4 N., R. 41 E. These gravel deposits are small remnants of a much larger river terrace and stand 1,050 to 1,100 feet above Yellowstone River. The gravel, which is 60 feet thick, is thoroughly cemented at the base into a conglomerate. The deposit contains boulders a foot or more in thickness and consists of igneous rocks ranging in composition from granite to basalt, particularly andesitic porphyries. Agate, silicified wood, and fragments of coal clinker occur in it, indicating that at least some of the coal had been burned along its outcrop before the gravel was deposited.

This gravel terrace is equivalent to similar terraces in the Tullock Creek field described by Rogers,[11] which stand 1,100 feet above the Yellowstone. In the area south of Huntley deposits of gravel and conglomerate make prominent plateaus at an altitude of 3,900 to 4,000 feet, or about 1,000 feet above the Yellowstone River, and are probably equivalent to the deposits just described.[12] On the divide between the Yellowstone and the Missouri, north of Terry, remnants of a gravel terrace 1,200 feet or more above the Yellowstone probably represents this same level.

According to Alden[13] the amount of cutting by Yellowstone River since these gravel deposits were laid down and a study of relative altitudes suggest that they are to be correlated either with the gravel capping the Cypress Hills in Canada, which McConnell[14] and Lambe[15] determined by fossils to be of Oligocene age, or with the Flaxville gravel, of Miocene or Pliocene age, in northeastern Montana.[16]

The northern edge of the Oligocene or Miocene (?) gravel deposits is about 12 miles south of the terrace along the Yellowstone River, and the vertical interval between them is 900 to 1,000 feet. The area intervening between the Oligocene (?) gravel deposits and the well-defined terraces bordering the Yellowstone is covered with a mantle of gravel which is not arranged in any well-defined system

[11] Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek coal field, Rosebud and Big Horn Counties, Mont.: U. S. Geol Survey Bull. 749, p. 47, 1923.

[12] Hancock, E. T., Geology and oil and gas prospects of the Huntley field, Mont.: U. S. Geol. Survey Bull. 711, pp. 128–129, 1920.

[13] Alden, W. C., Physiographic development of the northern Great Plains: Geol. Soc. America Bull., vol. 35, pp. 385–424, 1924.

[14] McConnell, T. G., On the Cypress Hills, Wood Mountain, and adjacent country: Canada Geol. Survey Ann. Rept., new ser., vol. 1, pp. 1c–78c, 1886.

[15] Lambe, L. M., A new species of *Hyracodon* (*H. priscidens*) from the Oligocene of the Cypress Hills, Assiniboia: Canada Roy. Soc. Proc. and Trans., 2d ser., vol. 11, sec. 4, pp. 37–42, 1906; Fossil horses of the Oligocene of the Cypress Hills: Idem, pp. 43–52; Vertebrata of the Oligocene of the Cypress Hills, Saskatchewan: Canada Geol. Survey Contr. Paleontology, vol. 3, pt. 4, 1908.

[16] Collier, A. J., and Thom, W. T., jr., The Flaxville gravel and its relation to other terrace gravels of the northern Great Plains: U. S. Geol. Survey Prof. Paper 108, pp. 179–184, 1918.

of terraces and has been reworked so many times that its relations are obscured. A small remnant of a terrace with gravel locally cemented to a conglomerate 10 feet thick, in the central part of T. 5 N., R. 41 E., stands 700 feet above the river. If the higher gravel corresponds to that on the Cypress Hills, this may correspond to the Flaxville gravel, of late Tertiary age.

QUATERNARY SYSTEM

PLEISTOCENE DEPOSITS

A broad and well-defined terrace borders the Yellowstone River on the south about 200 feet above the river flood plain. The gravel capping this terrace consists of smoothly rounded unconsolidated pebbles of many kinds of igneous rock, quartz, jasper, and limestone and is undoubtedly of Pleistocene age. This terrace is well preserved at somewhat varying heights above the Yellowstone throughout much of the river's course in eastern Montana. Farther west it extends for several miles up the southern tributaries of the river and is especially well developed on the Big Horn River and Fly and Pryor Creeks in the Huntley field.[17]

RECENT ALLUVIUM

The fine sand, silt, and gravel now being deposited in the flood plain of the Yellowstone River and its tributaries constitute the most recent deposit in the Forsyth field. It ranges in thickness from a few feet to about 40 feet and underlies some of the best agricultural land in the field. This land is irrigated and produces large crops of sugar beets and alfalfa. (See pl. 7.) The flood plains of the larger tributaries of the Yellowstone range from half a mile in width near their mouths to a few hundred feet near their sources, and all of them are cut up into small areas by the meandering of the streams.

STRUCTURE

The Forsyth field lies in a broad, shallow syncline or structural trough pitching gently southeastward, which connects the Powder River Basin and the structural depression of the Bull Mountains. The axis of this syncline in the Forsyth field follows closely a line drawn between Castle Rock and the northeast corner of T. 1 S., R. 41 E., and separates the Big Horn and Porcupine uplifts on the west and north, respectively. The strongest dips in the field occur in its northwest corner, where the rocks are affected by the Porcupine uplift. The sandstone member of the Judith River formation, which

[17] Rogers, G. S., and Lee, Wallace, op. cit. Hancock, E. T., op. cit.

is the lowest formation brought to the surface by the uplift, dips 3° SE. in this area. Dips of like amount were observed on concretionary layers in the Bearpaw shale. The basal sandstone of the Lance crops out in a prominent escarpment striking about east and dipping 2°–3° S. South of the escarpment, however, the rocks flatten out appreciably and over large areas have a normal southeasterly inclination of less than 1°. The western limb of the sandstone member of the Judith River dips beneath the alluvium of the Yellowstone River at an angle of about 2° a few miles upstream from the western limit of the field.

Within the major structural depression between the Big Horn and Porcupine uplifts the rocks are gently folded into several small anticlinal and synclinal folds. Nearly all the dips are less than 1° and they are determined only by noting the altitudes of coal beds and the distribution of their outcrops. Two gentle anticlines belonging to the Porcupine dome system of uplifts cross the area approximately parallel to the axis of the major syncline. One of these anticlines follows a line drawn between the northwest corner of sec. 2, T. 1 S., R. 41 E., and the southeast corner of sec. 11, T. 3 N., R. 39 E. Gentle doming, which has affected the position of the outcrop of coal beds, occurs along the axis of this fold near the SW. ¼ sec. 29, T. 1 N., R. 41 E., sec. 12, T. 1 N., R. 40 E., and sec. 11, T. 3 N., R. 39 E. West of the line of folding the rocks dip gently into the axis of the major syncline, west of which they rise uniformly westward at an angle less than 1°. Another line of folding, modified by a fault zone, also crosses the field in a northwesterly direction from the northwest corner of T. 2 N., R. 41 E. Several small normal faults, having maximum throws of about 60 feet, occur near the axis of this uplift along the boundary between T. 3 N., R. 40 E. and T. 3 N., R. 41 E. Further details regarding the structure are included in the township descriptions.

ECONOMIC GEOLOGY

COAL

GENERAL SECTION

The coal in the Forsyth field occurs in the Tullock member of the Lance formation and in the Lebo shale and Tongue River members of the Fort Union formation. The strata are nearly horizontal, and the coal beds crop out in regular order one above another from the vicinity of Forsyth southward to the top of Wolf Mountain. The coals of the Tullock member though persistent are generally too thin and dirty to be of much economic importance in this area, which contains a number of thicker beds near by.

Only one coal bed, the Big Dirty bed, was mapped in the Lebo shale member of the Fort Union. The Big Dirty bed, as its name implies, is usually dirty and consists of carbonaceous shale, carbonaceous sandstone, bone, and thin stringers of coal. Locally, as described below, it contains as much as 11 feet of apparently clean coal, though it is suspected that an analysis of this coal would show a high ash content. The Lebo member contains several carbonaceous zones above the Big Dirty bed, but the layers of coal in them are only an inch or two thick and alternate with much thicker beds of shale.

The principal coal reserves in the field occur in the Tongue River member of the Fort Union formation. There are eight coal beds, ranging from 3 to 30 feet in thickness, in the lower 725 feet of this member, and these will best repay attention by persons interested in the exploitation of the coal. The upper 1,000 feet of the Tongue River member contains four coal beds of extremely irregular thickness. These beds all crop out in the rough, timbered country at the foot and in the slopes of Wolf Mountain and at present are valuable only as sources of domestic fuel for individual homesteaders living near by.

The stratigraphic position of the coal beds in the Forsyth field and their relations to the coals of the Tullock Creek field are shown graphically in Plate 8. The following brief summary gives the names of the principal coal beds and the average intervals between them:

Sequence and average thickness of the coal beds in the Forsyth coal field, and distances between them

	Feet
Clinker; caps Wolf Mountain.	
Interval (upper part of Tongue River member)	310
Coal	3
Interval	200
Coal	3
Interval	230
Coal; Richard bed	4
Interval	103
Coal; Proctor bed	3
Interval	90
Coal; Sawyer bed	7
Interval	50
Coal; Popham bed	3
Interval	160
Coal; Lee bed	10
Interval	110
Coal; Rosebud bed	20
Interval	18
Coal; McKay bed	6

	Feet
Interval	30
Coal; Stocker Creek bed	6
Interval	130
Coal; Robinson bed	6
Interval	45
Coal; Burley bed	4
Interval	130
Base of Tongue River member of Fort Union formation.	
Interval	130
Coal; Big Dirty bed	7
Base of Lebo shale member of Fort Union formation.	
Interval	35
Coal; Hamre bed	3
Interval	200
Coal; Wright bed	3
Base of Tullock member of Lance formation.	
Interval	675
Base of Hell Creek member of Lance formation.	
Interval	1,000
Base of Bearpaw shale.	

Some of the beds listed above contain workable coal in parts of their extent in the Forsyth field, and the distribution of the tracts containing valuable coal reserves is outlined in the following descriptions of the several beds.

THE COAL BEDS

The coal beds in the Forsyth field were mapped by stadia traverses tied to land corners. The outcrop lines of practically all accessible coal beds of workable thickness and quality as thus determined are shown on Plate 7. The numbers along the outcrop lines indicate the locations where the coal beds were measured and refer to Plate 10 where the measurements are represented graphically. A more detailed description of the character of the coal beds than that given below will be found in the township descriptions.

COALS OF THE TULLOCK MEMBER OF LANCE FORMATION

Wright bed.—The Wright bed, at the base of the Tullock member of the Lance formation, is the lowest coal in the Forsyth field. Because of its stratigraphic position it crops out nearer the Yellowstone Valley than any of the overlying coals and has been mined for a number of years to supply local demand in Forsyth. In several mines in the basins of Smith and Armells Creeks and vicinity it ranges from 3 to 4 feet in thickness. (See pls. 7 and 10.) This bed crops out in the rough country at the base of the bluffs on the east side of Armells Creek and extends about 2 miles up the forks of the creek before it passes beneath the stream level. Along Armells

Creek it ranges from a foot or less to 3 feet in thickness and at many points occurs in two benches about 26 feet apart. (See pl. 10, locations 22, 23, 24, 25.) On the west side of Armells Creek below its forks and along Reservation Creek the Wright bed is persistently present but nowhere was observed to contain more than a foot of coal.

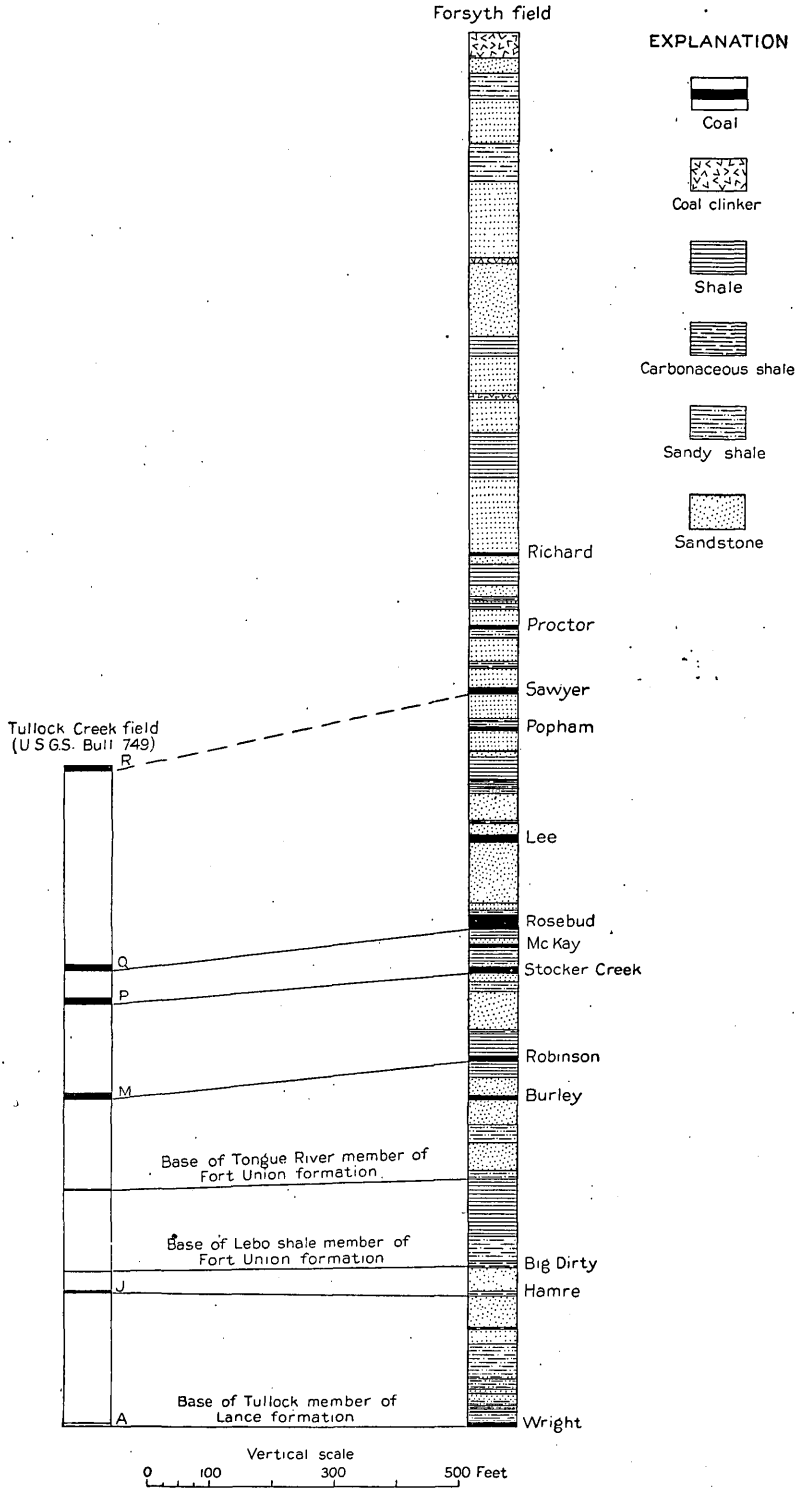
Hamre bed.—The Hamre bed occurs at an average interval of 200 feet above the Wright bed and crops out at the base of the heavy sandstone which makes the rim rock at the top of the Tullock member. It averages 3 feet in thickness and for the most part is made up of carbonaceous shale and coal, interbedded with which are innumerable thin stringers of carbonaceous sandstone. On the east side of Armells Creek, in T. 5 N., R. 40 E., it contained locally as much as 3 feet of coal in its basal part, and its outcrop was mapped for a little more than 3 miles. (See pl. 10, secs. 7–13.) The Hamre bed was recognized at many other places in the northwestern part of the field, but because of its generally worthless character it was not mapped.

In the interval between the Wright and Hamre beds there are several thin beds of coal which in places may attain a maximum thickness of 2 or 3 feet on their outcrops. They are, however, very narrow lenses, and because of their uneven thickness they were not mapped.

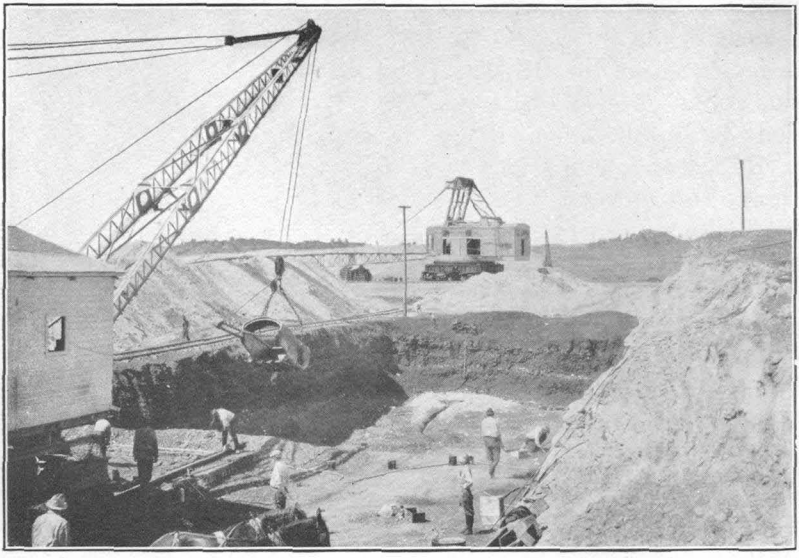
COALS OF THE LEBO SHALE MEMBER OF FORT UNION FORMATION

Big Dirty bed.—The Big Dirty bed, which lies at the base of the Lebo shale member of the Fort Union formation and 35 feet above the Hamre bed, ranges from 3 to 13 feet in thickness and usually consists of carbonaceous shale, carbonaceous sandstone, and thin lenticular beds of coal. (See pl. 10.) Locally where it is more than 6 feet thick its lower part may contain as much as 3 feet of coal. The only place in the field where the Big Dirty bed was observed to contain coal of workable thickness and quality was along the boundary between T. 3 N., R. 40 E., and T. 3 N., R. 41 E., and along the East Fork of Armells Creek near by, where it contains from 6 to 11 feet of what is apparently a fair grade of coal. (See pl. 10, secs. 76, 77, 79, etc.) Along the tributaries of the West Fork of Armells Creek in T. 3 N., Rs. 39 and 40 E., the Big Dirty bed locally contains 3 feet of coal in its lower part overlain by 7 feet of carbonaceous shale and thin beds of coal some of which attain in places a thickness of 3 feet or more. (See pl. 10, secs. 46, 47, 70, 71.)

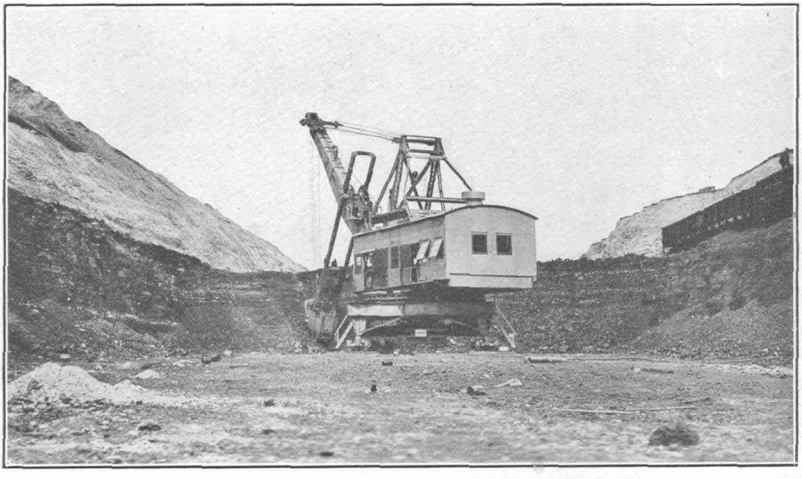
As previously stated, thin layers of coal associated with beds of carbonaceous shale occur elsewhere in the Lebo member within the Forsyth field, but they are of no value and will not be described.



STRATIGRAPHIC SECTIONS OF THE LANCE AND FORT UNION FORMATIONS IN THE FORSYTH AND TULLOCK CREEK FIELDS, MONTANA, SHOWING POSITION AND CORRELATION OF THE COAL BEDS



A



B

STRIP PIT OF THE NORTHWESTERN IMPROVEMENT CO. AT COLSTRIP, MONT.

COALS OF THE TONGUE RIVER MEMBER OF FORT UNION FORMATION

Burley bed.—The Burley bed, 130 feet above the base of the Tongue River member of the Fort Union, is the lowest of the valuable coals in the field. It is extensively burned in the vicinity of the Burley ranch, in the SE. ¼ sec. 24, T. 3 N., R. 41 E., where it contains about 5 feet of coal. (See pl. 10, locations 83–85.) Measurements of this bed along the West Fork of Armells Creek in T. 2 N., Rs. 38 and 39 E. (pl. 10, secs. 41, 119, 120), showed that its average thickness for that area is about 3 feet.

Robinson bed.—In the Armells Creek area the Robinson bed occurs 43 feet above the Burley bed, and its outcrops can be traced almost continuously across the field. East of the East Fork of Armells Creek, in T. 2 N., R. 41 E., it ranges from 2½ to 4½ feet in thickness. (See pl. 10, secs. 148, 149.) In the valleys of the West Fork of Armells Creek and its tributaries, in T. 2 N., R. 39 E., it attains a maximum thickness of about 8 feet. (See pl. 10, sec. 114.) On the east side of the Sarpy Creek-Tullock Creek divide, in T. 3 N., R. 39 E., it maintains an average thickness of 5 feet and is correlated with bed M of the Tullock Creek coal field.[18] (See pl. 10, secs. 52–58.)

Stocker Creek bed.—The Stocker Creek bed lies 130 feet above the Robinson bed and crops out in that part of the field northwest of the northwest corner of T. 1 N., R. 41 E. Measurements of this bed along Stocker Creek and on tributaries of the West Fork of Armells Creek, in T. 2 N., R. 40 E., showed its average thickness to be about 6 feet. (See pl. 10, secs. 123–128.) The maximum thickness of the bed observed in the field was 9 feet in the SW. ¼ sec. 15, T. 2 N., R. 38 E. (See pl. 10, sec. 97.)

McKay bed.—Throughout a large part of this field the McKay bed may be considered a split of the Rosebud bed, for many measurements showed that the interval between them in several places is less than 7 feet. (See pl. 10, secs. 221, 222.) The maximum observed interval between the Rosebud and McKay beds in the field is 30 feet at location 95, in the NE. ¼ sec. 3, T. 2 N., R. 38 E.

Rosebud bed.—The Rosebud bed, about 360 feet above the base of the Tongue River member of the Fort Union, is the most valuable coal bed in the Forsyth field and is exploited by the Northwestern Improvement Co. at Colstrip. Although outcrops of the bed are rare, its position where unexposed can be determined very closely by tracing the contact of the heavy and conspicuous slag formed by the burning of the bed with the unburned overburden, it being assumed that burning of the bed has not taken place through more than a few

[18] Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek coal field, Montana: U. S. Geol. Survey Bull. 749, pp. 75, 76, 1923.

hundred feet beyond the point where the clinker abuts against unbaked rock.

North of the divide between Rosebud Creek and the East Fork of Armells Creek, the Rosebud bed maintains an average thickness of about 20 feet, as estimated from measurements of part of the bed and thicknesses reported from drill holes. The maximum observed thickness for this part of the field was 23 feet at location 102, in the SW.¼ sec. 35, T. 2 N., R. 39 E. (See pl. 10.) The best exposures of the Rosebud bed occur in small tributaries of Miller Coulee in the southeastern part of T. 1 N., R. 41 E. (pls. 5, *B*; 6, *B*), where it crops out in cut banks at locations 221 and 222 and has clean exposures of about 28 feet of coal. (See pl. 10.) The lack of exposures along Rosebud Creek prevented the detailed mapping of the Rosebud bed in that area though a number of measurements of part of the bed were made. Observations in Lee Coulee, in Tps. 1 N. and 1 S., R. 41 E., suggest that the Rosebud bed in the general area of Rosebud Creek is replaced by sandstone and sandy shale in many places, and this condition would account for the small number of exposures of the bed.

Lee bed.—The Lee bed, which lies about 115 feet above the Rosebud bed, is not present in that part of the field north of the area drained by Rosebud Creek. Along Rosebud Creek it ranges from a thin trace up to 11 feet in thickness.

Popham bed.—The Popham bed, though it does not average more than 3 feet in thickness, is very persistent. It lies 50 feet below the Sawyer bed, or about 290 feet above the Rosebud bed. It was mapped in detail only in T. 1 N., R. 40 E.

Sawyer bed.—The Sawyer bed, 336 feet above the Rosebud bed, has been burned out over a large area, and its slag now makes a resistant cap rock on the divides along the main drainage lines. It is unburned in the rough and inaccessible country along the foothills of Wolf Mountain and ranges from a thin trace to 20 feet in thickness. It is replaced by carbonaceous shale northwest of T. 1 N., R. 40 E.

Proctor bed.—The Proctor bed lies 90 feet above the Sawyer bed and was mapped only in the rough country at the base of Wolf Mountain in T. 1 N., R. 39 E., at locations 164 to 168, where its average thickness is slightly more than 3 feet. (See pl. 10.)

Richard bed.—The Richard bed crops out at the base of Wolf Mountain and was mapped for about 3 miles in the southeastern part of T. 1 N., R. 39 E. It contains an average of 3½ feet of coal but is of no economic value because of its general inaccessibility.

PHYSICAL AND CHEMICAL CHARACTER

The coal in the Forsyth field is of subbituminous rank, has a conchoidal fracture, and is shiny black on a freshly exposed surface. This coal, like that of the Sheridan field, slacks after a short exposure to weather. Owing to loss of moisture it becomes dull black, and a network of cracks, some of which are at right angles to each other, develops in it, so that the small pieces which fall off as the coal crumbles are roughly cubical.

Of the several samples taken in the field, the analyses of which are given below, that from the unweathered Rosebud bed at the Colstrip mine of the Northwestern Improvement Co. (No. 19659) most nearly represents the true character of the coals. The sample of the Wright bed (No. 96584), the lowest coal in the field, was taken 50 feet from the entry of the Wright mine, in sec. 7, T. 5 N., R. 40 E. This mine has been abandoned for a year or more, and the sample consequently consisted of weathered coal. The sample of the Sawyer bed (No. 96587) was taken from an open pit at location 206A in a coulee, where a face of coal about 75 feet long had been cut back by settlers a maximum distance of 25 feet. Care was taken to obtain as fresh coal as possible under these conditions, but it was slightly weathered. The sample of the Lee bed at the McKay mine (No. 96583) was cut from a face of coal 150 feet from the entry of a drift mine less than a week after the mine had been active for a short time. The thickness of the Lee bed at this mine is nearly 11 feet, but only the upper 6 feet is mined, and only that part was sampled. It should be remembered, therefore, in comparing the value of the coal in the Forsyth field with that of coals from other fields where fresh samples have been cut by standard methods in underground mines, that the analysis of the Rosebud bed is the only one truly representative of the Forsyth coals given in this report, the heating values of the other samples as shown in the table of analyses on page 30 and in Figure 1 being probably somewhat too low.

In the following table analyses of representative samples from Williston, N. Dak.; Glendive, Miles City, Red Lodge, Bear Creek, Bull Mountain (Roundup), and Sand Coulee, Mont.; Sheridan, Wyo.; Hocking Valley, Ohio; and Pittsburgh, Pa., are also given in order to afford a basis of comparison between the Forsyth coal and other coals with which it will have to compete in the market. These analyses are given in four forms: Form A represents the composition of the sample as it is received in the laboratory. The amount of moisture contained in a sample "as received" is proportional to the amount of moisture and water in the mine at the time the sample was taken, therefore the amount of moisture in

several analyses of samples from the same bed may differ widely. Form B represents the composition of the sample after it has been air-dried under uniform conditions until its weight becomes constant. This form of analysis is best adapted for general comparisons. Form C shows the theoretical composition of the coal after all the moisture has been eliminated. Form D represents the composition of the coal as it would be if all the ash and moisture were removed. Forms C and D represent conditions that do not actually exist in nature.

Analyses of samples of coal from the Forsyth field and of average samples from other fields

Laboratory No.	Source	Air-drying loss	Form of analysis	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Heating value	
									Calories	British thermal units
96584	Forsyth, Mont., Wright bed, Wright mine, SE. ¼ sec. 7, T. 5 N., R. 40 E.	6.5	A	23.7	28.6	35.7	12.0	0.6	4,489	8,080
			B	18.4	30.6	38.2	12.8	.7	4,800	8,640
			C	------	37.5	46.8	15.7	.8	5,883	10,590
			D	------	44.5	55.5	------	1.0	6,978	12,560
19659	Forsyth, Mont., Rosebud bed, Colstrip mine, sec. 34, T. 2 N., R. 41 E., composite of 4 analyses.	6.6	A	24.1	28.4	40.2	7.3	.7	5,050	9,090
			B	18.7	30.4	43.1	7.8	.8	5,406	9,730
			C	------	37.4	53.0	9.6	1.0	6,644	11,960
			D	------	41.4	58.6	------	1.1	7,350	13,230
96587	Forsyth, Mont., open pit on Sawyer bed, NW. ¼ sec. 30, T. 1 N., R. 40 E.	8.1	A	26.6	28.9	37.7	6.8	1.8	4,489	8,080
			B	20.1	31.5	41.0	7.4	2.0	4,889	8,800
			C	------	39.4	51.4	9.2	2.5	6,117	11,010
			D	------	43.4	56.6	------	2.7	6,739	12,130
96583	Forsyth, Mont., Lee bed, McKay mine, SW. ¼ sec. 34, T. 1 S., R. 41 E.	8.4	A	23.9	28.7	40.3	7.1	.6	5,089	9,160
			B	16.9	31.3	44.0	7.8	.6	5,550	9,950
			C	------	37.7	52.9	9.4	.8	6,683	12,030
			D	------	41.6	58.4	------	.8	7,372	12,270
	Williston, N. Dak., average of 7 mine samples. Bull. 531, pp. 100–101.	30.9	A	41.5	26.9	26.2	5.3	.63	3,512	6,320
			B	14.8	39.1	38.3	7.8	.93	5,124	9,222
			C	------	46.0	44.8	9.1	1.08	6,011	10,820
			D	------	50.7	49.3	------	1.20	6,612	11,902
	Glendive, Mont., field. Snider mine. Average of 5 samples. Bull. 471, p. 274.	13.9	A	32.9	26.6	32.9	7.49	1.04	4,056	7,300
			B	21.7	31.0	38.5	8.82	1.22	4,764	8,577
			C	------	39.7	49.1	11.21	1.55	6,038	10,870
			D	------	44.7	55.3	------	1.75	6,776	12,197
	Miles City, Mont. Average of 5 samples from Kircher bed.	17.9	A	30.1	27.5	33.4	9.05	.68	4,195	7,551
			B	14.7	33.6	40.6	11.03	.83	5,047	9,086
			C	------	39.3	47.7	12.95	.98	5,994	10,789
			D	------	45.1	54.8	------	1.12	6,917	12,452
	Sheridan, Wyo. Average of 20 mine samples.	10.4	A	23.3	32.2	41.1	3.46	.35	5,194	9,350
			B	14.3	35.9	45.9	3.86	.39	5,801	10,442
			C	------	41.9	53.6	4.51	.45	6,771	12,188
			D	------	43.9	56.1	------	.48	7,091	12,756
29466	Red Lodge, Mont.	6.3	A	11.3	33.6	44.5	10.6	.72	5,795	10,440
			B	5.3	35.9	47.5	11.3	.77	6,185	11,140
			C	------	37.9	50.2	11.9	.81	6,535	11,760
			D	------	43.0	57.0	------	.92	7,420	13,360
15130	Bear Creek, Mont.	3.0	A	10.0	33.9	44.8	11.3	2.26	5,885	10,590
			B	7.2	35.0	46.2	11.6	2.33	6,065	11,920
			C	------	37.7	49.8	12.5	2.51	6,535	11,760
			D	------	43.1	56.9	------	2.87	7,475	13,450
	Bull Mountain, Mont. Average of 9 mine samples. Bull. 647, pp. 51–53.	6.5	A	15.0	29.9	48.8	6.29	.58	5,974	10,754
			B	8.8	32.1	52.4	6.72	.63	6,409	11,539
			C	------	35.2	57.4	7.41	.69	7,026	12,651
			D	------	38.0	61.9	------	.75	7,624	13,662

Analyses of samples of coal from the Forsyth field and of average samples from other fields—Continued

Laboratory No.	Source	Air-drying loss	Form of analysis	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Heating value	
									Calories	British thermal units
4115	Sand Coulee, Mont.	2.4	A	6.0	28.4	51.4	14.2	2.38	6,195	11,150
			B	3.7	29.1	52.7	14.5	2.44	6,350	11,430
			C	------	30.3	54.7	15.0	2.53	6,590	11,870
			D	------	35.6	64.4	------	2.98	7,760	13,970
7712	Coal No. 6, Hocking Valley, Ohio.	5.5	A	9.4	32.4	53.4	4.43	.54	6,805	12,250
			B	4.5	34.3	56.5	4.69	.57	7,200	12,960
			C	------	35.9	59.2	4.91	.60	7,535	13,570
			D	------	37.8	62.2	------	.63	7,925	14,270
23097	Pittsburgh coal, Fayette County, Pa.	1.2	A	2.5	35.7	53.6	8.17	1.76	7,585	13,650
			B	1.3	36.1	54.3	8.27	1.78	7,675	13,820
			C	------	36.6	55.0	8.38	1.81	7,780	14,000
			D	------	40.0	60.0	------	1.98	8,490	15,290

The Lance coal (No. 96584) in the Forsyth field shows a high ash content. Its sulphur content, however, is no higher than that of the three Fort Union coals in the same area (Nos. 19659, 96583, and 96587). Its heating value is equal to that of the Sawyer bed (No. 96587), which showed a similar amount of weathering when sampled. The coal from the Rosebud bed (No. 19659) is the most representative of the several samples. A comparison of this sample with the average of 20 fresh samples from the Sheridan field shows that the Forsyth coal is slightly inferior in quality to the Sheridan coal. From the analyses given above Figure 1 has been prepared in order to give a rough means of comparison of the coals. This figure shows clearly that the coals of the Fort Union formation in North Dakota, Montana, and Wyoming rise in rank the nearer they approach the areas of mountainous uplift. This is seen on comparing the heating value of the Williston lignite, which lies in nearly flat undisturbed rocks, with that of the coal from the Sheridan field, which is nearer the Big Horn Mountains.

In Figure 1 the line marked "coal as mined" represents the heating value of the coal as it is received from the mine—that is, its heating value in approximately the condition in which it will be put on the market and consumed. The line marked "pure coal" shows the heating value of the coals after their ash and moisture have been theoretically eliminated. The line marked "coal as mined" shows the relative value of the coals to the consumer, and the coals rank in the order in which they stand in Figure 1, Williston lignite being the lowest grade of coal given and Pittsburgh bituminous the highest. Figure 1 shows that the unweathered samples of Forsyth coal are only slightly lower in rank than the

fresh samples from the Sheridan field and that both are somewhat lower than the Red Lodge, Bear Creek, and Bull Mountain coals. From a study of these comparative values it can be concluded, therefore, that the coals with which the Forsyth field will have to compete are those from Sheridan and vicinity, Red Lodge, Bear Creek, the Bull Mountains, and Sand Coulee.

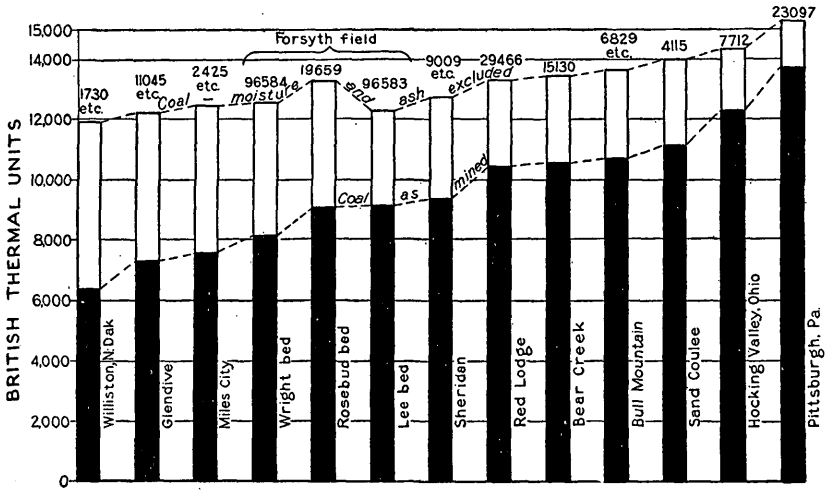


FIGURE 1.—Heating value of coals from Forsyth, Mont., and some other coals

COAL CLINKER

Where the rocks of the Tongue River member of the Fort Union formation crop out in the Forsyth field the clinker or "scoria" formed by the fusing and baking of clay, shale, and sandstone by a burning coal bed is very conspicuous. Because it offers greater resistance to erosion than the associated rocks the clinker usually occurs as a cap rock on buttes, ridges, and divides. The coal beds in the Tullock and Lebo members of the Lance and Fort Union formations, respectively, are burned in few places, and those that have been burned are only a few inches thick.

The burning of coal beds on the outcrop is probably due to spontaneous combustion or occasionally to fires set by man. Where a thick coal bed has burned slowly for a considerable period the slag thus formed may be 100 feet or more in thickness. The slag of the Sawyer bed, which is well exposed on the divide between the East Fork of Armells Creek and Rosebud Creek in the central part of T. 1 N., R. 41 E., and elsewhere in the southern part of the field, and that of the Rosebud bed in the Armells Creek area average about

50 feet in thickness. The Burley and Lee beds are clinkered extensively along their outcrops, and so are several thinner beds in the upper part of the Tongue River member of the Fort Union.

The amount of rock fused or baked by the burning of the coal depends upon the thickness of the coal bed and upon the proportion of lime in the rock. Where the cover is thick burning probably does not extend back more than 75 feet from the outcrop. If the coal bed lies flat and the cover is fairly thin the bed may burn over several square miles. Where two thick coal beds are separated by a small interval and both have burned to some extent the great quantity of clinker either in place or slumped down makes it impossible in some places to determine the amount of coal left unburned in the two beds, particularly in the lower bed. This is well illustrated in the Armells Creek area, where the McKay bed, which lies from 7 to 21 feet below the Rosebud bed and averages 7 feet in thickness, can not be mapped accurately because it is usually concealed by débris from the overlying Rosebud clinker.

The rapidity of the burning is determined by the supply of air. When heated to a kindling temperature the coal smolders until slumping takes place and crevices are formed along which air is admitted as through natural chimneys. The heat close to these vents becomes intense, and the overlying rocks are fused into a vesicular slag. Back from the outcrop and away from natural vents the burning becomes slower until a point is reached where no free oxygen is present and burning ceases.

The character of the clinker depends partly on the amount of heat to which the rock has been subjected, and partly on the amount of lime in the heated rock. Near the sources of air supply, or where the absence of lime renders the rocks readily fusible, their original texture has been destroyed and they are converted into a bright reddish-green or purple vesicular slag with flow structure. In the upper part of the slag the rocks have been merely baked to a brick-red color and retain their original texture. It is common to find perfectly preserved fossil plant impressions in the upper part of thick clinkers. Further details of the physical and chemical changes accompanying the formation of clinker are given in a paper by Rogers.[19]

DEVELOPMENT

At the time when the Forsyth field was examined development of the coals was restricted to its northern part, where several

[19] Rogers, G. S., Baked shale and slag formed by the burning of coal beds: U. S. Geol. Survey Prof. Paper 108, pp. 1–10, 1918.

small mines within 5 or 6 miles of Forsyth exploit the Wright bed to supply the local market. Several openings, referred to as the Lore mines, have been driven in on the Wright bed in secs. 1 and 2, T. 5 N., R. 41 E. The largest of these openings is about 200 feet long and comprises several rooms. The Wright mine, in sec. 7, T. 5 N., R. 40 E., was opened to supply Forsyth in times of coal shortage but is now abandoned. The Woodward and Griggs mines, on Smith Creek in sections 22 and 23, respectively, of the same township, are small entries from which coal is mined only part of the year. An attempt was made to mine the Hamre bed near the W. ½ sec. 29, T. 5 N., R. 40 E., but after an entry had been driven about 100 feet it was abandoned because of the poor quality of the coal.

The thick coal beds in the Tongue River member of the Fort Union formation have been used for years as a source of fuel by settlers. The usual procedure is for several settlers working together to obtain their winter's supply of coal by blasting it off from the face of one of the several well-known outcrops in the field. Practically all the prominent exposures of coal are in this way sources of domestic fuel, and for this reason they are discussed in detail only in the individual township descriptions. Several small timbered entries have been driven on the Lee bed on Rosebud Creek.

The completion of the Armells Creek branch of the Northern Pacific Railway has made accessible an enormous tonnage of subbituminous coal contained in the Rosebud and other coal beds. The coals are thick, persistent, and comparatively free from partings. Furthermore, a great quantity of this coal can be recovered by strip mining, and until this supply is exhausted there will probably be no attempts to mine the coal from underground diggings.

The Northwestern Improvement Co. is strip mining the Rosebud coal bed on a large scale at Colstrip, where the bed averages about 28 feet in thickness. The coal is mined in a completely electrified open pit, the power being supplied by the Montana Power Co., which extended its 55,000-volt 3-phase 60-cycle power line from Billings to Colstrip, a distance of 100 miles.

The pit was opened by a Marion model 360 electric stripper, with a 155-foot drag-line boom with 6-yard bucket and a 90-foot shovel boom with 6-yard bucket. The coal-loading shovel is a Bucyrus model 175–B, with a 75-foot boom and 7-yard bucket. Other electrical equipment in the pit consists of one gasoline drag-line 2½-yard bucket, with a 60-foot boom; one 20-ton locomotive crane, two 60-ton electric storage-battery locomotives, one electric well drill, and two portable-type air compressors. The coal is first blasted and then loaded directly into standard 50-ton steel coal cars,

which run on a track laid on top of the coal. The shovel loads a 50-ton car in about 6 minutes, or a 10-car train in approximately 1 hour. At the present time about 3,300 tons of coal are mined daily. The coal is used by the Northern Pacific Railway between Jamestown, N. Dak., and Missoula, Mont.

Excellent conditions for stripping the Rosebud bed exist on the low divide between the headwaters of the West Fork of Armells Creek and Stocker Creek, near Castle Rock, in Tps. 1 and 2 N., R. 40 E. A spur track about 9 miles long up the valley of Stocker Creek would make this area accessible. Further details of the mining conditions in the field are included in the several township descriptions.

Timber necessary for mining is abundant, especially in those areas where the Tongue River member of the Fort Union formation crops out. It is not believed that a water supply from artesian flows will be obtained where coal mining on a large scale is likely to be undertaken. Wells drilled to a depth of 600 to 1,400 feet below the Rosebud coal will undoubtedly encounter beds containing water, which will rise part way to the surface but will not flow. The water in the well 1,520 feet deep at Colstrip stands about 400 feet below the top of the casing. Flood waters impounded in reservoirs may be more satisfactory for use in boilers than well water, which may cause foaming.

Profitable strip mining of the Rosebud coal bed will depend upon the thickness and nature of the cover overlying the bed. For the Rosebud bed at Colstrip 100 feet has been arbitrarily considered to be the maximum thickness of overburden that can be economically removed by steam shovels under ordinary conditions. As shown by the sections on pages 18 and 19, the greater part of the 100-foot interval above the Rosebud bed in this field in places consists of hard massive sandstone, which must be blasted before it can be removed by shovels. At Colstrip and in the Castle Rock area this sandstone has been largely eroded or is loosely consolidated and should present no serious obstacle to stripping, except possibly in and near low divides where its basal portion may be more indurated.

Springs issue from the bases of most of the coal beds in the field, owing to the presence of an impervious shale bed beneath the coal. For this reason it is suggested that drift mines and other openings on coal beds be so located that the entries will follow the rise of the beds and supply a natural drainage of the mine.

Estimated quantity of coal present and recoverable in the Forsyth coal field, by townships, in net tons

Township	Estimated reserves [1]		Known reserves estimated to be recoverable by present methods.	
	Known	Possible additional	By strip mining	By underground mining
T. 4 N., R. 38 E.	----------	6,000,000	----------	4,000,000
T. 3 N., R. 38 E.	49,256,000	89,240,000	----------	35,000,000
T. 2 N., R. 38 E.	438,240,000	193,536,000	8,640,000	308,000,000
T. 1 N., R. 38 E.	466,560,000	200,000,000	----------	329,000,000
T. 3 N., R. 39 E.	24,000,000	62,208,000	----------	17,500,000
T. 2 N., R. 39 E.	341,800,000	164,512,000	11,520,000	245,500,000
T. 1 N., R. 39 E.	953,856,000	622,080,000	2,600,000	665,000,000
T. 5 N., R. 40 E.	13,824,000	46,080,000	----------	9,800,000
T. 4 N., R. 40 E.	16,128,000	39,168,000	----------	11,200,000
T. 3 N., R. 40 E.	89,000,000	83,000,000	----------	63,000,000
T. 2 N., R. 40 E.	200,064,000	124,416,000	13,000,000	140,000,000
T. 1 N., R. 40 E.	760,320,000	621,080,000	39,000,000	532,000,000
T. 1 S., R. 40 E.	228,152,000	829,440,000	----------	161,000,000
T. 2 S., R. 40 E.	52,208,000	172,800,000	----------	42,000,000
T. 3 N., R. 41 E.	55,296,000	27,648,000	----------	38,000,000
T. 2 N., R. 41 E.	342,520,000	138,240,000	78,000,000	240,000,000
T. 1 N., R. 41 E.	975,000,000	400,000,000	107,000,000	682,500,000
T. 1 S., R. 41 E.	253,440,000	300,000,000	----------	175,000,000
T. 2 S., R. 41 E.	180,000,000	120,000,000	----------	126,000,000
	5,439,664,000	4,239,448,000	259,760,000	3,824,500,000

[1] Beds less than 3 feet thick not included in the estimate.

TOWNSHIP DESCRIPTIONS

In the following pages are presented detailed data upon the stratigraphy and structure of the rocks in the several townships, with especial emphasis laid upon the position, character, and thickness of the coal beds. General conclusions drawn from these data have been given in preceding pages. All coal beds mapped are represented on Plate 7, and the location of points where detailed sections were measured along outcrop lines are indicated by numbers. Corresponding numbers are used in Plate 10, in which the coal sections are represented graphically.

On the map the outcrop lines of the coal beds where exposed, inferred, or represented by slag are indicated by distinctive patterns, and so are those areas where the Rosebud coal bed can be worked by strip mining. The townships are described in tiers from west to east, beginning with the northern township in each tier.

T. 6 N., R. 38 E.—The alluvial plain of the Yellowstone River in T. 6 N., R. 38 E., is bordered on the south by a bluff of the sandstone member of the Judith River formation and terrace gravel. (See pl. 2, *A*, and pp. 8–9.) The remainder of the township is occupied by Bearpaw shale overlain by terrace gravel and presents a rolling, monotonous type of topography, unbroken except where crossed by the larger streams. The outcrop of the sandstone member of the Judith River represents the highest structural point in the Forsyth field and the dip of the member is about 3° SE. This township contains no coal.

T. 5 N., R. 38 E.—The southern part of T. 5 N., R. 38 E., where the Hell Creek member of the Lance formation crops out, has been extensively dissected

by Reservation Creek and its tributaries, making it rough and almost impassable. The northern part of the township has the Bearpaw shale as the highest formation, and this shale and the terrace gravel produce a rolling, grass-covered country devoid of prominent topographic features. The strata in the township are on the southern limb of the Porcupine uplift and, as near as could be determined, dip about 2° S. No coal of any value occurs in this township.

T. 4 N., R. 38 E.—The southern part of T. 4 N., R. 38 E., is moderately rough and is unsettled. Its central part is occupied by the divide between East Bear and Blacktail Creeks, which is covered with a mantle of terrace gravel. The land in the northern part of the township is very rough and inaccessible. A fair road follows the valley of East Beaver Creek and forks in section 26, one branch crossing the divide in section 25 into the basin of Reservation Creek, and the other branch taking a southerly direction to the crest of the gravel-capped terrace in sec. 1, T. 3 N., R. 38 E.

The Hell Creek and Tullock members of the Lance formation and the Lebo shale and Tongue River members of the Fort Union formation crop out in this township as shown on Plate 7. The Hell Creek member consists here of light-colored sandstone and sandy shale similar to the beds of the overlying Tullock member, which is exposed in an escarpment striking nearly east in the northern part of the township. The Lebo shale weathers into low, rounded hills capped with terrace gravel, becoming approximately level as the crests of the divides are approached. The Tongue River member crops out as a conspicuous gravel-covered escarpment in the southeastern part of the township. In the SE. ¼ sec. 36, there is a small remnant of the Oligocene or Miocene (?) gravel terrace standing at an altitude of about 3,650 feet. Reworked gravel from this horizon is spread over practically the entire township.

The structure in the township is exceedingly simple. The rocks are slightly affected by the southwest end of the Porcupine uplift and dip uniformly southward at an angle of not more than 1°.

No exposures of coal were observed in the Tullock member in the township, and if any are concealed in the gravel slopes they are in all probability too thin to be of any value. Only one exposure of the Big Dirty bed was seen, at location 26 in section 28, where the overlying gravel had been removed and 4 feet 8 inches of dirty coal was found. Although the Big Dirty bed was not mapped in detail its position is shown with a fair degree of accuracy on Plate 7 by the line of contact between the Tullock and Lebo members. The only coal bed that should occur in the Tongue River member in this township is the Burley bed, and its outcrop should be restricted to the extreme southeastern part of the township. No outcrop of this bed or any other Tongue River coal was observed in this area, however.

T. 3 N., R. 38 E.—The divide between the drainage basins of Sarpy Creek and Armells Creek, in the southeastern part of T. 3 N., R. 38 E., is so heavily forested and so rugged that it is accessible only by saddle horse. In the northern part of the township a fair road crosses the divide and follows a northwesterly direction along the valley of East Beaver Creek. The township is everywhere maturely dissected. The streams are all intermittent and flow in narrow canyons, the walls of which are usually of massive sandstone. The main divide rises about 400 feet above the lowest parts of the township in sections 23 and 24 and is composed of massive light-colored sandstone, capped in sections 14 and 23 by remnants of the Oligocene or Miocene (?) river gravel bench.

The upper part of the Lebo shale member of the Fort Union formation and the lower 400 feet of the Tongue River member crop out in T. 3 N., R. 38 E.

Rock exposures are generally poor owing to the presence of timber. A detailed section of the coal-bearing rocks in the township is given on page 20.

The Burley bed was measured at location 44, where it contained 2 feet 8 inches of coal. (See pl. 10.) At location 41 it is 4 feet thick and crops out in the bottom of the North Fork of Trail Creek near the Robinson ranch. At the Thompson prospect, in the SW. ¼ sec. 1, a bed assumed to be the Burley contained 3 feet 10 inches of coal. An abandoned prospect on this same bed at location 43 was reported to have shown a thickness of 3 feet of coal. In the central and northern parts of the township the mantle of gravel caused by the disintegration of an Oligocene or Miocene (?) gravel deposit has concealed the Burley as well as the coal beds above it.

The Robinson bed is well exposed in a cut bank along a narrow ravine at location 35 (pl. 10), where it contains 7 feet of coal. It is somewhat clinkered in the general vicinity of this location. It crops out again under similar conditions at location 36, where it contains 6 feet 5 inches of coal with a 3-inch clay parting. No exposures of it were observed farther north on the west side of the main divide and its crop line as shown on Plate 7 is inferred. Only one outcrop of the Robinson bed was observed on the east side of the divide, at location 37, where is was 7 feet 1 inch thick.

The Stocker Creek bed was measured on the side of a hill at location 40 (pl. 10), where it consists of an upper and a lower bench of coal 1 foot and 1 foot 7 inches thick, respectively, separated by 3 feet of carbonaceous shale. At location 42 it crops out in the bottom of a narrow coulee and is 2 feet 10 inches thick.

The Rosebud bed is nowhere well exposed in this township. Positive evidence as to its position is supplied by a partial section showing 4 feet 11 inches of coal, measured at location 38 (pl. 10), and the crop line of the basal part of the massive sandstone which lies above it. This sandstone as a rule is exceptionally well developed in this area. The McKay bed lies from 27 to 30 feet below the Rosebud in this township, and their crop lines nearly coincide. The clinkered outcrop of the Rosebud bed is very conspicuous just beneath the summit of the high divide in sections 23 and 24. The McKay bed is slightly more than 29 feet below the Rosebud bed at location 38 and contains 2 feet 3 inches of coal. At location 39 the McKay bed is 2 feet 7 inches thick and crops out about 30 feet below a coal blossom which undoubtedly represents the basal portion of the Rosebud bed. The McKay bed is 2 feet thick at location 94, but no outcrop of the Rosebud bed was observed in the heavy timber at this place.

T. 2 N., R. 38 E.—In T. 2 N., R. 38 E., the northward extension of Wolf Mountain makes the divide between Sarpy Creek and the West Fork of Armells Creek. The southeastern part of the township is rough, heavily timbered, and unsettled. In the central and northern parts the main north-south divide rises abruptly several hundred feet above the surrounding country and, though very narrow, proves a great obstacle to travel. A single road crosses the divide through a pass in section 14 and affords communication between the valleys of Sarpy and Armells Creeks.

The rocks which crop out in T. 2 N., R. 38 E., belong to the Tongue River member of the Fort Union formation and consist of light-colored sandstone, sandy shale, and coal, included in the 1,250 feet of rocks lying above the base of the Burley coal bed. The Sawyer bed is represented by carbonaceous shale in this township, but practically all other beds in the Tongue River member of the Fort Union are present, though none higher than the Rosebud were mapped.

The Stocker Creek bed crops out in the valley of Horse Creek along the western border of the township and in the northern part of section 1. In a cut bank at location 97 (pl. 10) it contains 9 feet of clean coal. At location 96 its upper 7 feet crops out in a bench rising above a grass-covered knoll. No other outcrops of the bed were observed in the township, and its inferred position as shown on Plate 7 was determined by mapping the basal part of a massive sandstone which lies just above it. At location 99 a somewhat lower bed exposed in the bottom of a small tributary of Horse Creek showed two 1-foot benches of coal separated by 2 inches of clay.

The Rosebud bed crops out on both sides of the Sarpy Creek-Armells Creek divide and in places is heavily clinkered. No measurements of its thickness could be obtained in sections 21 and 28, though its position was easily determined by tracing clinker mounds in the grass-covered slopes. In that part of the township west of the old Crow Reservation fence it is clinkered over a large area. At location 92 (pl. 10) the Rosebud bed is 8 feet thick, showing a pronounced thinning from east to west in this particular township. In a coulee at location 91 the upper 4 feet of the Rosebud crops out, and the bed is fully exposed at location 90, where it contains 12½ feet of coal in its lower part, above which is a clay parting 8 inches thick and then 8 inches of coal. A few hundred feet downstream and 30 feet lower the McKay bed crops out at location 95 (pl. 10) and is 3 feet thick. At location 93 the McKay bed is 3 feet 5 inches thick, but the Rosebud bed where it would crop out is in the heavy timber and is not exposed. The outcrop of the Rosebud bed enters the eastern part of the township near the northwest corner of section 24, and the bed is exposed in cut banks along several small streams which have their sources at the base of the eastward-facing bluffs. In the North Fork of Donley Creek at location 86 (pl. 10) it contains 14 feet of coal in its lower part, overlain by about 4 feet of coal and bone, most of which, however, is coal. A similar measurement of the bed was made less than a quarter of a mile farther north, at location 87. The base of the coal was not exposed at either of these locations. At location 88 its upper part as exposed contains 9½ feet of coal split by a 4-inch carbonaceous shale parting. At location 89 it crops out in a cut bank, where it has been the source of fuel for settlers for many years. When the examination was made the basal part of the bed was concealed by débris. The total thickness of the bed at this location is about 25 feet, and the upper 13 feet of the bed is badly split by clay partings. (See pl. 10.)

As a rule the Rosebud bed in this township appears only in coulee bottoms and is overlain with too much overburden to be stripped advantageously. In the central and southwestern parts of section 13, however, there are several amphitheater-shaped depressions between long, narrow divides where the coal could be taken out by stripping, but it is not believed that there is a sufficient quantity available to make such an undertaking profitable at present.

Nearly all the valuable coal beds of the Tongue River member of the Fort Union formation are found in this township. It is estimated that the total tonnage of the Rosebud bed alone under the fractional part of the township here described is 300,000,000 tons.

T. 1 N., R. 38 E.—In T. 1 N., R. 38 E., the East Fork of Sarpy Creek, which is a perennial stream, contains only a little water during the summer. The land along the creek is rolling and is excellently adapted to farming. Almost all of the township is on the west side of Wolf Mountain; hence it receives a heavier rainfall than those areas east of the mountain. As a consequence of this abundant water supply the diversity of crops is far greater here than in any other part of the Forsyth field. On the northeast side of the East Fork

of Sarpy Creek the land rises rapidly toward Wolf Mountain (pl. 4, *A*), which stands approximately 1,200 feet above the creek. The western slopes of Wolf Mountain are rough, unsettled, and accessible only by saddle horse.

The rocks exposed in T. 1 N., R. 38 E., are included in the 1,050 feet of rocks lying above the Stocker Creek coal bed.

The rocks are well exposed in the deep and narrow ravines which lead up to the top of Wolf Mountain, but on the divides they are usually concealed by grass or timber. The rocks have an inclination to the east and southeast of less than 1° and consist of alternating sandstone and sandy shale of a light-yellow color, intercalated with which are coal beds of differing thickness and persistency.

The Stocker Creek bed crops out just above creek level at location 154 (pl. 10), where it is 4 feet thick. No other exposure of this bed occurs in the township.

The Rosebud bed is extensively clinkered in the valley of the East Fork of Sarpy Creek, so the unburned coal in it is rarely exposed. A measurement of part of the Rosebud bed was obtained at location 151 (pl. 10), where its upper 5 feet crops out in a grassy hillside. A similar exposure occurs at location 152, where the upper 6 feet of the bed crops out in a natural cut beside an old wagon trail. In a ravine at location 153 the total thickness of the Rosebud bed, which is here 14 feet, is exposed. In the same ravine a few hundred feet west of the west line of section 4 the bed has been stripped by settlers.

A detailed section measured from the top of the Rosebud bed upward 1,000 feet failed to reveal any coal beds thicker than 3 feet. It is reported that a well drilled for the Tennessee Oil & Gas Co. in the SW. ¼ sec. 34 reached the depth of 1,000 feet and was then abandoned. The log of this well is not available, and no information can be given regarding the number, position, and thickness of the coal beds penetrated.

The total tonnage of coal in the Rosebud bed in this township is estimated to be 327,600,000 tons, nearly all of which could be mined by underground methods only. This fact, together with the geographic position of the township in relation to railroad lines either built or likely to be built, makes it highly improbable that the coals in the township will be exploited on a large scale in the near future.

Tps. 1 and 2 S., R. 38 E.—The eastern two tiers of sections of T. 1 S., R. 38 E., and not quite two full sections of T. 2 S., R. 38 E., are included in the Forsyth field. These areas lie on the western slopes of Wolf Mountain and are rough and heavily timbered. The surface strata belong to the Tongue River member of the Fort Union formation and, though not mapped in detail, are known to contain valuable coals.

T. 6 N., R. 39 E.—In T. 6 N., R. 39 E. the outcrop of the Bearpaw shale south of the alluvial plain of the Yellowstone River makes a strip of low, rounded gravel-capped hills that become progressively wider westward. The lower part of the Hell Creek member of the Lance formation crops out in a prominent pine-clad sandstone escarpment which strikes northeast; east of Armells Creek it composes the bluffs rising abruptly above the flood plains.

The distribution of the outcrops is determined by the Porcupine uplift, and the average inclination of the strata is about 3° SE. The township contains no coal.

T. 5 N., R. 39 E.—Armells Creek, in T. 5 N., R. 39 E., is bordered on both sides by very rough country. Travel is restricted to the main county road along Armells Creek; elsewhere the township, except for a trail leading up Cottonwood Creek a few miles, is inaccessible to vehicles.

The Bearpaw shale crops out in parts of sections 5 and 6 and is bordered by a pine-clad escarpment of the lower sandstone of the Hell Creek member of the Lance. This sandstone is massive and usually forms barriers to travel that are almost impassable even on horseback. The most prominent topographic feature is the mesalike hill of sandstone of the Tullock member, which caps the divide between Reservation and Armells Creeks in section 31.

The attitude of the strata is determined by the Porcupine uplift, their inclination being to the southeast and ranging from a maximum of 4° in section 6 to less than 1° in the southeastern part of the township. A detailed hand-level section, measured from the mouth of Cottonwood Creek, in section 36, to the top of the mesalike hill in section 31, gave 401 feet as the thickness of strata of the Hell Creek member of the Lance formation exposed along the line traversed. The lower 165 feet of the Tullock member crops out in section 31 and contains several coals, none of which are more than 18 inches thick in this township.

T. 4 N., R. 39 E.—East of the divide between Armells and Reservation Creeks and in the northwestern part of T. 4 N., R. 39 E., the land is rough, broken, and unsettled, but the area at the head of Reservation Creek has a rolling surface and is easily accessible. The divide between the two creeks is capped by terrace gravel and is fairly level.

The Hell Creek member of the Lance formation crops out in the bluffs along Reservation Creek in the northwestern part of the township and is made up of grayish-yellow sandstone and sandy shale. The Tullock member is well exposed along Reservation Creek and in the maturely dissected areas east of the main divide, where its uppermost sandstone forms a resistant cap rock on the divides between the eastward-flowing streams. The Lebo shale member of the Fort Union formation crops out in a narrow strip having low relief. The Tongue River member of the Fort Union is the surface formation in the southwestern part of the township and is made up of yellow sandstone and sandy shale standing in bluffs above the surrounding Lebo lowlands. The crest of the main divide is formed by a narrow remnant of the Oligocene or Miocene (?) terrace, the reworked gravel from which has concealed the rocks at lower levels.

Several coal beds 1 foot or less in thickness were observed in the Tullock member in the eastern part of the township, but in its western part no coal beds were found. The Big Dirty coal bed, at the base of the Lebo shale, is persistent but is too dirty to be of any value. At location 27 it contained 3 feet 6 inches of carbonaceous shale with thin and irregular layers of coal. The Hamre bed is persistent but is also valueless. A measurement of it at location 28 gave 2 feet 6 inches of carbonaceous sandstone and coal. The bluffs of Tongue River rocks are covered with gravel washed down from the Oligocene or Miocene (?) terrace and exposures are relatively few. As only the lower part of the member is exposed, it can be safely assumed that no coals of economic importance are concealed beneath the gravel. At location 30 a coal bed 1 foot 1 inch in thickness crops out.

T. 3 N., R. 39 E.—The land west of the West Fork of Armells Creek for a maximum distance of 3 miles is broken and rough, owing to the erosion of the nonresistant sandstone and sandy shale of the Tullock and Lebo members of the Lance and Fort Union formations. The central part of the township, where the Tongue River member of the Fort Union crops out, is rolling, treeless country of moderate relief and is well adapted to dry farming. The most prominent topographic feature is the bold escarpment of Tongue River rocks which rises about 300 feet above the surrounding lowlands along the western

edge of the township. The top of this escarpment is composed of the Oligocene or Miocene (?) terrace gravel and stands at an altitude of about 3,675 feet.

The lowest coal bed that crops out in the township is the Big Dirty bed, measurements of which made at locations 45 to 50 (pl. 10) show that it contains about 9 feet of carbonaceous shale and coal. The Robinson bed was measured at locations 52 to 58 (pl. 10) in the rough country at the base of the Tongue River escarpment; it averages 5 feet in thickness.

The only measurement of the Rosebud bed in this township was obtained at location 51 (pl. 10) where it contains 7 feet 2 inches of coal split by a 1-inch parting. Smaller beds were measured at location 59, in the NW. ¼ sec. 19, 160 feet below the Rosebud bed, where two benches of coal 1 foot 7 inches and 5 inches thick are separated by a 2-inch parting of carbonaceous shale, and at location 60 in the SW. ¼ sec. 30, 30 feet above the Robinson bed, where 1 foot 9 inches of coal was found.

An axis of gentle anticlinal folding passes across the northeastern part of the township and local doming on it occurs in section 11. Strong southwest dips were observed in section 23 and gentle southeast dips in the western parts of the township.

T. 2 N., R. 39 E.—The lower part of the Tongue River member of the Fort Union formation crops out in the northern part of T. 2 N., R. 39 E., and forms a rolling plain of moderate relief. In the central part of the township the Rosebud clinker forms a plateau dissected by many streams. The clinker makes a prominent rim rock along the creek valleys, and the slopes below it are covered with débris, which effectively conceals the coal beds. In the southern part of the township, where the Rosebud bed is unburned, the land is of moderate relief near the outcrop of the bed, but at a short distance back it becomes rough and broken.

The Burley bed crops out on the West Fork of Armells Creek at locations 119 and 120 and averages 4 feet in thickness. (See pl. 10.) West of the creek it is either concealed or absent and no measurements of it were obtained.

The Robinson bed is usually concealed where its outcrop line occurs in the bluffs, and measurements of it are obtainable only where streams have cut through it. Measurements made at locations 111 to 114 on the West Fork of Armells Creek show that it contains about 5 feet of coal in its lower part, overlain by about 3 feet of coal split by bone partings. (See pl. 10.) At location 115 a measurement of part of the bed showed more than 4 feet of coal. At location 116, in the bottom of the South Fork of Donley Creek, 3 feet of the bed crops out and its top is eroded. At locations 117 and 118, in the South Fork of Trail Creek, it is more than 3 feet thick.

The Stocker Creek bed, which occurs near the base of a rather prominent sandstone, was measured at locations 105 to 110 (pl. 10); it contains on the average 6 feet of coal overlain by 3 feet of coal and carbonaceous shale.

The Rosebud bed underlies a portion of the southern part of the township and is exposed, either wholly or in part, in narrow ravines. At location 101 (pl. 10) 5 feet of coal crops out in the side of a small mound. In the bottom of a ravine, at location 102, its total thickness of 23 feet is exposed, and at location 103 its upper 15 feet crops out. At location 104 its upper 12 feet is exposed in a cut bank. West of location 104 there are no exposures of the Rosebud bed and the position of its outcrop line as shown on Plate 7 was determined by mapping the contact of baked and unbaked rock.

The Rosebud can be mined by stripping in the E. ½ sec. 33 along the South Fork of Donley Creek. The land adjoining the creek is fairly level over

approximately half a section, and the measurement at location 104 indicates that the coal is more than 12 feet thick.

From the measurements given above it is estimated that there are 125,000,000 tons of Rosebud coal in the township, most of which can be taken out only by underground mining.

T. 1 N., R. 39 E.—Almost all of T. 1 N., R. 39 E., lies in the rough country composing Wolf Mountain, which crosses the southwestern part of the township and makes the divide between Armells and Sarpy Creeks. The summit of the mountain is formed by a thick clinker, which stands about 1,300 feet above the surrounding country. The mountain slopes are heavily timbered and accessible only by saddle horse.

The rocks that crop out in the township belong to the Tongue River member of the Fort Union formation, and as the relief is great, about 1,300 feet of the member is exposed. (See pp. 18–19.)

The Rosebud bed crops out at locations 155 and 156 and is more than 15 feet thick. (See pl. 10.)

The Popham bed averages 4 feet in thickness and was measured at locations 157 to 163. (See pl. 10.)

The Proctor bed also averages about 4 feet in thickness and is represented on Plate 10 by locations 164 to 168.

The Richard bed crops out along the east line of the township, and measurements made at locations 169 to 173 (pl. 10) show that its average thickness is about 3½ feet.

Two unnamed coal beds are clinkered along their outcrops on both sides of Wolf Mountain, and no measurements of their thicknesses were obtainable. The position of their outcrop lines as shown on Plate 7 is only approximate.

Tps. 1 and 2 S., R. 39 E.—Tps. 1 and 2 S., R. 39 E., are crossed by Wolf Mountain and are rough, heavily timbered, and unsettled. The rocks which crop out in these areas are included in the interval between the Sawyer coal bed and the clinker making the summit of the mountain. The absence of thick coal beds and the general inaccessibility of this area make it unlikely that the coal in these townships will be exploited in the near future. A reconnaissance examination of the area was made and the following section was measured.

Section of the Tongue River member of the Fort Union formation in sec. 15, T. 1 S., R. 39 E.

	Ft.	in.
Sandstone, yellowish white, with brown concretionary lenses	53	
Shale, carbonaceous, slightly clinkered	4	
Sandstone, yellowish white	63	
Sandstone, brown; makes a ledge	20	
Sandstone, yellowish white, very soft and shaly	110	
Shale, grayish white	26	8
Shale, carbonaceous	2	
Sandstone, yellowish white, concretionary	30	
Coal		6
Carbonaceous shale	1	2
Coal	1	6
Carbonaceous shale	5	
Sandstone, whitish, concretionary	53	4
Shale, dark gray	26	8
Coal	1	8

	Ft.	in.
Shale, gray	15	
Sandstone, whitish; makes a ledge	42	
Shale, gray	5	
Coal	5	8
Shale, gray	5	
Sandstone, gray, soft	23	
Coal	3	
Carbonaceous shale		1
Coal; Richard (?) bed	3	
Carbonaceous shale		7
Coal	5	
	505	10

T. 6 N., R. 40 E.—That part of T. 6 N., R. 40 E., which lies within the Forsyth field is rough and broken. West of Smith Creek the Yellowstone is undercutting its south bank, but east of the creek it swings northward, making a flood plain about a mile wide on which Forsyth is situated. The bluffs south of Forsyth rise abruptly several hundred feet above the flood plain and are capped with river gravel.

The rocks which crop out in this township belong to the Hell Creek member of the Lance formation and consist of alternating light and dark colored sandstone and sandy shale showing marked lateral variation and dipping slightly eastward. The nature of the Hell Creek member is indicated by the general section on pages 11–12. No coal occurs in this township.

T. 5 N., R. 40 E.—In T. 5 N., R. 40 E., the divide between Armells and Smith Creeks breaks off suddenly on the west, making a conspicuous escarpment which stands about 600 feet above the level of Armells Creek. (See pl. 2, *B*.) The crest of the divide is covered with terrace gravel and slopes gently toward the Yellowstone River. The drainage basin of Smith Creek consists of very rough land, and travel within it is restricted to the main valley and the divides. The southeastern part of the township consists of badlands and is inaccessible to vehicles.

The Hell Creek member of the Lance formation crops out at the base of the bluffs along the western edge of the township and is overlain by the escarpment-forming Tullock member. (See pl. 2, *B*.) Similar conditions exist on Smith Creek, although the area occupied by the Hell Creek member is larger. Representative sections of the Tullock member measured in this township are given on pages 13 and 14.

The Lebo shale member of the Fort Union formation crops out in the southern and eastern parts of the township and is eroded into almost impassable badlands. The basal sandstone and sandy shale of the Tongue River member make conspicuous bluffs above the Lebo badlands in section 36 and occur as outliers on a gravel-covered Lebo plain in sections 24 and 25.

The Wright coal bed, at the base of the Tullock member of the Lance formation, is the only coal bed of economic importance in the township and has been opened in three places to supply domestic fuel to Forsyth. At the Wright mine, in section 7, it contains 4 feet 2 inches of coal split by a 1-inch clay parting. (See pl. 10.) There are two timbered entries at this mine; the larger one is about 100 feet long and 5 feet high. At the time of examination the mine was abandoned and badly caved. Coal sample No. 96584 (p. 30) was taken at the Wright mine. Other measurements of the Wright bed in this vicinity are given in sections 2 to 4, Plate 10. At location 2 it is 1 foot 1 inch thick, and for nearly 4 miles to the south it was not mapped in detail. At location 5 it is 2

feet 6 inches thick, and to the north it is concealed in terrace gravel. At the Griggs mine, in section 23, the Wright bed is 4 feet 4 inches thick and is all clean coal. This mine was formerly equipped for drift mining on a small scale, but at the time of examination most of the equipment had been removed and the mine was idle. The Woodward mine, in section 22, consists of two entries, each about 200 feet long, in which the Wright bed is 4 feet 1 inch thick. No outcrops of the Wright bed were observed in the gravel-covered slopes in the northeastern part of the township. At location 1, in section 30, the Wright bed suddenly thickens and contains 3 feet 5 inches of coal cropping out in a ravine at the base of the Tullock escarpment.

The Hamre bed crops out about 35 feet below the sandstone that makes the rim rock on the Tullock escarpment and consists of a mixture of coal and carbonaceous sandstone. An entry about 100 feet long was driven in on the outcrop of the Hamre bed at location 10, but was abandoned because of the bony character of the coal. At locations 7 to 9 and 11 to 14 (pl. 10) it contains a maximum amount of 3 feet 5 inches of dirty coal in its lower part, which may be replaced by carbonaceous shale and bone within a few hundred feet of the point where the measurements were made.

At location 17 a coal lens 60 feet below the Hamre bed gave the following measurements:

Section at location 17, T. 5 N., R. 40 E.

	Ft.	in.
Coal		4
Sandstone		½
Coal		3
Sandstone		1
Coal	2	3
	2	11½

The Big Dirty bed crops out at several places in the township, but because it is impure it was not mapped in detail. The following measurements illustrate its character.

Section at small prospect in sec. 24 (Big Dirty bed), T. 5 N., R. 40 E.

	Ft.	in.
Carbonaceous shale and bone		7
Clay	1	
Carbonaceous shale and streaks of coal		8
Bone		4
Shale		1
Bone		10
Bone with streaks of coal		3½
Bone		11
Coal		10
Bone and carbonaceous sandstone		11½
Bone with streaks of coal	1	
Coal	1	
	8	6

The Hamre bed near this prospect consists of 7 feet of carbonaceous shale, bone, and thin lenses of coal; the thickest lens of coal measures 7 inches. At location 18 the Big Dirty bed crops out as shown in the following section:

Section at location 18, T. 5 N., R. 40 E.

	Ft.	in.
Carbonaceous shale		2
Coal		2½
Carbonaceous shale		4
Carbonaceous shale, bone, and thin streaks of coal	3	8
Shale		½
Coal		2
Shale		¼
Coal		3
	4	10¼

T. 4 N., R. 40 E.—Armells Creek and its forks in T. 4 N., R. 40 E., flow in relatively narrow valleys bordered by nearly vertical bluffs of sandstone and sandy shale several hundred feet high, which make natural barriers to travel across drainage lines. Outside the valleys of the creeks the land is rough, broken, and unsettled.

The Hell Creek member of the Lance formation here consists of somber-colored sandstone and clay. The Tullock member makes a conspicuous escarpment along the creek valleys which extend several miles up the larger tributaries. Here, as farther north, the top of the member consists of a resistant sandstone which makes a persistent and conspicuous rim rock. The Lebo shale member of the Fort Union formation, as usual, makes a low, featureless plain above the Tullock escarpment. The outcrop of the Tongue River member is restricted to a narrow promotory in section 1.

The Wright bed is the only coal of value in T. 4 N., R. 40 E.; it crops out near the base of the bluffs along Armells Creek. The bed occurs in two benches separated by a maximum interval of 27 feet. Both benches are persistent in position, but rarely do both contain coal at the same location. At location 19 the lower bench contains 2 feet 4 inches of coal in two layers separated by 1½ inches of carbonaceous shale. Similar measurements of the lower bench were made at locations 20, 21, 24, and 25. (See pl. 10.) Both benches of the Wright bed are present at location 22, where the lower bench contains 2 feet 8 inches of coal split by a 1-inch parting of carbonaceous shale and the upper bench 1 foot 4 inches of carbonaceous shale overlain by a like amount of coal. At location 23 on the promontory between the forks of Armells Creek, the upper and lower benches contain 2 feet 4 inches and 2 feet 2½ inches of coal, respectively, and are 26½ feet apart. No exposures of the Wright bed were observed in the northwestern part of the township west of Armells Creek.

The Big Dirty bed was not mapped in detail in this township. Its character is indicated by the following measurement:

Section of Big Dirty bed at location 61, in the SW. ¼ sec. 36, T. 4 N., R. 40 E.

	Ft.	in.
Coal, bony	2	
Coal		7
Bone		7
Coal		8
Bone	1	
Coal		8
	5	6

The Hamre bed, although persistent in this township, is so impure that it is unworkable. The following measurement obtained on the promontory in the SE. ¼ sec. 23 illustrates its character:

Section of the Hamre bed in T. 4 N., R. 40 E.

	Ft.	in.
Coal		8
Bone		7
Coal		3
Bone		8
Coal		11
	3	1

T. 3 N., R. 40 E.—The land on both sides of the divide in T. 3. N., R. 40 E., is rough and generally inaccessible. The escarpment of the Tullock member of the Lance formation is a prominent topographic feature in the western part of the township and is overlain by the Lebo shale member of the Fort Union formation, which makes a fairly level top on the divide but is more dissected where it lies on the slopes. (See pl. 4, *B*.) The Tongue River member of the Fort Union occurs as outliers on a plain of Lebo shale in the northern part of the township and underlies a much larger area in its southern part, where it gives rise to rolling country of moderate relief.

A line of gentle anticlinal folding passes diagonally across the eastern part of the township. A fault with a throw of about 50 feet occurs on the east limb of this fold in sections 13 and 14.

The Big Dirty coal bed crops out persistently and contains about 10 feet of coal and carbonaceous shale. At location 70 its upper part contains 4 feet 10 inches of coal, and this is the maximum thickness of coal observed in a single part of it in the township. Other sections of the Big Dirty bed, measured at locations 62, 63, 69, and 71, are represented in Plate 10.

A coal bed which contains about 4 feet of coal and is probably equivalent to the Burley crops out at locations 73 and 74. (See pl. 10.) This bed was not observed at its horizon in adjacent coulees and is probably a small lens produced by the abrupt thickening of a thin seam of coal.

The Hamre bed is of no value in this township, and only one section of it is given here;

Section of Hamre bed at location 72, SE. ¼ sec. 36, T. 3 N., R. 40 E.

	Ft.	in.
Carbonaceous shale	2	5
Bony coal		9
Carbonaceous shale	1	1
Bone and bony coal	3	9
	8	

T. 2 N., R. 40 E.—In the northern part of T. 2 N., R. 40 E., the land is rolling, and exposures of beds other than the sandstone rim rocks are poor. In the southern part of the township, where the coal-bearing part of the Tongue River member crops out, the land is rough and broken. The creeks flow in narrow valleys rimmed by massive sandstone and clinker. The sandstone above the Rosebud bed averages about 60 feet in thickness and makes a conspicuous wall at the base of the highest bluffs. (See pl. 6, *A*.)

The Robinson, Stocker Creek, and Rosebud beds underlie parts of the township. Measurements of the Robinson bed on the west side of the main divide were made at locations 129 to 133 (pl. 10), where it contained about 4 feet of coal. The Robinson bed could not be traced in the northern part of this township. At location 136 what is probably the Robinson bed contains 3 feet 2 inches of coal. A bed in the stratigraphic position of the Robinson contains about 3 feet of coal at locations 134 and 135. (See pl. 10.) A small outlier at location 137 is encircled by a coal bed 4 feet 8 inches thick, which may be the Robinson bed.

Several measurements of the Stocker Creek bed showed that it is 60 feet below the Rosebud and ranges from 3 to 6 feet in thickness. Sections of it are shown by locations 123 to 128. (See pl. 10.)

The Rosebud bed underlies the divide in the southwestern part of the township and several outliers in section 21 and vicinity, where it is not entirely burned. The only exposures of the bed observed were at locations 121 and 122, where 5 feet and 10½ feet, respectively, of unburned coal crops out. It is estimated that the total quantity of Rosebud coal underlying the township is 42,000,000 tons, of which 13,000,000 tons can be advantageously recovered by strip mining.

T. 1 N., R. 40 E.—The valley of the East Fork of Armells Creek in T. 1 N., R. 40 E., is about a mile wide and is well adapted to dry farming. It is separated from the valley of Stocker Creek on the north by a narrow divide about 300 feet high, which is crossed by several roads and trails. The divide between the East Fork of Armells Creek and Lee and Richard Coulees, tributaries of Rosebud Creek, occupies the central part of the township and is fairly accessible on its north side. On its south side, however, clinker escarpments stand about 250 feet above the bottom strips along the creeks, and the land is rough and broken, becoming almost impassable on the slopes of Wolf Mountain in the southwestern part of the township.

The axis of the syncline between the Big Horn and Porcupine uplifts crosses the central part of the township and is paralleled on the east by a line of gentle anticlinal folding, on which local doming has occurred in section 12. 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 NE. ¼ sec. 7, T. 1 N., R. 41 E., and dips beneath the creek again in the SW. ¼ sec. 11, T. 1 N., R. 40 E. (See pl. 7.)

The rocks that crop out in the township belong to that part of the Tongue River member of the Fort Union formation which is included in the interval between the Rosebud and Richard coal beds. The rocks other than coal beds consist of light-colored sandstone and sandy shale.

The gentle doming of the strata in section 12 has exposed the Rosebud bed at location 176 (pl. 10), where nearly 11 feet of it crops out. No other exposures of the bed occur in this immediate vicinity, as its outcrop is clinkered. At location 175 the upper 13 feet of the Rosebud bed crops out in a cut bank, and its total thickness at this location is reported to be 28 feet. The outcrop of the Rosebud bed is extensively clinkered west of location 175, and no exposures of unburned coal were observed. A well drilled near the Cooley ranch in section 4 is reported to have penetrated 24 feet of coal beginning at a depth of 6 feet below the surface.

The Lee bed crops out at location 177, in section 35, and contains nearly 9 feet of coal split by two thin partings of sandy shale. (See pl. 10.) The Lee bed is not developed in the northern part of the township.

The Popham bed crops out 45 feet below the Sawyer bed and although it averages only about 4 feet in thickness was mapped in detail. Sections along its outcrop line at locations 178 to 200 are given on Plate 10.

The Sawyer bed is unburned only in the western part of the township and has a maximum thickness of more than 17 feet at location 213. (See pl. 10.) It thins rapidly toward the northwest and at location 203 is only 1 foot 8 inches thick. Other sections of the Sawyer bed are represented in Plate 10 by sections 201, 202, 204–a, 205, 206, 206–a, and 209 to 213. At location 206–a, in the NW. ¼ sec. 30, the Sawyer bed is 6 feet 8 inches thick and a face of it about 75 feet long has been cut back a maximum distance of 25 feet. Coal sample 96587 was taken at this location. (See p. 30.)

A measurement of the Richard bed made at location 215, at the south quarter corner of section 31, showed 6 feet 4 inches of coal, and one made at location 217, in the SW. ¼ sec. 19, showed 3 feet 2 inches of coal overlain by 3 inches of carbonaceous shale.

At location 204, in the SW. ¼ sec. 18, a coal bed 1 foot 3 inches thick crops out 78 feet above the Popham bed.

Conditions excellent for the recovery of a large tonnage from the Rosebud bed by strip mining exist in parts of sections 4, 5, and 6 of this township and in parts of secs. 31 and 32, T. 2 N., R. 40 E. The land lies in a topographic saddle between the headwaters of Stocker Creek and the West Fork of Armells Creek and is fairly level. The record of the well at the Cooley ranch, in section 4, and exposures at locations 155 and 156, in sec. 1, T. 1 N., R. 39 E., show that the Rosebud bed is more than 20 feet thick. The approximate outline of the area from which coal in the Rosebud can be taken out by strip mining, including tracts in sections 11, 12, 13, and 14, is shown on Plate 7. A rough estimate of the coal thus recoverable in this township is placed at 39,000,000 tons.

T. 1 S., R. 40 E.—The principal tributaries of Rosebud Creek in T. 1 S., R. 40 E., are separated by long, narrow, and level clinker-capped divides, which stand about 250 feet above the valley bottoms. The clinker makes a resistant cap rock above bluffs of yellow sandstone and sandy shale and protects dissected remnants of a former extensive slag-covered plateau. The coals are unburned in the western part of the township, and the land is very rugged and inaccessible. Trails extend part way up all the creeks, and most of them end at deserted ranches. The inaccessibility of the area and the lack of good drinking water have served to keep this township almost unsettled.

The rocks in the township belong to that part of the Tongue River member of the Fort Union formation which is included in the interval between the Lee and Richard coal beds. The dip is uniformly about 1° SE. The Lee bed crops out near the base of the bluffs throughout the township and is extremely clinkered. Its maximum thickness in Slough Grass Creek is 6 feet 4 inches at location 249. Other measurements of it in Slough Grass Creek are given on Plate 10 by locations 250 to 254. Only one measurement of it was obtained in Little Cottonwood Creek, at location 255, where it contains 5 feet 7 inches of coal split by 3 inches of shale. At location 256 slightly more than 2 feet remains unburned. At location 257 it is nearly 14 feet thick but includes a sandstone parting more than 5 feet thick in its middle part in addition to several smaller partings. (See pl. 10.)

The Sawyer bed crops out in the almost impassable badlands in the western part of the township. On the Middle Fork of Richard Coulee, at location 258, it is more than 9 feet thick and is badly split by partings. (See pl. 10.) Its maximum observed thickness occurs at location 265, where it consists of an

upper and a lower bench, containing 4 feet 5 inches and 8 feet 5 inches of coal, respectively, separated by a bed of carbonaceous shale 15 feet thick. Other sections are given in Plate 10 by locations 259 to 264 and 266. The Popham bed crops out in the township, but because of its close vertical proximity to the Lee and Sawyer beds it was not mapped in detail. Its general character in the township is illustrated in Plate 10 by sections 267 and 268.

T. 2 S., R. 40 E.—That part of T. 2 S., R. 40 E., which was examined includes slightly less than two tiers of sections lying north of the Cheyenne Indian Reservation. The land included in this area is very rugged and is largely occupied by the divide between Big Cottonwood Creek and Lynch Coulee.

On Big Cottonweed Creek, at location 278, 4 feet 10 inches of coal, with its base unexposed, crops out in the stream bottom and may be the top of the Rosebud bed. The Lee bed is 4 feet 9 inches thick at location 269. The Sawyer bed is extensively burned along its outcrop and no measurements of its thickness could be obtained.

T. 6 N., R. 41 E.—The alluvial plain south of the Yellowstone River in T. 6 N., R. 41 E., is less than a quarter of a mile wide and is bordered by gravel-capped bluffs about 200 feet high. The rest of the township is occupied by a terrace of Pleistocene river gravel, which is traversed by good roads and is well settled.

The Hell Creek and Tullock members of the Lance formation underlie the terrace gravel in this township and crop out at irregular intervals along Slaughter House Creek and in the bluffs of the Yellowstone River. No coal was observed in this township.

T. 5 N., R. 41 E.—The divide which occupies the central part of T. 5 N., R. 41 E., stands about 700 feet above the level of the Yellowstone River. Its summit is composed of terrace gravel locally cemented into a conglomerate 10 feet thick and represents a river terrace intermediate in age between the Oligocene or Miocene (?) bench in T. 4 N., Rs. 39 and 41 E., and the main terrace along the Yellowstone River. As indicated on pages 20–22 this deposit may represent the Flaxville gravel, of Miocene or Pliocene age. East of the main divide and in the drainage basin of West Rosebud Creek the land is very rough and broken and is traversed by only one road, which follows the creek bottom. In the western part of the township a mantle of terrace gravel has produced a rolling type of topography which becomes increasingly rough toward the head-waters of West Rosebud Creek.

The contact line of the Hell Creek and Tullock members of the Lance formation as shown on Plate 7 is inferred, for the lack of continuous exposures makes it impossible to draw a well-defined line between them, The Lebo shale member of the Fort Union formation underlies the divide in the central part of the township and makes an extensive badlands area along the West Fork of Rosebud Creek. The Tongue River member of the Fort Union crops out on long, narrow spurs and outliers in sections 30 and 31.

The Wright coal bed has been opened at six places along a coulee in sections 1 and 2 to supply domestic fuel to Forsyth. These openings are referred to as the Lore mines. The largest opening extends in 200 feet and comprises several rooms. The main openings are 5 feet high and 5 feet wide and have a soft sandstone roof. The section on page 51 illustrates the character of the Wright bed at these openings.

Section on the Wright coal bed in T. 5 N., R. 41 E.

	Ft.	in.
Carbonaceous shale		2½
Coal		5
Carbonaceous shale		1
Coal		6½
Carbonaceous shale		1½
Coal	2	
	3	4½

A coal bed 2 feet 4 inches thick was seen in the bluffs on the West Fork of Rosebud Creek, at the center of section 25, but thinned to less than 1 foot within a few hundred feet. The Hamre bed crops out below the Tullock rim rock as follows:

Sections of the Hamre coal bed in T. 5 N., R. 41 E.

SE. ¼ sec. 9

	Ft.	in.
Coal, dirty	1	9
Carbonaceous shale		2
Coal, soft, bony	2	3
	4	2

NE. ¼ sec. 34

	Ft.	in.
Carbonaceous shale and coal		10
Carbonaceous shale		¾
Bone		5
Carbonaceous shale		1
Bone		6½
Carbonaceous shale		1
Coal		6
Carbonaceous shale		1½
Coal		9
	3	4¾

The Big Dirty bed averages about 6 feet in thickness and is made up of carbonaceous shale and dirty coal. The best exposure of it in the township occurs on the narrow ridge in the NW. ¼ sec. 22, where it is nearly 7 feet thick but very dirty. The Big Dirty bed was not mapped in detail, but its outcrop is represented with fair precision on Plate 7 by the contact line between the Tullock and Lebo shale members.

T. 4 N., R. 41 E.—The plateau-like divide which crosses T. 4 N., R. 41 E., ranges in width from less than a mile in its southern part to a maximum of about 5 miles in its northern part. Its most prominent topographic features are several flat-topped hills and ridges capped with Oligocene or Miocene (?) gravel, which rise several hundred feet above the general level of the divide in sections 8, 14, 15, and 16. (See pl. 7.) The land on either side of the divide is exceedingly rough and has neither roads nor trails.

The upper part of the Tullock member of the Lance formation crops out in the stream bottoms along the borders of the township. The Lebo shale member of the Fort Union formation is nearly 170 feet thick (see p. 16) and crops out in a relatively narrow band between the escarpment-forming sandstones of the Tullock and Tongue River members. The lower 208 feet of the Tongue River member crops out in bold escarpments above the somber-colored Lebo clays and is made up of yellow sandstone and thin lenticular coal beds. (See p. 20.)

No coal of value occurs in the township. The Hamre bed contains 18 inches of coal at location 33 in the SW. ¼ sec. 19. The Big Dirty bed is persistent but thinner and more bony than at any other place along its outcrop in the entire field. The following measurements show its character and thickness:

Sections of the Big Dirty bed in T. 4 N., R. 41 E.

Location 31, NE. ¼ sec. 31

	Ft.	in.
Coal		10
Coal, dirty		3
Coal		9
Bone	1	8
	3	6

Location 32, SE. ¼ sec. 30

	Ft.	in.
Coal and carbonaceous shale	3	

Location 34, NE. ¼ sec. 25

	Ft.	in.
Coal		6
Bone		8
Carbonaceous shale and coal	3	6
	4	8

T. 3 N., R. 41 E.—The divide in the northern part of T. 3 N., R. 41 E., is characterized by long narrow ridges of Tongue River sandstone, bordered by badland slopes of Lebo shale. In the southern part of the township near the East Fork of Armells Creek the land is of moderate relief but becomes rougher as the main divide is approached, and west of the creek is so dissected as to be almost impassable.

The East Fork of Armells Creek flows along the axis of a syncline paralleling an anticline which crosses the southwestern part of the township. West of the creek the rocks rise at an angle of about 3°, which is sufficient to expose the upper part of the Tullock member in the stream bottoms. This line of folding is modified by a northwestward-trending fault zone which runs slightly east of the anticlinal axis. The faults are normal and are dropped on the west about 60 feet. (See pl. 7.)

At location 75, in the NE. ¼ sec. 6, the Big Dirty bed contains about 4 feet of coal and carbonaceous shale. At location 76, about 1½ miles to the south, it is 6½ feet thick and of fair quality. Along the fault zone in the southeastern part of the township it attains a maximum thickness of 11 feet at location 77 and appears to consist of a good grade of subbituminous coal. Other measurements of this bed are represented in Plate 10 by sections 78, 79, and 80. At locations 81 and 82 it again assumes its normal dirty character, as the following sections will show:

Sections of the Big Dirty bed in T. 3 N., R. 41 E.

Location 81, SE. ¼ sec. 31

	Ft.	in.
Carbonaceous shale	1	1
Coal		2
Bone		5
Coal	1	6
Bone		5
Coal		8
Coal, sandy		7
Coal		6
Bone	1	
Clay		5
	6	7

Location 82, SW. ¼ sec. 31. (See pl. 3.)

	Ft.	in.
Coal	1	1
Clay		2
Coal		1
Clay		2
Coal		1
Clay		1
Coal		½
Clay		7
Bone		1½
Coal, dirty	1	1
Sandstone		½
Coal		5
Sandstone		½
Coal, dirty	1	8
Bone		3
Coal		10
	6	9

The Burley bed underlies the highest part of the divide in the central and southern parts of the township and is in places extensively burned. Outcrops of the bed are rare, however, on account of the rolling, grass-covered nature of the country. It was measured at locations 83, 84, and 85 (pl. 10) and showed an average thickness of 4½ feet.

T. 2 N., R. 41 E.—In the northern part of T. 2 N., R. 41 E., the East Fork of Armells Creek is bordered by bluffs that rise 300 feet above the level of the creek, and in the southern part of the township the clinker made by the burning of the Rosebud coal bed has produced a continuous line of bluffs and rounded hills along the creek. In those areas along the creek where the Rosebud bed has not been burned the land is gently rolling and rises in smooth grass-covered slopes to higher and rougher areas in sections 31 and 32. The Armells Creek branch of the Northern Pacific Railway and the main road to Forsyth follow the valley of the East Fork of Armells Creek, and a branch road to Castle Rock follows Stocker Creek.

In the southern part of the township the rocks have an average dip eastward of about 20 feet to the mile, the dip increasing slightly toward the west. In the central and northern parts of the township the dip is about 30 feet to the mile to the east, and there may be a slight reversal of dip in sections 17 and 18.

The Burley coal bed crops out at the head of Sprague Basin in sections 1 and 2 and at the base of the bluffs along the east side of the East Fork of Armells Creek. At location 143 (pl. 10) it contains 5 feet of coal, and at the Wimer place, location 144, some 2 feet of the bed shows in a spring, and it is reported to be 6 feet thick. At location 145 the bed shows 4 feet 4 inches of coal, and at location 146 it contains 4 feet of coal. A bed which may be the Burley bed contains 3½ feet of coal at location 147. It was impossible to trace this bed in the grass-covered and forested areas along Stocker Creek.

The Robinson bed crops out at the base of a sandstone which makes a prominent rim rock near the base of the bluffs on the east side of the East Fork of Armells Creek and is 50 feet above the Burley bed. Although exposures of this bed are few its position is easily determined by noting the outcrop of the massive sandstone immediately above it. At location 148 (pl. 10) it contains 2½ feet of coal; at location 149 it contains 4½ feet of coal. The outcrop line south of location 148 shown for it on Plate 7 is inferred.

The McKay and Rosebud beds are extensively burned in this township. The divide between the East Fork of Armells Creek and Stocker Creek and the divide between the East Fork of Armells Creek and Spring Creek in sections 13, 14, and 15 consist largely of clinker formed by the burning of these beds. Both beds are burned in sections 25 and 36 also. In the absence of outcrops the present margin of the Rosebud bed was mapped by reference from the contact of its clinker with cover, it being assumed that the coal would lie unburned back of this contact a distance directly proportional to the thickness of the cover. The McKay bed lies from 8 to 21 feet below the Rosebud bed and where unburned itself is usually concealed by clinker of the Rosebud bed. At location 150 (pl. 10) it is exposed directly beneath the Rosebud slag in a coulee and is more than 6 feet thick.

On Pony Creek, at location 142 (pl. 10), the upper 10 feet of the Rosebud bed is exposed, and is extensively burned in the next township on the east. At location 217, some 6 feet of the Rosebud bed crops out in a reservoir just south of the township line. At location 141 a 14-foot bed of coal, containing two bone partings 1 and 10 inches thick, crops out in a narrow ravine, with the base of the bed unexposed. Measurements of part of the bed at locations 138, 139, and 140 (see pl. 10), averaged about 6 feet. The average thickness of the Rosebud

bed in this township, as determined by drill records, is reported to be 28 feet. On Plate 7 those areas in this township where the coal in this bed can be recovered by strip mining are shown in stippled pattern. It is estimated that the Rosebud bed contains 187,000,000 tons of coal in T. 2 N., R. 41 E., of which about 78,000,000 tons can be taken out by stripping.

T. 1 N., R. 41 E.—The flood plain of the East Fork of Armells Creek is about a quarter of a mile wide in T. 1 N., R. 41 E., and the land on each side of the creek bottom for about half a mile is made up of smooth rounded slopes which become rougher farther away from the valley. The divide between Armells and Rosebud Creeks is capped by clinker from the burning of the Sawyer coal bed and stands about 375 feet above the level of the surrounding country. Miller Coulee and its tributaries occupy a basin about 3 miles wide which is almost surrounded by precipitous clinker-capped bluffs of sandstone and sandy shale. The topographic features along Lee Coulee are similar to those of Miller Coulee, though its valley is narrower. Roads traverse the valleys of the larger streams along the township borders, but none cross the inaccessible divide in its central part.

In the central and eastern parts of the township the rocks rise westward about 25 feet to the mile. Gentle doming of the strata occurs near the southwestern corner of section 29 along the axis of a minor anticlinal fold. (See p. 23.) Similar doming on the same anticlinal axis occurs in sec. 12, T. 1 N., R. 40 E., and has increased the westward rise of the rocks in secs. 6 and 7, T. 1 N., R. 41 E., to about 1½°.

The rocks that crop out in T. 1 N., R. 41 E., belong to that part of the Tongue River member of the Fort Union formation included in the interval between the McKay and Sawyer coal beds. (See p. 19.) The sandstone above the Rosebud coal bed is about 140 feet thick in Miller and Lee Coulees, where it makes a conspicuous ledge at the base of the precipitous bluffs. (See pl. 5, *A*.)

The upper 6 feet of the Rosebud bed crops out in a small reservoir at location 217. (See pl. 10.) Along the East Fork of Armells Creek west of location 217 the Rosebud bed is covered until brought above stream level by the increased westward rise of the rocks, and at location 216 it crops out 11½ feet. At the Kimball ranch in the SW. ¼ sec. 6, a coal bed 8 feet thick 40 feet below the surface was penetrated in a well and is probably the Stocker Creek bed. At location 218 the Rosebud bed is 18 feet thick at an abandoned prospect, and at location 218–a (pl. 10) the McKay bed is 7 feet thick. The Rosebud and McKay beds are fully exposed in cut banks at locations 221 and 222 and are about 28 and 10 feet thick, respectively. (See pls. 5, *B*; 6, *B*; and 10; and p. 19.) No other exposures of the Rosebud bed were observed in Miller Coulee, and the outcrop line of the bed as shown on Plate 7 was mapped largely by reference to the contact of baked and unbaked rock. At location 223 the upper 11 feet of the Rosebud bed crops out and is cut off by a fault having a throw of about 32½ feet. (See pl. 7.) The McKay(?) bed is unburned at locations 227 and 228 and has a maximum thickness of 4 feet 5 inches. At an abandoned prospect at location 224 the Rosebud bed is 10 feet thick, and farther downstream it is only a foot thick, having been almost entirely replaced by sandstone and sandy shale. No other exposures of the Rosebud bed were observed in Lee Coulee, though heavy clinker at its horizon in sections 29 and 30 indicates that it is at a slight depth below the surface.

The Lee bed is 105 feet above the Rosebud and first appears along Lee Coulee, where it is heavily clinkered. Only one measurement of it was made, at location 225, where its upper 6 feet crops out.

The Sawyer bed is unburned at location 226 (pl. 10) and is 11 feet thick.

Those parts of the township where the coal of the Rosebud bed can be recovered by strip mining are indicated on Plate 7 by stippled pattern. The best belt for strip mining lies along the East Fork of Armells Creek, where the coal is at a depth of less than 60 feet over a considerable area, and the overburden is loosely consolidated sandstone and sandy shale. Smaller stripping areas occur in SE. ¼ sec. 12 and in and near the northern part of section 24. It is estimated that the total quantity of coal in the Rosebud bed (exclusive of the McKay bed) within the township is 843,000,000 tons, of which approximately 107,000,000 tons can be recovered by strip mining.

T. 1 S., R. 41 E.—In T. 1 S., R. 41 E., Rosebud Creek has a flood plain ranging from a few hundred feet to nearly half a mile wide. Its tributaries occupy U-shaped valleys separated by continuous and rather narrow clinker-capped divides, which stand about 350 feet above the stream bottoms. (See pl. 7.) Good water is obtained from drilled wells at ranches along Rosebud Creek, but in other parts of the township the water is too alkaline for drinking. The road between Forsyth and Sheridan follows Rosebud Creek and is graded. Other roads and trails which traverse the township are shown on Plate 7.

The rocks in the township belong to that part of the Tongue River member of the Fort Union formation which lies between the Rosebud and Sawyer coal beds. The interval between the Rosebud and Lee coal beds is 115 feet and is largely occupied by massive sandstones. A similar sandstone about 60 feet thick crops out above the Lee bed, so that a double sandstone bench appears to run along the creek valleys.

The maximum thickness of the Rosebud bed reported in the township is 12 feet in a well near the Groves place, at location 232. Measurements made at locations 229, 230, 231, 233, and 234 are shown graphically in Plate 10. It was impossible to obtain more measurements of the bed because of the soil cover at its horizon along the valleys of the creeks. The general westward rise of the rocks and an occasional small clinker mound near stream level suggest, however, that it is at only a slight depth beneath the surface on all the western tributaries of Rosebud Creek.

On the west side of Rosebud Creek the Lee bed crops out high in the bluffs and is nearly everywhere inaccessible. East of Rosebud Creek it has been opened at two places by settlers. At the McKay mine, in the SW. ¼ sec. 34, it is about 11 feet thick, but only 6 feet of it is mined. This mine has been driven in about 150 feet and is well timbered. Coal sample No. 96583 was taken at this mine. (See p. 30.) The Lynch mine, in the SE. ¼ sec. 25, has a timbered entry about 150 feet long on the Lee bed, the upper 7 feet of which crops out in a coulee beneath a massive sandstone. Other measurements of the Lee bed in this township are represented in Plate 10 by sections 236 to 245.

No unburned coal of the Sawyer bed remains in the township.

T. 2 S., R. 41 E.—Approximately the northern third of T. 2 S., R. 41 E., is included in the Forsyth field. The rocks exposed in this area belong to the Tongue River member of the Fort Union formation and crop out in nearly vertical bluffs rising about 350 feet above Rosebud Creek.

The Rosebud bed has a maximum observed thickness of 13 feet at location 247. Other measurements were made at locations 246 and 248. (See pl. 10.) No exposures of the Lee bed were observed in the bluffs. East of Rosebud Creek the Sawyer bed is unburned in places on the divide between Rosebud and Rye Grass Creeks, but its outcrop is everywhere heavily clinkered.