UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

GEOLOGICAL SURVEY
W. C. Mendenhall, Director

Bulletin 847—C

THE RICHEY-LAMBERT COAL FIELD

RICHLAND AND DAWSON COUNTIES MONTANA

BY

FRANK S. PARKER

Contributions to economic geology, 1934-36
(Pages 121-174)

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1936

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - Price 35 cents

CONTENTS

ILLUSTRATIONS

THE RICHEY-LAMBERT COAL FIELD, RICHLAND AND DAWSON COUNTIES, MONTANA

By FRANK S. PARKER

ABSTRACT

The Richey-Lambert coal field is an area of about 900 square miles in Richland and Dawson Counties, eastern Montana, along the divide between the Missouri and Yellowstone Rivers. In this region only flat-lying continental rocks occur near the surface. About 300 feet of the Lebo shale member and about 930 feet of the coal-bearing Tongue River member of the Fort Union formation, of Eocene age, are exposed in the area. Deposits of terrace gravel at two levels in the field are tentatively correlated with the gravel on the Cypress Hills, Saskatchewan, which has been assigned to the Oligocene by the Canada Geological Survey, and with the Flaxville gravel, of upper Miocene or Pliocene age. Terrace gravel also occurs at various lower levels and is probably of early Pleistocene age. There are altogether indications of five different levels of terraces, as well as traces of a channel formed by the diversion of the Missouri River drainage through this area during the Illinoian or Iowan glacial stage. In the northern part of the field glacial till and glacial erratics are present. Alluvium of Pleistocene (?) and Recent age covers the floors of the valleys to depths of as much as 30 feet.

The strata of the Fort Union formation have an average dip of about 20 feet to the mile to the south, southeast, or east. The only noticeable folds in the area are a small dome with a closure of about 50 feet, an anticline with a relief of about 100 feet extending beyond the boundary of the field, and a shallow syncline.

The prominent coal beds exposed in the field occur in the lower 700 feet of the Tongue River member of the Fort Union formation. The beds are lenticular and are irregular in extent and thickness. The maximum thicknesses of the coal beds shown on the geologic map range from 4 to 21 feet. All the coal in the field is lignite; its average heating value as mined, shown by analyses of four samples from different beds, is 7,035 British thermal units. Mining operations have been confined to small entries and open cuts that are used to obtain coal for domestic use locally. The total coal reserves of the field in beds in the Fort Union formation are estimated at 12,994,000 short tons.

INTRODUCTION

Location and relations of the field.—The Richey-Lambert coal field includes an area of about 900 square miles in parts of Richland and Dawson Counties, eastern Montana, along the divide between the Yellowstone and Missouri Rivers. It embraces Tps. 19 and 20 N.,

R. 50 E., Tps. 21, 22, and 23 N., Rs. 50 to 55 E., and T. 24 N., Rs. 51 to 55 E. This field is but a small part of the great area of coal-bearing rocks which extends from central North Dakota to the Big Horn and Musselshell Rivers in Montana and from northern Wyoming into Canada. The coal of this great area ranges in rank from subbituminous in the western and southern parts to lignite in

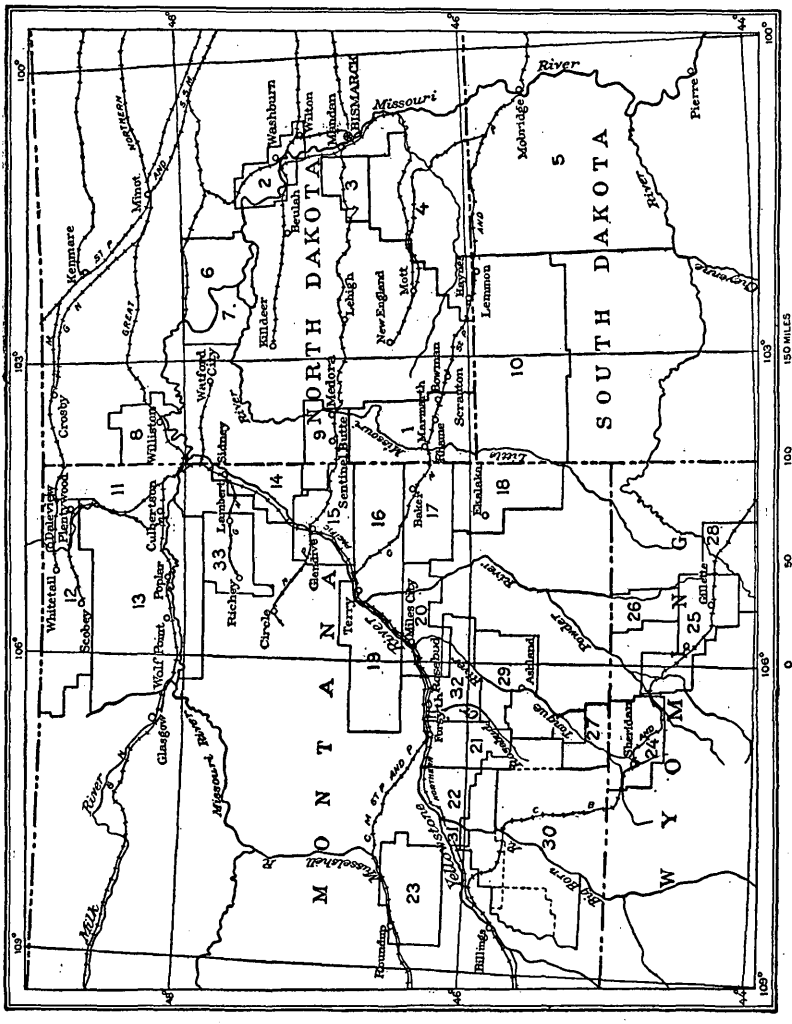


FIGURE 33.—Index map showing location of the Richey-Lambert coal field and its relation to other coal fields of Montana and adjacent States.

the eastern and northern parts. The Richey-Lambert field lies within that part of the area which contains only lignitic coal.

The different coal fields in Montana and adjacent States and the publications of the United States Geological Survey in which they are described are listed in the following table, and their locations are shown in figure 33.

Coal fields whose locations are shown in figure 33

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

Field work.—Field work was undertaken in the Richey-Lambert field to obtain data on its geology and coal resources, for use in the administration of the public lands. The field work in Tps. 19 to 23 N., R. 50 E., and Tps. 21 and 22 N., R. 51 E., was done in 1929 by A. J. Collier, assisted by M. N. Bramlette, M. P. Billings, H. E. Thomas, and the writer. The field work in the rest of the area was done in 1930 by the writer, assisted by P. A. Davison, J. W. Wyckoff, and G. F. Taylor. Robert Pierce, who served as cook and camp hand, occasionally assisted with the field work. G. C. Sleight acted as rodman from June 6 to June 15, 1930. The mapping of geologic formations, coal beds, and geographic features of the area was done with the plane table and explorer's alidade. Data from United States General Land Office surveys were used in compiling the base map, and the features of the area were mapped by means of stadia traverses from land corners. Altitudes were determined by a net of traverses from bench marks established at Richey, Enid, and Lambert by engineers of the Great Northern Railway, 7 feet being subtracted from the altitudes shown on the bench marks in order to reduce them to the datum plane of mean sea level. The probable error in altitude of the points shown on plate 22 does not exceed 10 feet.

Acknowledgments.—The services of the field assistants who gathered many of the data used in the report are gratefully acknowledged by the writer. Acknowledgment is also due to A. J. Collier, under whose direction part of the area was mapped and who gave material asistance in the preparation of the report; to W. G. Pierce, who aided in organizing the party in 1930 and instructing the members in the technique of mapping and who offered much valuable advice during the preparation of the report; to H. D. Miser, under whose direction the survey was made; and to A. A. Baker, whose helpful criticisms and suggestions guided the writer in preparing

this report. The writer wishes to express his appreciation of the aid and cooperation of the ranchers, merchants, and mine owners of the region.

Previous surveys and reports.—All of the Richey-Lambert field has been subdivided by surveys of the United States General Land Office. Portions of T. 21 N., Rs. 54 and 55 E., were surveyed in 1899, but the remainder of these townships and the other townships of the area were surveyed between 1907 and 1909. The land corners were shown with pits and marked stones, and many of these are still preserved, although some have been destroyed by road grading and erosion.

The topography of the part of the field that lies east of R. 52 E. is shown by the topograhpic map of the Glendive quadrangle, published by the United States Geological Survey. This map is on the relatively small scale of 1:250,000, and consequently the surface features are somewhat generalized. The altitudes shown for points in the Richey-Lambert field on the Glendive topographic map are 30 to 50 feet higher than the altitudes determined by the writer for the same points. Maps showing houses, drainage, roads, and railroads have also been prepared by the county surveyors of Richland and Dawson Counties.

Although the existence of coal in this area has been known since the earliest settlement, no detailed description of it or of the general geology has been published. Detailed reports on the geology and coal resources of neighboring areas to the east and south and a reconnaissance report on the adjoining area to the north have been published by the United States Geological Survey. (See fig. 33.) An examination of McCone County, which adjoins the Richey-Lambert field on the west, has been made for a report, as yet unpublished. A sketch map showing the structure of an area including the northern part of the Richey-Lambert field was published as part of a Department of the Interior memorandum for the press, dated May 6, 1921.

The general aspects of the stratigraphy of the portion of the Great Plains that includes the Richey-Lambert field have been discussed in several papers.[1] The physiography of eastern Montana

[1] Dobbin, C. E., and Reeside, J. B., Jr., The contact of the Fox Hills and Lance formations: U. S. Geol. Survey Prof. Paper 158, pp. 9–25, 1929. Thom, W. T., Jr., and Dobbin, C. E., Stratigraphy of Cretaceous-Eocene transition beds in eastern Montana and the Dakotas: Geol. Soc. America Bull., vol. 35, pp. 481–505, 1924. Leonard, A. G., The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: Jour. Geology, vol. 19, pp. 507–547, 1911. Calvert, W. R., Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey Bull. 471, pp. 187–201, 1912. Rogers, G. S., The Little Sheep Mountain coal field, Dawson, Custer, and Rosebud Counties, Mont.: U. S. Geol. Survey Bull. 531, pp. 159–227, 1913. Collier, A. J., Geology of northeastern Montana: U. S. Geol. Survey Prof. Paper 120, pp. 17–39, 1918.

has been studied by Alden [2], who has described some of the more prominent features within the Richey-Lambert coal field with reference to their relations to the general physiography of the region.

GEOGRAPHY

Land forms.—The Richey-Lambert area is a part of the Northern Great Plains province and is characterized by rolling hills, open valleys, small badland areas, and remnants of upland. The field shows two rather distinct types of topography separated by the northeastward-trending divide between the Missouri and Yellowstone Rivers. The divide lies 2,600 to 3,100 feet above sea level through most of its course across the field, but near Enid a pass crosses it at an altitude of 2,380 feet. Southeast of the divide are three extensive upland areas (shown by the pattern representing the Flaxville (?) gravel on pl. 26) separated by wide troughlike valleys and bordered in many places by badlands and cliffs. Where the divide between the Yellowstone and Missouri Rivers follows the northeast margin of the upland, an escarpment 60 to 200 feet in height separates it from the lower country to the northwest. The largest upland area is the Retah Table, in the southern part of the field. It is a gravel-floored plain that slopes gently toward the southeast. A few rounded hills rise above it, and broad, shallow stream courses are cut into it. The upland area south of Lambert slopes gently eastward and is an almost featureless plain. The upland area north of Enid and Lambert slopes appreciably to the south and merges with the slope of the Fox Creek Valley. It is characterized by rolling hills and well-marked stream courses.

The country northwest of the Yellowstone-Missouri divide is for the most part rolling but displays varied features at places, such as isolated buttes, small mesas and benches that are formed by layers of calcareous concretions, gravel deposits, and masses of rock fused or baked by the burning of adjacent coal beds. The major valleys are wide and open, with broad alluvial flats trenched by meandering stream channels to depths of as much as 30 feet. The alluvial flats are commonly bordered by low bluffs and small areas of badlands where the meanders approach their edges. Bluffs of this sort along the east side of Redwater Creek are 20 to 70 feet in height.

The minor creeks and their tributaries rise in small badland areas or on gentle rolling slopes, and those that are near the escarpment at the Missouri-Yellowstone divide are entrenched into the alluvium

[2] Alden, W. C., Physiographic development of the northern Great Plains: Geol. Soc. America Bull., vol. 35, pp. 385–424, 1924; Physiography and glacial geology of eastern Montana and adjacent areas: U. S. Geol. Survey Prof. Paper 174, 1932.

of their valleys to depths corresponding to those for the larger streams—that is, as much as 30 feet.

The highest point in the coal field, 3,117 feet above mean sea level, is near the Missouri-Yellowstone divide in sec. 17, T. 21 N., R. 53 E. It is occupied by a United States Geological Survey triangulation station. The lowest point in the area is on Redwater Creek at the northwest corner of the field, 2,089 feet above sea level. The total relief is thus 1,028 feet, but as a rule, the relief within a single township does not exceed 350 feet. Altitudes of some of the highest and lowest points are shown on plate 22.

Drainage and water supply.—The southeastern part of the Richey-Lambert coal field is drained by forks of Fox, Burns, and Thirteenmile Creeks, tributaries of the Yellowstone River; the northeastern part is drained by East Charley, Charley, and West Charley Creeks, tributaries of the Missouri River; the rest of the area is drained to the Missouri River north of the coal field by Redwater Creek and its tributaries, including East Redwater, Lisk, Pasture, Sullivan, Corral, and East and West Cottonwood Creeks.

Redwater Creek, the principal stream of the area, contains flowing water except in the summers of exceptionally dry years, when short reaches of the stream may be dry. During years of normal rainfall East Redwater Creek has a small sluggish flow in its lower reaches, and the other creeks of the area usually contain some water in shallow pools or may flow for short reaches. East Charley Creek contains flowing water for a mile or two below Spring Lake. The higher reaches of the main creeks and the tributaries flow only during rains and thaws.

Fox Lake, a small body of water in a marshy area west of Lambert, persists throughout the year, although there is much seasonal variation in its size. During times of heavy rain the lake occupies the entire marsh, but during dry periods the water surface is hidden by marsh plants and an alkali flat surrounds the marsh.

Spring Lake, on East Charley Creek, is little more than a large pool in the creek bed where springs supply an abundance of rather alkaline water.

A few small reservoirs formed by earth dams have been constructed by ranchers to impound storm waters of small creeks, but the water in them is soon lost through evaporation and seepage.

The surface water is usually alkaline and discolored as well as being open to contamination. It is unfit for domestic use, but where the supply is constant it appears to be satisfactory for watering livestock.

Most of the domestic water and a considerable amount of the water for livestock are obtained from shallow dug wells. At Richey and at a few ranches in the southern part of the field water is ob-

tained from drilled wells 50 to 350 feet in depth. Many wells and springs draw their water from coal beds, and in these the water is usually brownish and possesses a sulphurous odor. Water obtained from wells in the alluvium or in gravel is usually potable. Water from some of the wells in the Fort Union formation is highly alkaline and is not suitable for drinking, but water from other wells in the same formation may be palatable. Renick,[3] in his studies of ground water in an area of Fort Union rocks in east-central Montana, found that near the surface the water may contain a relatively high percentage of salts of magnesium and calcium, but in many places by the time water containing these salts has percolated to a depth of 125 feet the calcium and magnesium are exchanged for an equivalent amount of sodium. Water containing considerable amounts of salts of calcium is hard but usually fit for drinking. Water containing considerable amounts of salts of magnesium is hard and usually unsatisfactory for drinking. Water containing considerable amounts of sodium is usually soft but may be too alkaline to be drinkable.

The writer's observations accord in general with the conclusions of Perry[4]—namely, that good water at depths of 200 to 300 feet can usually be obtained from the Fort Union formation but that the conditions are unfavorable for flowing wells in this part of Montana.

Railroads, settlements, and roads.—A branch of the transcontinental line of the Great Northern Railway runs south from Snowden, Mont., to Sidney and thence westward through the central part of the coal field to Richey, its terminus. A branch of the Northern Pacific Railway extends northeastward from the main line at Glendive, 30 miles south of the coal field, and connects with the Richey branch of the Great Northern at Sidney, 50 miles east of Richey. Another branch of the Northern Pacific Railway extends northwestward from Glendive and passes within 4 miles of the southwest corner of the Richey-Lambert coal field.

Richey, with a population of 362 in 1930, is the largest town and the chief trading and shipping center in the coal field. Other settlements are Lane, Enid, and Lambert, on the Great Northern Railway. They serve as shipping and trading centers for their immediate neighborhoods. The largest towns near the field are Sidney, the county seat of Richland County; Glendive, the county seat of Dawson County; and Circle, the county seat of McCone County.

A through highway runs from Richey north to Regina, Saskatchewan, and south to Glendive. Graded highways from Circle,

[3] 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.

[4] Perry, E. S., Ground water in eastern and central Montana: Montana Bur. Mines and Geology Mem. 2, pp. 21–26, 1931.

Sidney, and Savage connect with this highway at Richey. Numerous graded roads radiate from the settlements to all parts of the coal field, and prairie roads lead from these to the various ranches and mines. In the less rugged parts of the area an automobile can be driven over the prairie to reach any point desired. The railroad, settlements, and roads are shown on plate 22.

STRATIGRAPHY

The rocks exposed in the Richey-Lambert coal field belong to the Eocene, Oligocene or Miocene, Miocene or Pliocene, Pleistocene, and Recent series. The Eocene series is represented by the Fort Union formation, which contains the coal deposits of the field. In this field the base of the Fort Union formation is not exposed, and about 150 feet of the upper portion has been removed by erosion. Deposits of terrace gravel that are doubtfully assigned to the Oligocene or Miocene and to the Miocene or Pliocene occur on the high hills and uplands in the southern and eastern parts of the field. Other gravel deposits that may be of late Tertiary or Pleistocene age occur at various lower altitudes and are widely distributed through the field. Glacial drift and till of Pleistocene age occur in the northern part of the field. Alluvium of Pleistocene (?) and Recent age covers the floors of the valleys. The thickness and character of the rocks are summarized in the following table:

Rocks exposed in the Richey-Lambert coal field, Mont.

System	Series	Formation	Character	Thickness (feet)
Quaternary.	Recent and Pleistocene (?).	Alluvium.	Silt, sand, and fine gravel of varying thickness deposited along larger stream courses and trenched by present streams.	0–30
		—Unconformity—		
	Pleistocene.	Illinoian or Iowan drift.	Glacial till composed of clay and boulders, in thin irregular patches; glacial erratic boulders of limestone and igneous and metamorphic rocks; some deposited in morainelike belts or ridges. Probably in part rafted by icebergs beyond limit of ice sheet.	0–15
		—Unconformity—		
		Lower terrace gravel.	Isolated deposits of terrace gravel at various altitudes above adjacent streams and 2,350 to 2,700 feet above sea level; composed of clay, silt, sand, and rounded pebbles of igneous and metamorphic rocks. A few boulders of rock similar to Fort Union rocks and detrital coal.	0–40
		—Unconformity—		
Tertiary.	Miocene or Pliocene.	Flaxville (?) gravel.	Terrace gravel of wide extent 2,500 to 2,950 feet above sea level and 600 to 1,050 feet above the Missouri and Yellowstone. Composed of coarse sand and pebbles of igneous and metamorphic rocks; maximum thickness not known.	0–30+
		—Unconformity—		
	Oligocene or Miocene.		Terrace gravel capping isolated hills in the highest parts of the field 2,750 to 3,100 feet above seal level and 850 to 1,200 feet above the Missouri and Yellowstone; composed of coarse sand and pebbles of metamorphic and igneous rocks; maximum thickness not known.	0–15+
		—Unconformity—		

Rocks exposed in the Richey-Lambert coal field, Mont.—Continued

System	Series	Formation	Character	Thickness (feet)
Tertiary.	Eocene.	Fort Union formation.	Tongue River member: Light-yellow to light-gray sandstone and gray to white shale, commonly lenticular and locally cross-bedded. Contains several thick extensive beds of lignite which have burned at some outcrops, fusing and baking the overlying rock to slag and clinker. Upper part of member removed by erosion.	950±
			Lebo shale member: Interbedded gray sandstone and dark-gray shale with a few beds of buff to light-yellow sandstone. Sandstone is usually lenticular and cross-bedded. Small angular brown sideritic concretions are common. Base of member not exposed in this field.	300+

TERTIARY SYSTEM

EOCENE SERIES

FORT UNION FORMATION

The rocks of the Fort Union formation, except for the areas that are covered by the thin mantle of terrace gravel, glacial till, and alluvium, are the surface rocks over the entire field. They are about 1,230 feet thick in the Richey-Lambert field, but this is not the full thickness of the formation, for the base is not revealed, and about 150 feet of the upper part has been removed by erosion. The formation is separated into two members—the Lebo shale member below and Tongue River member above. Fossil plant remains are abundant, and shells of fresh-water mollusks are common, but the stratigraphic range of these forms is so wide that they are not useful in determining closely the age of the strata. The identification of the formation and members is based on their lithology and continuity with other fields where the beds have been identified.[5]

LEBO SHALE MEMBER

The Lebo shale member crops out in the northwestern part of the Richey-Lambert field along Redwater Creek and its tributaries. Commonly it is dissected into badlands that offer a contrast to the rolling topography of the Tongue River member (see pl. 24, *A*). The Lebo member is made up of thin beds of dark-gray finely laminated shale, thick massive or lenticular beds of cross-bedded gray argillaceous sandstone, thin beds of dark-gray to black carbonaceous shale, and, in the upper part of the member, scattered thin beds of buff to

[5] Thom, W. T., Jr., and Dobbin, C. E., Stratigraphy of Cretaceous-Eocene transition beds in eastern Montana and the Dakotas: Geol. Soc. America Bull., vol. 35, pp. 493–495, 1924.

light-yellow massive argillaceous sandstone. Layers of limy concretions occur at many horizons. Layers of siderite, which weathers into angular pebbles, give the outcrops a rusty appearance.

A petrographic examination of a sample obtained from a sandstone bed near the middle of the member in sec. 8, T. 24 N., R. 51 E., showed a considerable amount of silt and clay and secondary calcite. The material was washed and cleaned in the laboratory with dilute hydrochloric acid and separated into light and heavy fractions by treatment with bromoform of specific gravity 2.88. The light fraction was found to be composed of a large number of angular grains of glassy quartz and a minor amount of subangular frosted grains of quartz, angular grains of orthoclase and oligoclase, grains of primary and secondary calcite, rounded grains of chert, particles of coal, flakes of mica and chlorite, and a few shardlike grains of rhyolitic glass. The heavy fraction was found to be composed dominantly of ilmenite, magnetite, and leucoxene with abundant garnet and epidote; in this fraction titanite and zircon are common, kyanite and sillimanite rare, and tourmaline very rare.

In large exposures the Lebo shale member is readily distinguished from the overlying Tongue River member by the preponderance of gray shale and gray sandstone as contrasted with the yellow sandstones and pale-gray shales of the Tongue River member. The upper part of the Lebo member contains a few beds of yellow sandstone, and the lowest part of the Tongue River member contains beds of dark-gray shale, and so where exposures are small, difficulty is encountered in determining the contact between them. For the purposes of mapping, the contact was placed arbitrarily at the base of the lowest thick yellow sandstone. This horizon is from 30 to 40 feet below the Carroll coal bed, and where the sandstone does not crop out the contact was drawn 30 feet below the Carroll coal bed. Only the uppermost 300 feet of the Lebo shale member is exposed in the Richey-Lambert coal field, but estimates made by Collier[6] in T. 22 N., Rs. 46 and 47 E., in McCone County, where the entire formation is revealed, indicate that the thickness of the Lebo shale member in this part of Montana is about 350 feet. The lower contact of the member in that and other counties in Montana is placed at the base of the Big Dirty bed, the highest persistent coal bed below the gray shale beds.

TONGUE RIVER MEMBER

The Tongue River member is at the surface over most of the Richey-Lambert field and at most places forms a rolling sod-covered surface. It is composed predominantly of thick cross-bedded or massive beds of yellow, light-buff, or white sandstone interbedded

[6] Collier, A. J., personal communication.

with light-gray shale and a few beds of thin brown carbonaceous shales. (See pl. 23, *B*.) It includes a few thick extensive beds of lignite and many thin lenticular or discontinuous beds of lignite. Near the base of the member a few beds of dark-gray shale are interbedded with the lighter-colored sandstone and shale. Discontinuous beds of calcareous concretions are common at all horizons, and many of the sandstones have numerous ferruginous concretions about the size and shape of toy marbles.

A petrographic examination of a sample from the lowest thick bed of yellow sandstone in sec. 8, T. 24 N., R. 51 E., showed a considerable amount of clay and fine material. The material was washed and treated in the laboratory with dilute hydrochloric acid and separated into light and heavy fractions by treatment with bromoform of specific gravity 2.88. The lighter fraction was found to be composed preponderantly of angular and subangular glassy grains of quartz and a minor amount of rounded subangular frosty grains of quartz, subangular to rounded grains of orthoclase, plagioclase, chert, and coal, flakes of mica and chlorite, and a few grains of mica schist. In the heavy fraction ilmenite, magnetite, and leucoxene were most prominent, titanite and tourmaline abundant in about equal amounts, garnet slightly less abundant, epidote common, zircon, in broken stubby crystals, and rutile scarce, and hornblende and zoisite rare. The difference in mineral composition of the heavy fractions of the sample from the Lebo shale and Tongue River members suggests a possibility of differentiating the members on the basis of relative percentages of garnet and tourmaline, but many more samples from other beds in the members must be shown to have similar characteristics before such criteria could be accepted as being diagnostic.

The upper part of the Tongue River member has been removed by erosion in the Richey-Lambert field, but about 950 feet of the member is exposed. Collier found that the Tongue River member in McCone County has a thickness of nearly 1,100 feet and is overlain by the Sentinel Butte shale member of the Fort Union (?) formation. In the Richey-Lambert field not only is the Sentinel Butte member absent but about 150 feet of the Tongue River member has been removed by erosion.

OLIGOCENE OR MIOCENE SERIES

An old gravel caps the summits of the highest hills and ridges rising above the Retah Table (see pls. 23, *B*, and 26) and isolated hills elsewhere along the divide between the Yellowstone and Missouri Rivers. The deposit is as much as 15 feet thick at the best exposures, but the maximum thickness may be greater. Its surface

is rounded, suggesting that the upper portion of the gravel bed has been removed by erosion. The contact between this gravel and the underlying Tongue River member of the Fort Union formation is locally irregular but forms a rather even plane dipping to the northeast, slightly discordant to the dip of the Tongue River strata. The altitude of the contact ranges from 3,100 feet above sea level, or 1,200 feet above the Yellowstone and Missouri Rivers, on the Retah Table to 2,750 feet above sea level, or 850 feet above the Missouri and Yellowstone, in the northeastern part of the field.

The gravel is composed of coarse, well-rounded pebbles of various igneous and metamorphic rocks, including quartzite, granite, and volcanic rocks in a matrix of fine gravel, sand, and silt. Most of the pebbles are one-eighth inch to 2 inches in diameter, but the largest are 3 inches in diameter. The gravel is generally unconsolidated but locally is cemented by lime.

As no fossils were found in the gravel, its age cannot be determined directly. It is separated from the Tongue River member by an angular unconformity, which represents a time of deformation and of erosion of 150 to 200 feet of the Tongue River member and also of an unknown amount of the overlying Sentinel Butte member of the Fort Union (?) formation. This gravel is tentatively correlated with the gravel on the Cypress Hills, Saskatchewan, on the basis of its height above the Missouri and Yellowstone Rivers, its composition, and its relation to lower terraces, for it resembles in these respects the gravel capping Big Sheep Mountain, in T. 15 N., R. 47 E., Montana, that was tentatively correlated by Alden[7] with the gravel on the Cypress Hills.

MIOCENE OR PLIOCENE SERIES

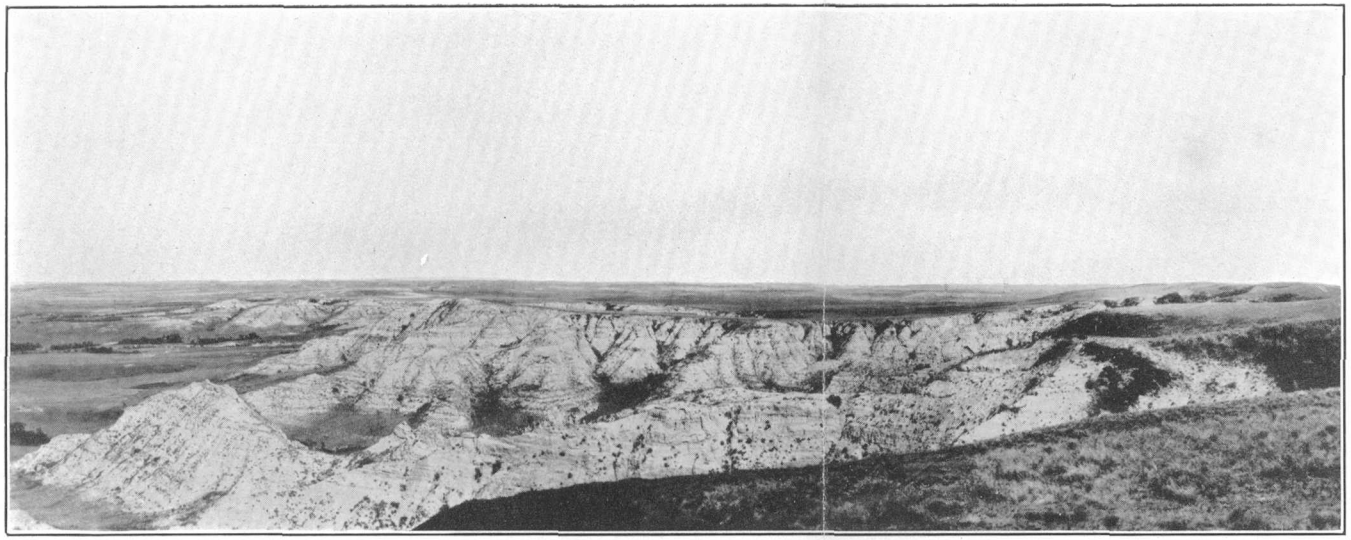
FLAXVILLE (?) GRAVEL

The gravel that is tentatively correlated with the Flaxville gravel floors the flat or gently rolling upland surface of nearly 90 square miles in the southern and eastern parts of the Richey-Lambert coal field. (See pl. 26.) It is commonly as much as 30 feet thick, and is indistinguishable in character from the Oligocene (?) gravel, but it is much wider in extent and lies 150 to 200 feet lower. It is 2,700 to 2,950 feet above sea level, or 800 to 1,050 feet above the Missouri and Yellowstone Rivers. Its contact with the underlying Tongue River member slopes about 10 feet to the mile to the southeast, or about 10 feet to the mile less than the dip of the Tongue River strata.

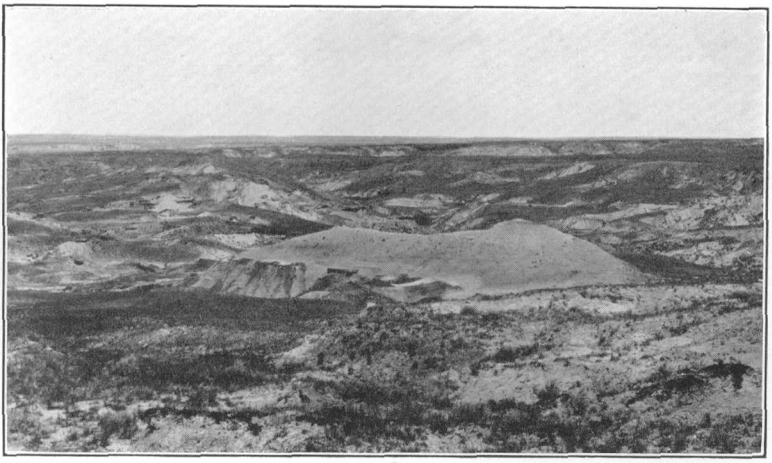
No fossils were found in this gravel in the Richey-Lambert area, but the wide extent and high altitude of the deposit suggest that it is the

[7] Alden, W. C., Physiography and glacial geology of eastern Montana: U. S. Geol. Survey Prof. Paper 174, p. 12, 1932.

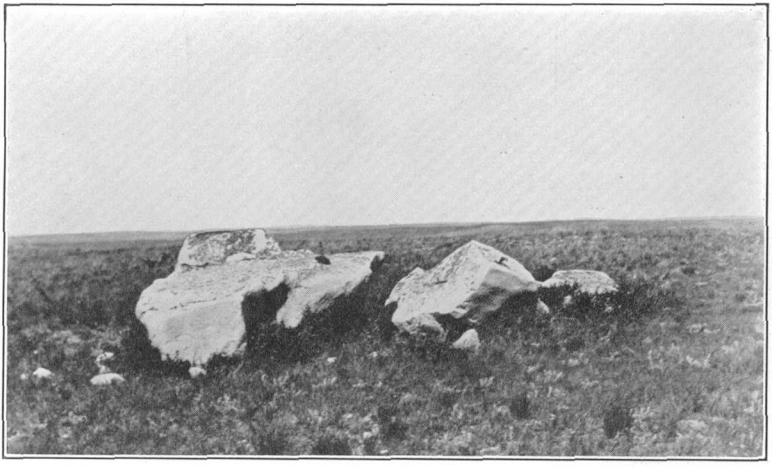
A. VIEW LOOKING SOUTHEAST ACROSS THE PLEISTOCENE DIVERSION CHANNEL OF THE MISSOURI RIVER WEST OF MANROCK STATION.



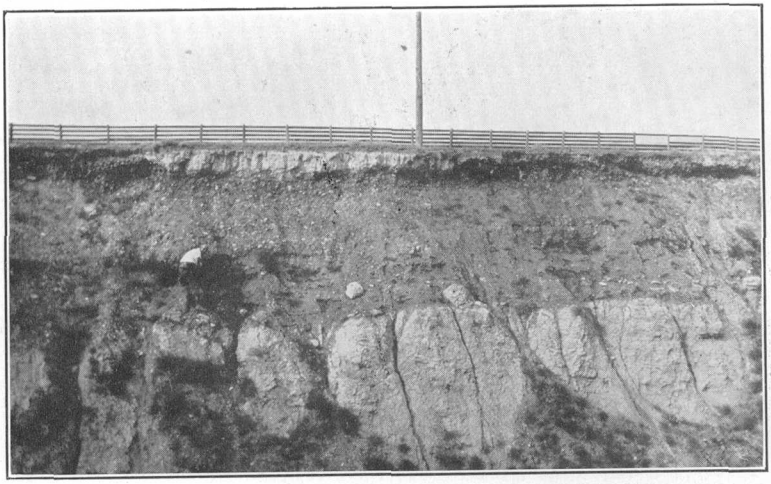
B. OUTCROP OF TONGUE RIVER MEMBER IN ESCARPMENT OF RETAH TABLE.



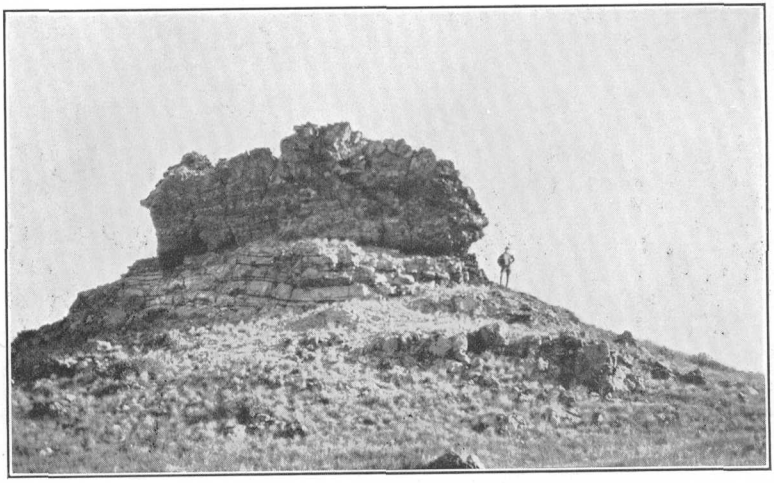
A. EXPOSURES OF LEBO SHALE MEMBER IN BADLANDS, T. 24 N., R. 51 E.



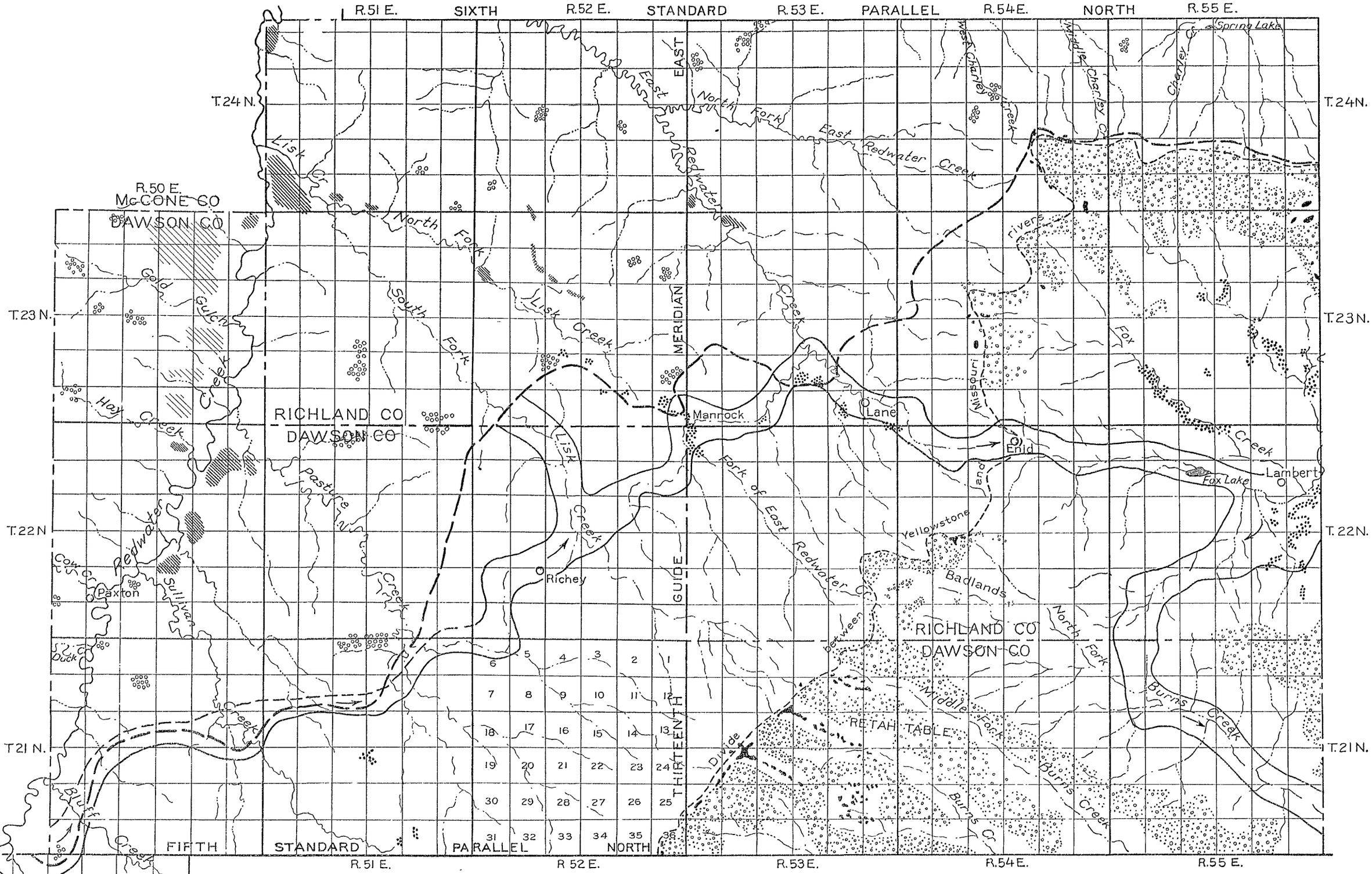
B. GLACIAL ERRATIC BOULDERS OF LIMESTONE, T. 24 N., R. 51 E.



A. TERRACE GRAVEL CONTAINING BOULDERS OF TONGUE RIVER ROCK AND DETRITAL COAL.



B. CLINKERS FORMED BY BURNING OF THE UNDERLYING PUST COAL BED, SEC. 36, T. 21 N., R. 55 E.



EXPLANATION

QUATERNARY	Pleistocene (?) and Recent	Postglacial terrace — *30 to 60 feet above adjacent streams*	QUATERNARY (CONT'D)	Pleistocene (continued) — Illinoian or Iowan: Boulder ridge — *Apparently morainal*
	Pleistocene	Southern boundary of occurrence of erratics and probably of Illinoian or Iowan ice sheets		Glacial till
		Diversion channel of Missouri River		Lower terrace gravel
		Upper terrace — *About 200 feet above Redwater Creek*	TERTIARY	Miocene or Pliocene: Flaxville (?) gravel
				Oligocene or Miocene: High-terrace gravel

MAP SHOWING GEOMORPHIC FEATURES OF THE RICHEY-LAMBERT COAL FIELD.

equivalent of the gravel of the Flaxville Plain, of upper Miocene or Pliocene age.[8] This plain extends over large areas in the northeastern part of Montana at altitudes ranging from 2,600 feet at the east to 3,200 feet at the west. Its altitude north of Wolf Point, about 60 miles from the Richey-Lambert field, is about 2,750 feet above sea level, or 800 feet above the Missouri River. The high altitude of the Flaxville (?) in the Richey-Lambert field may be due to its nearness to the still higher gravel-capped divide toward which the Flaxville Plain would presumably slope upward. The Flaxville (?) gravel in the Richey-Lambert field is of essentially the same character as the Flaxville gravel of northeastern Montana, and probably both were derived largely from similar older and once more extensive gravel deposits such as that on Big Sheep Mountain, to the southeast, and on the Cypress Hills, in southern Saskatchewan.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

LOWER TERRACE GRAVEL

Gravel deposits of small extent but widely distributed through the field stand at various altitudes from 2,300 to 2,700 feet above sea level. This gravel consists of rounded pebbles and coarse sand similar in composition to and probably derived from the Flaxville gravel, together with boulders of shale and sandstone and layers of detrital coal, silt, and clay, probably derived from the underlying Fort Union rocks. (See pl. 25, *A*.) Most of this gravel is adjacent to present streams and less than 50 feet above them. A few remnants of gravel deposits are found on ridges within a few miles north or west of the divide. These deposits are a hundred feet or more below the Flaxville Plain of the neighboring uplands.

The gravel on the ridges was deposited in ancient stream courses that existed in the earlier part of the Pleistocene epoch, before the development of the present drainage system, but the deposits adjacent to the present streams were formed later in Pleistocene time, after the present drainage system was well established. These deposits and the wide cut terrace on the west side of Redwater Creek may correspond to an early Pleistocene terrace along the Missouri River. The presence of glacial erratics on the surface of the terraces near Lane and Manrock and the absence of glacial material from the gravel show that those terraces, at least, were formed before the advance of the ice sheet into this area.

[8] 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.

IOWAN OR ILLINOIAN STAGE OF GLACIATION

Glacial till.—Small patches of glacial till, none more than 15 feet in thickness, are widely distributed over the northern part of the Richey-Lambert field. (See pl. 26.) The till, as shown by the few exposures, is composed of unsorted subangular boulders and pebbles of igneous and metamorphic rocks and limestone, coarse and fine sand, and clay. Most of the patches that have been mapped as till by the writer are not exposed in cross section but are regarded as till because of the presence of thick dark soil, distinct from the soil derived from Fort Union rocks, containing pebbles and boulders similar to those found in exposures of till. Alden[9] considers the glacial drift of this part of Montana to be of Illinoian or Iowan age.

In the northern part of sec. 4, T. 20 N., R. 50 E., and the southern part of sec. 31, T. 21 N., R. 50 E., and near the southeast corner of sec. 17, T. 22 N., R. 50 E., till has been baked and fused by burning of underlying coal beds.

Glacial erratics.—Glacial erratic material, including all gradations in size from small pebbles to boulders 6 feet in diameter (pl. 24, *B*), is strewn over the surface of the Richey-Lambert field north of the limit of the ice sheet (pl. 26). Boulders of granite or gneiss are most abundant, but there are also boulders of limestone, quartzite, schist, gabbro, and volcanic rock. A narrow ridge of boulders 3 to 6 feet in height extends through part of T. 23 N., R. 52 E., and possibly represents a moraine formed during the recession of the ice front. Some of the boulders at the lower levels in the southern part of the glaciated area may have been rafted by ice in ponded water along the ice front to their present position.

PLEISTOCENE (?) AND RECENT ALLUVIUM

The valleys of Redwater Creek and the other creeks in the Richey-Lambert area are filled with alluvium to a depth of as much as 30 feet. The alluvium is shown on plate 22 only where its extent is great, but it is present in almost all the smaller valleys of the area. It is unusually thick in the small valleys north of the escarpment that follows the divide between the Missouri and Yellowstone Rivers. The alluvial material consists principally of fine sand and clay with a few lenses of coarse sand and gravel.

At the present time the surfaces of the alluvial flats are above flood level and the alluvium is being eroded by these streams, which are entrenched as much as 30 feet into it. The absence of glacial erratics from the alluvial flats indicates that the alluvium was deposited after the melting of the ice sheet. No fossils have been obtained from the

[9] Alden, W. C., Physiography and glacial geology of eastern Montana and adjacent areas: U. S. Geol. Survey Prof. Paper 174, pp. 69, 82–83, 85–88, pls. 1 and 28, 1932.

alluvium in or near the Richey-Lambert field, and it may be of both Pleistocene and Recent age.

STRUCTURE

The Richey-Lambert coal field lies on the west side of a broad, shallow synclinal depression the center of which is about 70 miles to the east, near Williston, N. Dak. The dip of the strata is slight, and

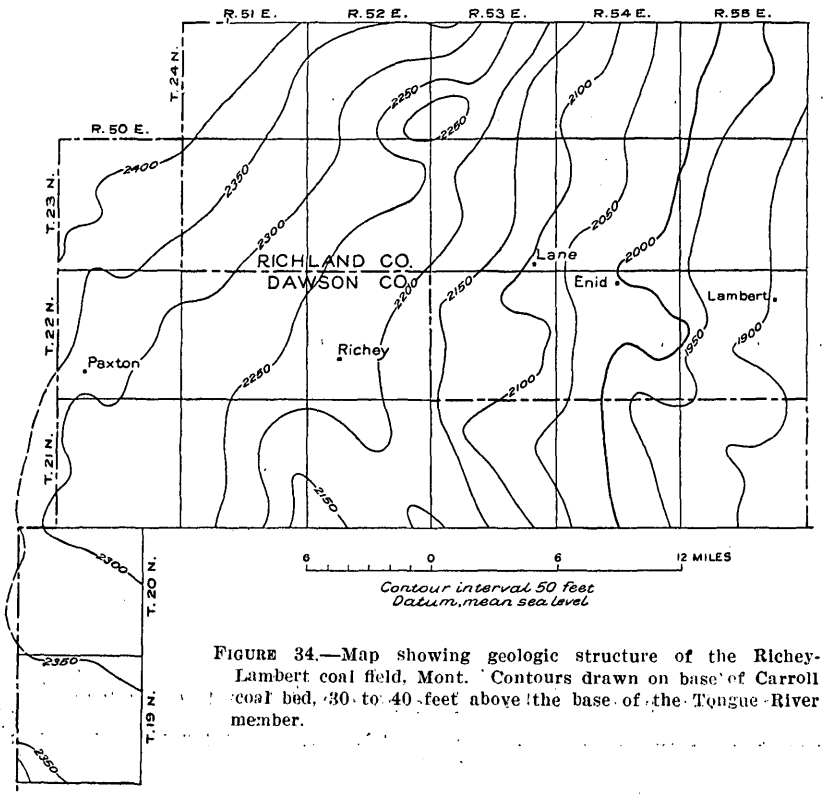


FIGURE 34.—Map showing geologic structure of the Richey-Lambert coal field, Mont. Contours drawn on base of Carroll coal bed, 30 to 40 feet above the base of the Tongue River member.

the total structural relief in the field is not more than 550 feet. The direction of dip is southeast or south in the western part of the field but in the eastern part it gradually changes to east. The map showing the geologic structure (fig. 34) was compiled from altitudes of the outcrops of the coal beds. The structure contours are drawn at the horizon of the base of the Carroll coal bed. Where the Carroll bed is not exposed stratigraphic intervals between it and the exposed beds were computed to determine its altitude. Because of the uncertainty in calculating the stratigraphic intervals, the contours represent only an approximation of the true structure of the field.

The only prominent folds in the field are a small dome with a closure of about 50 feet in T. 24 N., Rs. 52 and 53 E.; an anticline

with a structural relief of less than 100 feet extending beyond the limits of the field southeast of Richey; and a low anticline in T. 19 N., R. 50 E. The depth to which these minor folds extend cannot be determined, but it is possible that folds of this type may be the result of differential compaction of the underlying Lance and Fort Union strata and the normal shrinkage of coal beds subjected to load and may not exist in the deep-lying strata.

GEOMORPHIC HISTORY

The Richey-Lambert coal field lies at the southern border of the glaciated portion of the northern Great Plains. Several different terraces, as well as several features due to glaciation, are found in the field. Only the relative ages of the erosional and glacial features can be obtained from evidence within the field itself. The ages assigned to them in this report depend upon tentative correlations with similar features of known age occurring elsewhere in Montana. The ages of geomorphic features in Montana and the criteria used in determining these ages have been discussed by Alden.[10]

Pre-Oligocene (?) surface.—The Oligocene (?) gravel, the highest gravel in the region, rests upon a gently undulating erosion surface that bevels the slightly tilted rocks of the Fort Union formation. Presumably this surface at one time extended over much of the northern Great Plains. The dip of the surface is about 10 feet to the mile to the northeast and may represent the original grade of the erosion plain.

Flaxville (?) surface.—After the deposition of the Oligocene (?) gravel the region was subjected to active erosion, probably as a result of uplift or climatic change; and the streams not only removed great areas of the Oligocene (?) gravel but cut 150 to 200 feet deeper into the Fort Union rocks and formed a wide peneplain with only a few low hills and ridges rising above it. The Flaxville (?) gravel was deposited by streams in Miocene or Pliocene time in very broad, shallow valleys between the hills and ridges that were capped by the Oligocene (?) gravel. Probably much of the Flaxville (?) gravel was derived from erosion of the Oligocene (?) gravel. Although the Flaxville Plain north of the Missouri River slopes to the east, in contrast to its southeasterly direction in the Richey-Lambert field, the plain has perhaps not been warped. The southeast slope in the Richey-Lambert area is probably the original position of the plain, as it is marginal to remnants of the Oligocene (?) plain and would be expected to rise toward these higher ridges and hills.

[10] Alden, W. C., op. cit. (Prof. Paper 174).

Pliocene and early Pleistocene surface.—Much of the surface of the Richey-Lambert coal field was carved to practically its present form during the long period of erosion that followed the deposition of the Flaxville (?) gravel and continued until the advance of the ice sheet in the Illinoian or Iowan stage of the Pleistocene epoch. By the time the ice sheet advanced erosion had carved away most of the Flaxville (?) Plain, leaving in essentially their present form the escarpment and rolling hills and broad valleys of the portion of the field north of the Yellowstone-Missouri divide. Gravel derived from the Flaxville (?) Plain was deposited along the stream valleys, and through subsequent erosion areas of this gravel were left capping or flanking hills at levels well above the present streams. Probably the terrace 200 feet above Redwater Creek in T. 23 N., R. 50 E., belongs to this period of erosion.

Glacial features.—Although glaciation is known to have occurred several times in the Dakotas, it was only during the Illinoian or Iowan glacial stage that an ice sheet advanced as far southward as the Richey-Lambert field.[11] As this ice sheet advanced it forced the Missouri River from the portion of its channel north of the Richey-Lambert coal field and diverted it across this area. In the western part of the area the Missouri flowed eastward along the ice front and was ponded in some valleys. On a lake of this sort, in the valley of Redwater Creek, glacial erratic boulders were rafted by icebergs as far as 30 miles south of Paxton. The glacial diversion channel of the river (see pl. 23, *A*) left few traces in the western part of the field, for there it presumably followed different courses as the ice front advanced and retreated, but it is well marked east of Richey by a continuous belt of alluvium (see pl. 22) and by a series of low passes across not only the divides between the major creeks but even the divide between the Missouri and Yellowstone. Among the changes in drainage along the old channel is the piracy of the headwater portion of Lisk Creek south of Manrock, whereby this portion of Lisk Creek became tributary to East Redwater Creek. This piracy was a result of the cutting down by the river of the former divide between Lisk and Redwater Creeks where the diversion channel crossed it near Manrock.

The ice sheet probably caused little change in the topography of the area over which it passed. The deposits of till are thin and small and form only small hummocks. The writer concludes that the ice sheet was perhaps only a few hundred feet thick and not heavily loaded with detritus. The limit of the ice sheet, which is roughly shown by the distribution of the erratic boulders, coincides in the northern part of the field with the escarpment at the Missouri-

[11] Alden, W. C., op. cit. (Prof. Paper 174), pl. 1.

Yellowstone divide, indicating that the thickness of the ice was not great enough to override the higher ridges and the escarpment. (See pl. 26.)

Postglacial terrace.—After the melting of the ice, erosion was slightly accelerated, and the larger streams deepened their valleys 30 to 60 feet. The remnants of the former valley floors are here designated the "postglacial terrace." This terrace is distinct only adjacent to Redwater Creek. Elsewhere in the area it is represented by gentle valley slopes, which in a few places have a terracelike form adjacent to the larger creeks. The absence of glacial erratic boulders from the surface of this terrace shows that it was formed after the recession of the Illinoian or Iowan ice sheet.

Alluvial terrace and present streams.—After the formation of the postglacial terrace erosional activity increased, and the streams cut moderately wide, trenchlike valleys to depths of 30 to 70 feet below it. At the same time badlands and sharp tributary gullies were formed, and the escarpment at the Missouri-Yellowstone divide was cut farther back toward the southeast. Erosional activity then slackened, and alluvium was deposited and wide alluvial flats were formed. Near the center of the valleys the alluvium is over 30 feet thick.

After the deposition of the alluvium, erosion again became active, and at the present time the major streams flow in meandering trenches cut to depths of 30 feet into the alluvial filling of the valley bottom, the former alluvial flats being left as wide terraces, here designated the alluvial terrace. The extent of this terrace is indicated in a general way by the pattern representing alluvium on plate 22.

The stream trenches expose Fort Union strata only where meanders swing close to the margins of the alluvial flats. The major streams are now eroding their banks laterally, and downcutting is almost imperceptible. The smaller streams in many places have cut through 15 to 20 feet of alluvium and a few feet of bedrock and are still actively cutting downward and headward. The headward erosion of the smaller streams into the alluvium is noticeable in a single storm, and in the last decade the heads of the gullies in many places have retreated hundreds of feet. The rapid retreat of the heads of the gullies is graphically shown by the progressive relocation of prairie roads to skirt the heads of the gullies, the old stream crossings having become impassable by the deep trenching of the alluvium. The divide between the Missouri and Yellowstone Rivers is slowly continuing its retreat to the southeast begun in Pliocene time, and badlands are continuing to grow by dissection of the mature Pliocene surface.

Stream bluffs.—Bluffs occur at many places along the major streams, most commonly where the streams meander close to the

margins of the alluvial flats. These bluffs have been in process of formation since the start of the downcutting that formed the post-glacial terrace. They occur more commonly on the right side of the stream, regardless of the geologic structure of the bedrock or the direction in which the stream flows. For example, tributaries of Fox Creek that flow southeastward show the cutting of the right bank as prominently as Pasture and Lisk Creeks, which flow northwestward. Sullivan Creek is the only exception to this general condition. This selective erosion of the right bank may be a result of deflection of the stream by rotation of the earth.[12]

COAL

DISTRIBUTION AND CORRELATION OF THE COAL BEDS

All the thick coal beds cropping out in the Richey-Lambert field occur in the Tongue River member of the Fort Union formation. The strata are so nearly horizontal that the highest beds crop out at the higher altitudes, and the exposures of the beds follow closely the contours of the surface, forming large reentrants in the valleys and intricate patterns in the badlands. The beds vary in thickness or pinch out along the outcrop and, with the possible exception of the Carroll bed and the Big Dirty bed (not exposed), none of the beds occur beneath every township of the field. Plate 27 shows the thicknesses of the rocks exposed and also the stratigraphic positions and variations in thickness of the coal beds.

The beds derive their names from the names of mines or prospects upon them or from the names of the owners of ranches where they crop out. No definite correlation can be made between beds of the Richey-Lambert field and beds of the other fields in eastern Montana (see fig. 33), but the Pust bed occupies approximately the same stratigraphic position as the thick bed in sec. 1, T. 19 N., R. 56 E., tentatively correlated by Stebinger [13] with bed G of the Sidney field.

The coal beds described below and shown on plate 22 are the only ones of commercial value in the Richey-Lambert field. Where coal beds have more than one bench, the outcrop of the thickest bench is shown on the geologic map. Where the benches are essentially equal the outcrop of the lowest bench is shown. Numerous thin beds of small extent were found and examined, but such beds were not mapped.

Big Dirty bed.—The Big Dirty bed, which occurs at the base of the Lebo shale member, does not crop out in the Richey-Lambert

[12] Gilbert G. K., The sufficiency of terrestrial rotation for the deflection of streams Am. Jour. Sci., 3d ser., vol. 27, pp. 427–432, 1884. Baines, A. C., On the sufficiency of terrestrial rotation for the deflection of streams: Idem, vol. 28, pp. 434–436, 1884.

[13] Stebinger, Eugene, The Sidney lignite field, Dawson County, Mont.: U. S. Geol. Survey Bull. 471, p. 304, 1912.

field but was examined at a mine on its outcrop on Redwater Creek in sec. 23, T. 25 N., R. 50 E. At that point it is over 11 feet thick but contains four thin sandy partings. (See p. 157.) This bed or its equivalent is present at the base of the Lebo shale member over a large area in eastern Montana both north and south of the Richey-Lambert field and possibly underlies the entire field, where its depth from the surface may range from 100 to 1,200 feet. In most places this bed contains a great deal of impure coal and a large number of partings.

Carroll bed.—The Carroll bed, named from the Carroll mine, occurs 30 to 40 feet above the base of the Tongue River member and is found wherever this horizon is exposed in the field. Within the field the bed ranges in thickness from 2 feet at locality 127, in sec. 12, T. 23 N., R. 51 E., to 9 feet at locality 226, in sec. 6, T. 20 N., R. 50 E., but the average thickness is about 4 feet. The coal is usually pure and homogeneous, but in places numerous partings may be included. An analysis of coal from this bed at the Carroll mine (locality 146), in sec. 8, T. 22 N., R. 51 E., shows the coal as mined to have a heating value of 7,400 British thermal units.

Butterfield bed.—The Butterfield bed, named from the Butterfield mine, crops out in the southwestern part of the field about 100 feet above the Carroll bed. It usually consists of two benches separated by 3 to 20 feet of shale or sandstone. The lower bench attains a maximum thickness of 3 feet at locality 22, in sec. 9, T. 20 N., R. 50 E., and the upper bench attains a maximum thickness of 3 feet 7 inches at locality 212, in sec. 1, T. 20 N., R. 50 E. The bed becomes thinner to the north and was not mapped north of T. 21 N., R. 50 E. The lower bench of this bed has approximately the same stratigraphic position as the upper bench of the Lane beds, but no evidence was found to show that they are continuous.

Lane bed.—The Lane bed, named from the Lane mine, crops out in the northwestern and north-central parts of the field about 100 feet above the Carroll bed. In the north-central part of the field the bed is thick and usually contains rather pure coal. The maximum thickness measured is at the Lane mine (locality 57), in sec. 26, T. 23 N., R. 53 E., where the bed contains almost 11 feet of coal, including a 3-inch parting near the top, but because of the purity and thickness of the bed the coal is burned along most of its outcrop. In the northwestern part of the field the bed is thinner and was not mapped west of T. 22 N., R. 51 E. In this township an upper bench is present 4 to 22 feet above the Lane bed. The maximum thickness measured on the upper bench is 3 feet 8 inches at locality 150, in sec. 22. A sample collected from this bed at the Lane mine shows the coal as mined to have a heating value of 7,150 British thermal units.

Budka bed.—The Budka bed, named from the Budka ranch, crops out in the northern part of the field 40 to 60 feet above the Lane bed. It reaches a maximum thickness of 4 feet at locality 39, in sec. 25, T. 24 N., R. 53 E. North of this locality the bed is thinner and could not be traced beyond the east boundary of the township. South of the Updegraff mine, in sec. 2, T. 23 N., R. 53 E., the bed splits into several thin benches, which could not be traced. The bed usually contains a large number of partings, and the coal is somewhat bony.

Gaines bed.—The Gaines bed, named from the Gaines ranch, crops out in the southwestern part of the field about 210 feet above the Carroll bed. The bed varies in thickness and purity and was not mapped except where local thickening makes it of possible commercial interest. The bed commonly contains partings and in some places consists of two or three benches. The maximum thickness measured is 4 feet 6 inches, including partings, at locality 231, in sec. 31, T. 20 N., R. 50 E. Although all the outcrops marked "Gaines bed" on plate 22 occur at approximately the same stratigraphic position, it is possible that they are discontinuous and represent local lenses.

Solack bed.—The Solack bed, named from the Solack ranch, was mapped in T. 21 N., Rs. 51 and 52 E. It occurs about 260 feet above the Carroll bed and about 240 feet below the Pust bed. The bed is over 5 feet thick at locality 160, in sec. 14, T. 21 N., R. 51 E., but elsewhere it does not exceed 4 feet 6 inches. The coal bed contains many partings, and the coal is usually very dirty.

Lower Elvirio bed.—The Lower Elvirio bed, named from the Elvirio mine, 190 feet above the Lane bed, is of importance only in the northern part of T. 24 N., Rs. 54 and 55 E. The maximum thickness observed is at the Elvirio mine (locality 11), in sec. 12, T. 24 N., R. 54 E., where the bed contains 6 feet 11 inches of clean coal with two thin partings. Eastward the bed thins to 2 feet 8 inches at locality 9, in sec. 9, T. 24 N., R. 55 E., and thickens to 5 feet at locality 1, in sec. 1, T. 24 N., R. 55 E. Westward the bed becomes thinner, with increasing impurities, and could not be traced south of locality 32, in sec. 29, T. 24 N., R. 54 E. An analysis of coal from this bed at the Elvirio mine shows it to have a heating value as mined of 6,710 British thermal units.

Upper Elvirio bed.—The Upper Elvirio bed, 15 to 25 feet above the Lower Elvirio bed, is mapped in the central part of the field. The coal varies in thickness and purity, but the bed is persistent and is traceable from the Elvirio mine southward to locality 66, in sec. 7, T. 22 N., R. 54 E. The maximum thickness measured is 5 feet 4 inches at locality 41, in sec. 8, T. 23 N., R. 54 E. The bed in T. 23 N., Rs. 52 and 53 E., marked "Upper Elvirio?" on the geologic map, occurs at about the same stratigraphic position as the Upper Elvirio bed and may be an outlier of that bed. A well in sec. 30, T. 22 N.,

R. 55 E., penetrates a coal bed at the horizon of the Upper Elvirio bed, suggesting that that bed is continuous under a large area of the southeastern part of the field.

Stillson bed.—The Stillson bed, named from the Stillson mine, crops out in the southwestern part of the field about 400 feet above the Carroll bed and about 80 feet below the Pust bed. In T. 21 N., R. 51 E., at locality 185, in sec. 28, the bed contains 6 feet 5 inches of coal, and at locality 174, in sec. 27, it contains 6 feet 7 inches. At the Stillson mine (locality 237), in sec. 15, T. 19 N., R. 50 E., it contains 5 feet 11 inches of coal. The average thickness of the bed where it is mapped is about 4 feet.

Pust bed.—The Pust bed, named from the Pust mine, about 180 to 220 feet above the Upper Elvirio bed, is the only bed of commercial value in the southeastern part of the field. The bed is thin and of poor quality in the northern part of the field and could not be traced northeastward beyond locality 10, in sec. 19, T. 24 N., R. 55 E., where it contained only 2 feet of coal. In the central part of the field the bed contains an average thickness of about 5 feet of good coal. At the Painter mines (localities 267, 268, and 270), in secs. 28 and 33, T. 23 N., R. 54 E., the Pust bed contains 4 feet 7 inches to 6 feet 2 inches of coal, and at locality 269 a lower split, containing 3 feet of coal, is present 15 feet below the main Pust bed. Northeast of locality 274 the bed splits into thin beds containing carbonaceous shale. The maximum thickness observed on the Pust bed is at locality 259, in sec. 36, T. 21 N., R. 55 E., where the bed is 21 feet 8 inches thick and contains over 17 feet of good coal. The average thickness in the southern part of the field is about 11 feet. An analysis of a sample of coal from this bed at the Otto Pust mine (locality 265), in sec. 33, T. 22 N., R. 55 E., shows the coal as mined to have a heating value of 6,880 British thermal units.

Prittegurl bed.—The Prittegurl bed, named from the Prittegurl mine, crops out in the northeastern part of the field about 100 feet above the Pust bed. The bed contains 5 feet 8 inches of coal at the east border of the field at locality 2, in sec. 25, T. 24 N., R. 55 E., and thins irregularly to the west to 1 foot 9 inches at locality 7, sec. 28. The outcrop is concealed by terrace gravel in T. 23 N., R. 55 E., but at locality 278, in sec. 11, three thin coal beds separated from one another by 10 to 15 feet of shale and sandstone are exposed in a small badland area at approximately the horizon of the Prittegurl bed.

PHYSICAL AND CHEMICAL CHARACTER OF THE COAL

The coal of the Richey-Lambert field ranks as a good grade of lignite. It has a subconchoidal fracture and a brown streak. A fresh surface transverse to the bedding usually shows compact alter-

nate layers of dull and shiny material, but with exposure to the air the coal loses moisture and the surface becomes dull and lined with fine cracks, which deepen and multiply until finally the entire mass slacks to small grains and powder. Such slacking can be prevented by storage under water or in airtight bins. Frequently the woody texture of the original material is preserved with only a moderate flattening of the cells. In some places carbonized trunks of trees are present, and in one place part of a trunk has been silicified and the remainder transformed to coal. The beds usually contain bony layers and partings of shale.

In the table below are presented analyses of coals of the Richey-Lambert field and, for comparison, coals of various classes from fields elsewhere in the United States. Should commercial exploitation of the Richey-Lambert coal be attempted, competition in the market would be offered by coals of the classes listed in the table. Three forms of analyses are given. Form A represents the composition of the sample as received in the laboratory of the United States Bureau of Mines and approximates the composition of the coal as mined. Form B represents the composition of the sample with moisture excluded. Form C represents the composition of the sample with both moisture and ash excluded. Coal does not exist in nature with the composition shown in forms B and C, but these forms are included for the purpose of simplifying comparison.

Analyses of samples of coal from the Richey-Lambert field and of representative samples from other fields

Laboratory no.	Kind of coal and locality	Form of analysis	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Heating value	
								Calories	British thermal units
	Richey-Lambert field								
A65453	Lignite from Pust bed, Pust mine, sec. 28, T. 22 N., R. 55 E.	A	38.3	25.4	30.3	6.0	0.5	3,822	6,880
		B		41.1	49.2	9.7	.8	6,189	11,140
		C		45.6	54.4		.9	6,856	12,340
A65451	Lignite from Lower Elvirio bed, Elvirio mine, sec. 12, T. 24 N., R. 54 E.	A	38.3	25.7	30.0	6.0	.5	3,728	6,710
		B		41.6	48.6	9.8	.8	6,044	10,880
		C		46.1	53.9		.9	6,700	12,060
A65454	Lignite from Lane bed, Lane mine, sec. 26, T. 23 N., R. 53 E.	A	36.5	26.9	30.0	6.6	.9	3,972	7,150
		B		42.4	47.2	10.4	1.4	6,250	11,250
		C		47.4	52.6		1.5	6,978	12,560
A65452	Lignite from Carroll bed, Carroll mine, sec. 8, T. 22 N., R. 51 E.	A	33	25.5	36.0	5.5	.3	4,111	7,400
		B		38.1	53.7	8.2	.5	6,139	11,050
		C		41.5	58.5		1.6	6,683	12,030
	Other fields								
A45204	Lignite from Williston, N. Dak., Reclamation mine of Montana & Dakota Power Co.	A	37.9	26.7	30.4	5.0	.5	3,889	7,000
		B		43.0	49.0	8.0	.9	6,256	11,260
		C		46.7	53.3		1.0	6,806	12,250
A45881	Lignite from Zap, N. Dak., mine of Lucky Strike Coal Corporation.	A	33.6	27.1	33.2	6.1	.8	4,272	7,690
		B		40.9	49.9	9.2	1.3	6,439	11,590
		C		45.0	55.0		1.4	7,089	12,760
A45885	Lignite from Beulah, N. Dak., Minot White River Coal Co.	A	34.4	26.7	33.3	5.6	.8	4,139	7,450
		B		40.7	50.8	8.5	1.2	6,311	11,360
		C		44.5	55.5		1.3	6,900	12,420
A35365	Subbituminous coal from Colstrip, Mont., strip mine of Northwestern Improvement Co.	A	24.4	28.3	39.9	7.4	.6	5,028	9,050
		B		37.4	52.8	9.8	.8	6,650	11,970
		C		41.4	58.6		.9	7,367	13,260

BURNING OF THE COAL BEDS

The thick beds containing coal of good quality are commonly burned along their outcrop and for some distance beneath the overlying rock. Most of that which is burning at the present time or has burned since the beds were first mined has been ignited through the agency of man, but it is evident from the presence of pebbles of slag in the alluvium and terrace gravel that the coal had undergone some burning long before the present geologic epoch. The starting of some of the fires may be ascribed to prairie fires and lightning, but probably the greater number were caused by spontaneous combustion from slow oxidation of the coal.

As the coal burns, the overlying rocks are baked and fused to form clinker or scoria. Rogers[14] has described the physical and mineralogic changes that occur in the baking and fusing of these rocks. Because the clinkered rocks are much more resistant to erosion than the unburned rocks, they form the cap rocks of numerous buttes and benches. (See pl. 25, *B*.) The thickness of rock clinkered is a rough measure of the thickness and quality of the coal of the bed causing the clinkering.

Because the burning of the coal depends upon the supply of air, the amount of cover governs roughly the distance the bed will burn back from the outcrop. In areas of shallow cover the slumping caused by the burning of the coal opens fissures that permit a circulation of air, and in such areas the coal may be entirely burned out in a ridge several hundred feet wide. Where it was possible to judge, the boundary of the unburned coal has been shown on the map by a broken line bounding the area marked with the conventional symbol for clinkered rock. Where the burning is slight or the extent of burning could not be determined the outcrop is shown with the symbol for burned outcrop. Where two thick coal beds lie close together difficulty is encountered in tracing the burned outcrops, the slumping of the lower bed causing the ashes of the upper bed to be so disturbed that often no trace of them can be found.

MINING

Mining in the Richey-Lambert field has been confined to the small-scale operations undertaken to provide coal for domestic use of the residents. All the large coal beds have been prospected, and many small mines have been started and abandoned. In the past the greater proportion of the coal was taken from small mines located only short distances from ranch houses. With the advent of motor trucks the

[14] 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.

tendency has been toward larger mines at easily accessible points. At the present time the Pust, Lane, and Elvirio mines supply most of the coal used in and near the field.

The Lane mine, the largest in the field, is about 2 miles northwest of Lane, in T. 23 N., R. 53 E. It is easily reached by a good prairie road that connects with the system of graded roads covering the area. The mine consists of an entry driven into the outcrop of the Lane bed, from which two branching tunnels extend 250 or 300 feet into the hillside. Coal is mined from the face of the tunnels and from rooms and short drifts. Of the coal in the bed 7 feet is mined and 2 to 3 feet left as roof. No timbering is used except at air shafts and other points of weakness. The coal was formerly dumped directly from mine cars into trucks and wagons, but at the time the writer examined the workings a slump had buried the track to the tipple, and the trucks were being loaded by hand. The mine is most active during the fall and winter, but a small amount of coal is mined during the spring and summer.

The Carroll mine, in T. 22 N., R. 51 E., 7 miles west of Richey, supplies some of the coal used in Richey. It is easily accessible by prairie road. The mine consists of an entry at the outcrop of the Carroll bed driven about 300 feet into the hillside. About 7 feet of coal is mined and 3 to 6 inches left as roof. A few drifts and chambers have been opened from the entry. The mine tracks have been extended onto a tipple that permits loading trucks and wagons direct from the mine cars.

The Otto Pust mine, 6 miles southwest of Lambert, in T. 22 N., R. 55 E., supplies coal to the ranchers in and near the southeastern part of the field. It is reached by a good prairie road connecting with the graded road to Lambert. The mine consists of an entry at the outcrop of the Pust bed, driven 200 feet into the hillside. The lower 8 feet of the bed is mined, and the upper 3 feet left to support the roof. Timbering is used only at weak points in the roof. This mine is active only during the fall and winter.

The Elvirio mine, on the Lower Elvirio bed in T. 24 N., R. 54 E., supplies the ranchers in and near the northeastern part of the field. An entry 270 feet long has been driven into the outcrop. About 6½ feet of the bed is mined and 1 foot of coal is left in the roof. The mine is timbered for 100 feet from the mouth and at various weak points. It is readily accessible from the main graded roads by two prairie roads.

The Squires, Butterfield, Boller, Ballbrach, Stillson, Abbott, Stark, Jordan, and Miller mines and the other small mines and prospects are operated sporadically and supply coal to only their immediate vicinity.

There are many small areas and a few extensive areas in the Richey-Lambert field where coal could be recovered by open-pit mining, but the economic factors governing the depth at which such operations are practicable are so varied that no valid estimate of the reserves available for mining by such methods can be made at the present time. Areas where thick beds of coal are overlain by 50 feet or less of rock are discussed in the descriptions of T. 22 N., R. 55 E., and T. 24 N., Rs. 51, 52, and 53 E.

Development of coal mining on a large scale in this field will probably be delayed until the readily accessible areas containing coal of higher quality have been exhausted. Development of the small mines now in operation will yield sufficient coal to supply the inhabitants of the region for many years to come. Only a small amount of timber is available, and the water from most of the wells and streams is unsatisfactory for use in boilers because of the large amount of dissolved mineral matter.

COAL RESERVES

The table given below shows an estimate of the amount of coal in the different beds, by townships and for the field. Estimates are shown separately under a township heading only for beds cropping out in that township, and estimates of underlying beds in the Fort Union formation, including the Big Dirty bed at the base of the Lebo shale member, are shown grouped under one heading. Because of the impossibility of determining the thinning or thickening or variations in quality of coal where it is not exposed, the estimate indicates only approximately the amount of coal in the field. Because of their thinness and irregularity, no attempt was made to estimate the amount of coal in the numerous local beds. The maximum overburden on coal beds included in the estimate is 1,250 feet.

Estimated quantity of coal in beds of the Fort Union formation in the Richey-Lambert coal field, by townships, in millions of short tons

Township	Carroll	Lane	Butterfield	Budka	Gaines	Solack	Lower Elvirio	Upper Elvirio	Stillson	Pust	Pritegurl	Beds not exposed in township	Total
T. 19 N., R. 50 E.	------	------	------	------	35	------	------	------	103	------	------	397	535
T. 20 N., R. 50 E.	290	------	65	------	58	------	------	------	------	------	------	150	563
T. 21 N., R. 50 E.	206	------	40	------	------	------	------	------	------	------	------	160	406
T. 22 N., R. 50 E.	92	------	------	------	------	------	------	------	------	------	------	170	262
T. 23 N., R. 50 E.	27	------	------	------	------	------	------	------	------	------	------	180	207
T. 21 N., R. 51 E.	------	------	10	------	------	15	------	------	4	------	------	452	481
T. 22 N., R. 51 E.	252	128	------	------	------	------	------	------	------	------	------	170	550
T. 23 N., R. 51 E.	65	40	------	------	------	------	------	------	------	------	------	180	285
T. 24 N., R. 51 E.	34	2	------	------	------	------	------	------	------	------	------	200	236
T. 21 N., R. 52 E.	------	------	------	------	------	9	------	------	------	346	------	567	922
T. 22 N., R. 52 E.	------	244	------	------	------	------	------	------	------	------	------	320	564

Estimated quantity of coal in beds of the Fort Union formation in the Richey-Lambert coal field, by townships, in millions of short tons—Continued

Township	Carroll	Lane	Butterfield	Budka	Gaines	Solack	Lower Elvirio	Upper Elvirio	Stillson	Pust	Prittegurl	Beds not exposed in township	Total
T. 23 N., R. 52 E.	230	150	----	----	----	----	------	1	----	------	----	180	561
T. 24 N., R. 52 E.	62	22	----	----	----	----	------	------	----	------	----	200	284
T. 21 N., R. 53 E.	------	------	----	----	----	----	------	------	----	524	----	504	1,028
T. 22 N., R. 53 E.	------	------	----	----	----	----	------	2	----	75	----	550	627
T. 23 N., R. 53 E.	168	281	----	3	----	----	------	50	----	------	----	150	652
T. 24 N., R. 53 E.	154	129	----	39	----	----	1	------	----	------	----	150	473
T. 21 N., R. 54 E.	------	------	----	----	----	----	------	------	----	585	----	400	985
T. 22 N., R. 54 E.	------	------	----	----	----	----	------	86	----	229	----	310	625
T. 23 N., R. 54 E.	------	------	----	----	----	----	------	109	----	90	----	320	519
T. 24 N., R. 54 E.	------	151	----	5	----	----	48	2	----	23	----	160	389
T. 21 N., R. 55 E.	------	------	----	----	----	----	------	------	----	465	----	480	945
T. 22 N., R. 55 E.	------	------	----	----	----	----	------	------	----	79	----	480	559
T. 23 N., R. 55 E.	------	------	----	----	----	----	------	------	----	2	2	150	154
T. 24 N., R. 55 E.	------	------	----	----	----	----	11	------	----	2	19	150	182
	1,580	1,147	115	47	93	24	60	250	107	2,420	21	7,130	12,994

DETAILS BY TOWNSHIPS

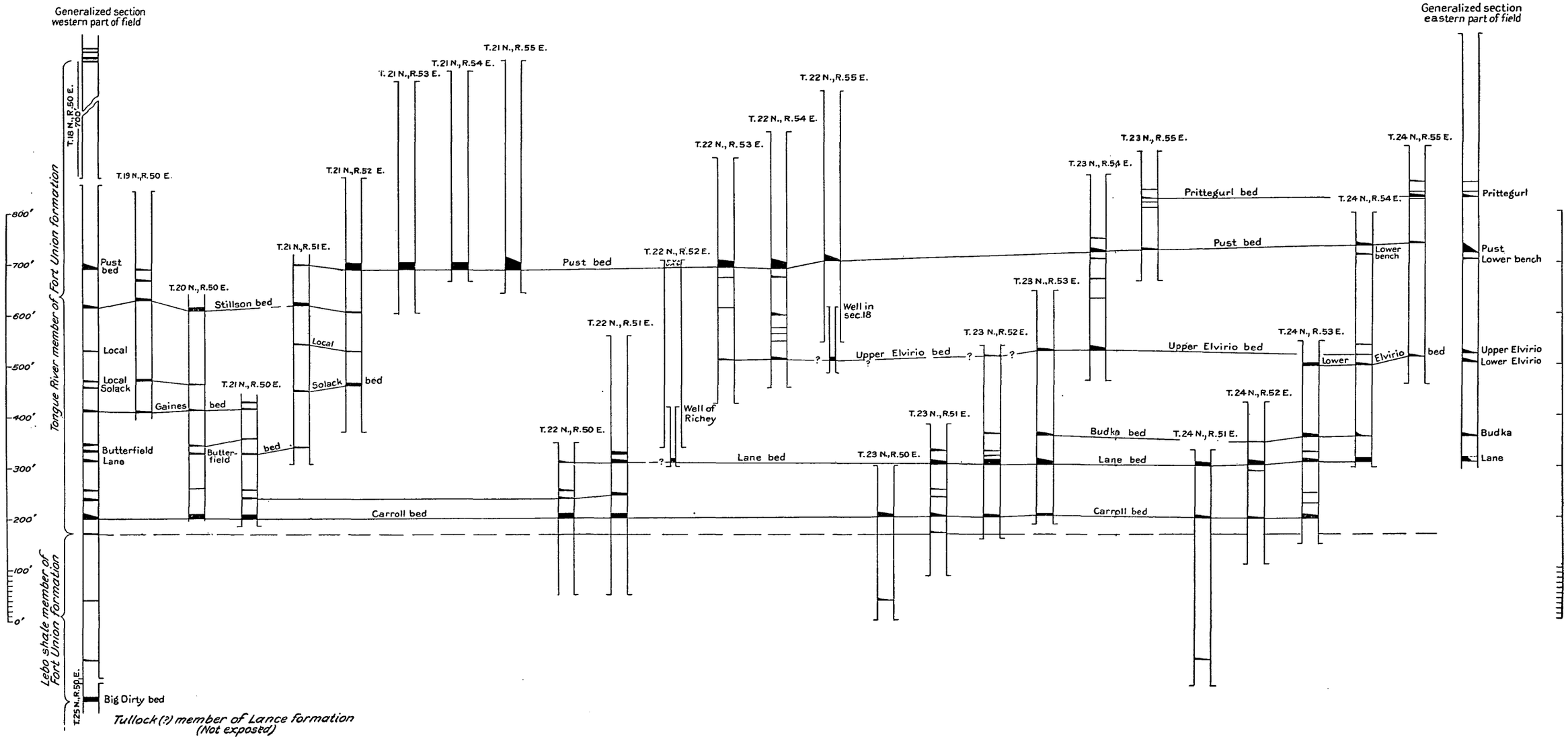
In the following pages the area is described by townships taken in order from south to north, beginning with the western column of townships. The locality numbers mentioned in the text are shown on plate 22, and the sections of the coal beds measured at these localities are shown graphically in figures 35 to 55 or described in the text.

T. 19 N., R. 50 E.—T. 19 N., R. 50 E., is drained by Corral and Cottonwood Creeks. The surface is rolling, and the valleys are broad. The Redwater branch of the Northern Pacific Railway is within 4 miles of the southwest corner of the township.

The Gaines bed, which crops out in sec. 6 along East Cottonwood Creek, is the lowest coal bed exposed in the township. At locality 232 the Gaines bed contains 3 feet 8 inches of coal with a 2-inch parting of clay near the middle. A local bed 60 to 75 feet above the Gaines bed crops out in the northwestern part of the township. At locality 233 this bed contains 3 feet 6 inches of coal, and at locality 238, 3 feet 5 inches, with a bench 15 feet below containing 1 foot 6 inches of coal. The Stillson bed crops out 150 feet above the local bed and ranges in thickness from 20 inches at locality 247 to 5 feet 11 inches at locality 237. The average thickness is about 4 feet. Local beds 40 and 54 feet above the Stillson bed were found at locality 244 with thicknesses of 23 and 14 inches, respectively. The local bed containing 23 inches of coal at locality 236, 45 feet above the Stillson bed, may be continuous with one of these local beds. (See fig. 35.)

Coal has been taken from the Stillson bed at the Stillson mine, in sec. 15. The coal has been removed by stripping the cover for a few feet back of the outcrop and is used only locally for domestic purposes.

T. 20 N., R. 50 E.—The surface of T. 20 N., R. 50 E., consists of rolling hills and ridges with a few isolated buttes capped by gravel or by clinkers of the burned Stillson bed. The area is drained by Bluff, Corral, and Cottonwood Creeks.



GENERALIZED SECTIONS SHOWING THE COAL BEDS AND THICKNESS OF ROCKS EXPOSED IN THE DIFFERENT TOWNSHIPS IN THE RICHEY-LAMBERT COAL FIELD.

The Carroll bed, which crops out in the bank of Redwater Creek at locality 226, in sec. 6, is the lowest coal bed exposed in the township. At this place the bed is 9 feet thick and the coal is of good quality. As this bed is over 5 feet thick elsewhere in this part of the Richey-Lambert field, it probably extends under this township with an average thickness of more than 5 feet. The Butterfield bed is found in the northern and western parts of the township.

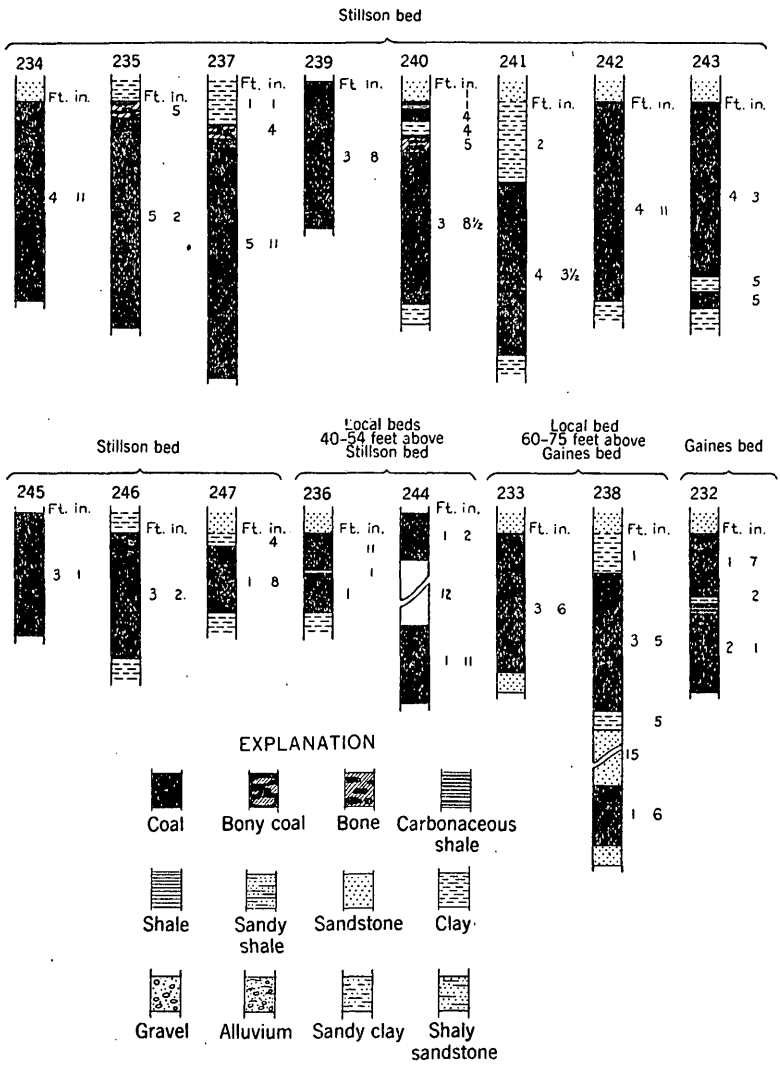


FIGURE 35.—Sections of coal beds in T. 19 N., R. 50 E.

The bed usually consists of two benches separated by 4 to 20 feet of sandy shale or sandstone. The lower bench is usually the thicker and is the one shown on plate 22. The upper bench has a maximum thickness of 3 feet 7 inches at locality 212 but pinches out west of locality 225. The lower bench has a maximum thickness of 3 feet of coal at locality 222, but the average thickness for its outcrop in this township is about 2 feet 6 inches. The Gaines

bed, which crops out in the western part of the township, contains a maximum of 4 feet of coal and two 3-inch partings at locality 231, in sec. 31, but thins northward and was not mapped beyond locality 227, where it contains only 20 inches of coal. A local bed about 60 feet above the Gaines bed was mapped in the southwestern part of the township as far north as locality 230, where it

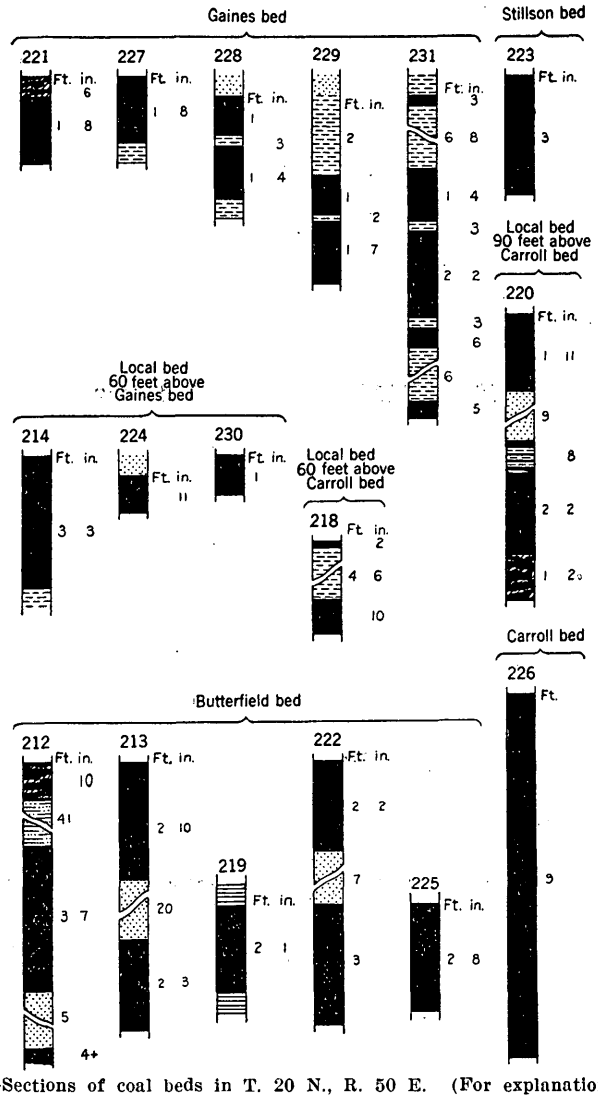


FIGURE 36.—Sections of coal beds in T. 20 N., R. 50 E. (For explanation see fig. 35, p. 149.)

contains 1 foot of coal. This bed or another bed having approximately the same stratigraphic position was found also at localities 224 and 214. At locality 214 it contains 3 feet 3 inches of coal, but it thins within a few hundred feet from this point to less than 2 feet. The Stillson bed crops out in a few isolated hills in the area and is usually burned out under the smaller hills. At locality 223, in sec. 36, the bed contains 3 feet of coal. (See fig. 36.) The total

coal in the township in the Stillson bed probably amounts to less than 200,000 tons.

Coal has been taken from the Carroll bed at a small open-cut mine at locality 226 and from the Butterfield bed at the Butterfield mine (locality 213). These mines supply only the small amount of coal used locally for domestic purposes.

T. 21 N., R. 50 E.—The principal feature of T. 21 N., R. 50 E., is the wide valley of Redwater Creek in the western part of the township. Sullivan and Bluff Creeks and small tributaries of Redwater Creek drain the remainder of the township.

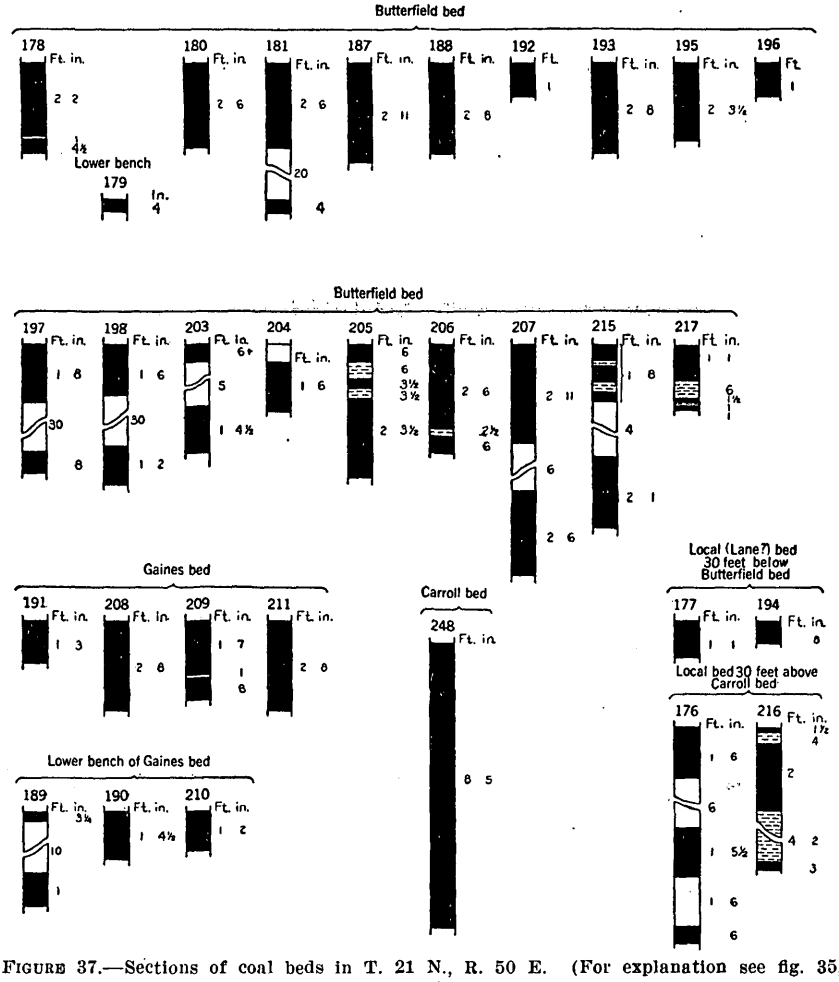


FIGURE 37.—Sections of coal beds in T. 21 N., R. 50 E. (For explanation see fig. 35, p. 149.)

The Carroll bed crops out along Redwater Creek in the lowest part of the area. A measurement at the Babcock mine (locality 248) shows a thickness of 8 feet 5 inches, and, to judge by the persistence and thickness of this bed elsewhere in adjoining townships, it probably extends beneath this township with an average thickness of at least 5 feet. A local bed of 3 benches, from 6 to 18 inches in thickness, 30 feet above the Carroll bed, was found at locality 176. A local bed, possibly continuous with the Lane bed, was measured

at localities 177 and 194, 20 feet below the Butterfield bed. It does not exceed 13 inches in thickness. The Butterfield bed consists of 2 benches separated by 4 to 30 feet of rock. The upper bench is shown on the map. It has a maximum thickness of 2 feet 11 inches at localities 187 and 207 and an average thickness of about 2 feet 3 inches. The maximum thickness of the lower bench is 2 feet 6 inches, at locality 207, but the average thickness is less than 2 feet. The Gaines bed was mapped in sec. 33. The bed contains 2 feet 8 inches of coal at localities 208 and 211 and 2 feet 3 inches of coal at locality 209, but elsewhere in the township it is less than 2 feet thick. A lower bench is present 10 feet below the main Gaines bed at localities 189, 190, and 210, but this bench does not exceed 17 inches in thickness. (See fig. 37.)

Coal was formerly taken from the Carroll bed at the Babcock mine (locality 248), in sec. 18, but this mine has been abandoned.

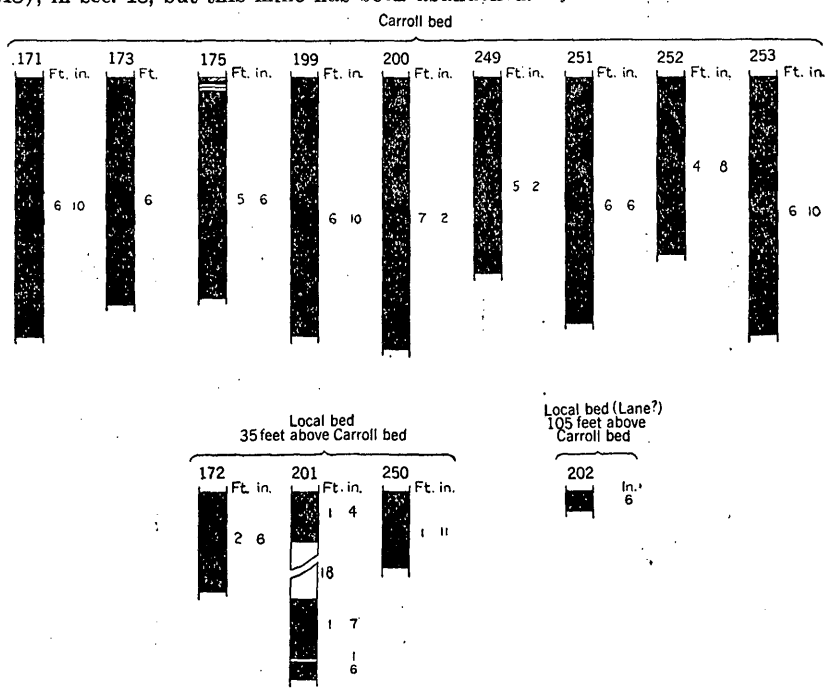


FIGURE 38.—Sections of coal beds in T. 22 N., R. 50 E. (For explanation see fig. 35, p. 149.)

T. 22 N., R. 50 E.—Redwater Creek and its tributaries, Sullivan, Pasture, Cow, and Hay Creeks, drain T. 22 N., R. 50 E. The valleys are broad and shallow, and the surface is gently rolling. Paxton post office is in sec. 29.

The Carroll bed is the only coal bed shown on the geologic map. It is 7 feet 2 inches thick at locality 200, but thins to 4 feet 8 inches at locality 252. The average thickness is about 6 feet 2 inches. A bed which does not exceed 2 feet 6 inches in thickness was found at localities 172, 201, and 250. A local bed, 6 inches thick, possibly continuous with the Lane bed, was found at locality 202, 105 feet above the Carroll bed. (See fig. 38.)

Coal has been taken from the Carroll bed from a small mine at locality 199 and from an abandoned mine, now burning, at locality 175. There are also prospect pits in the Carroll bed at localities 171 and 173.

T. 23 N., R. 50 E.—The wide valley of Redwater Creek occupies the eastern part of T. 23 N., R. 50 E. Extensive, gently sloping terraces about 200 feet above Redwater Creek form wide ridges in the central part of the township.

In the western part of the township the surface is gently rolling. Glacial boulders and till are present on the terraces and rolling hills. The area is drained by Hay Creek and Gold Gulch and by shorter tributaries of Redwater Creek.

The Carroll bed is the only bed of value cropping out in the township. It ranges in thickness from 6 feet 8 inches at locality 255 to 2 feet 8 inches at locality 257. The outcrop is commonly hidden by thick soil, glacial till, or the thin alluvium of the terraces. A local bed in the Lebo shale member, 150 feet below the Carroll bed, was found at locality 143. The bed consists of an upper bench and lower bench 10 inches and 20 inches thick respectively, separated by 8 feet of black carbonaceous shale. (See fig. 39.)

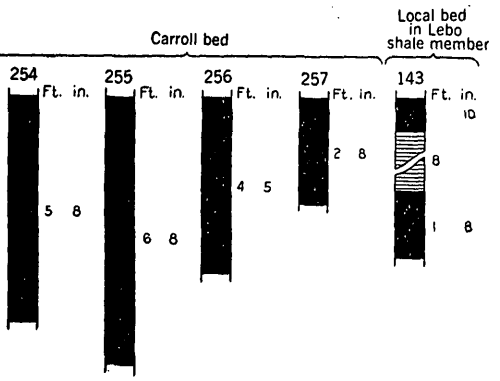


FIGURE 39.—Sections of coal beds in T. 23 N., R. 50 E. (For explanation see fig. 35, p. 149.)

The Carroll bed has been mined at the Stark mine (locality 254). This mine supplies the domestic coal for the township.

T. 21 N., R. 51 E.—With the exception of some prominent buttes in the southern part, the surface of T. 21 N., R. 51 E., is gently rolling. The hills

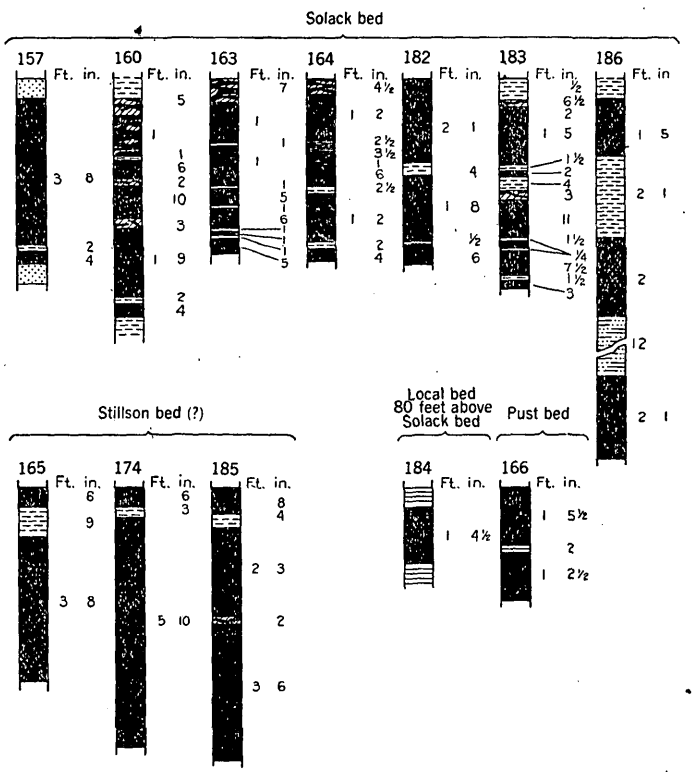


FIGURE 40.—Sections of coal beds in T. 21 N., R. 51 E. (For explanation see fig. 35, p. 149.)

and ridges of the northern part of the township are strewn with glacial boulders. Deposits of till are present in the northern part of secs. 3 and 4. The area is drained by Sullivan and Pasture Creeks and by a shorter tributary of Redwater Creek.

The Butterfield bed crops out along Sullivan Creek in the western part of the township. No measurements were obtained on the Butterfield bed in this township, but at locality 181, in sec. 13, T. 21 N., R. 50 E., 400 feet west of the township line, the Butterfield bed consists of a bench 2 feet 6 inches thick and a bench 20 feet lower 4 inches thick. Only the upper bench occurs in this area. The Solack bed was not traced continuously in this township. It contains a maximum of 4 feet 5 inches of coal with numerous partings of shale and bone at locality 160. The coal is usually bony, or the bed contains many partings. A local bed 80 feet above the Solack bed is exposed in several places in the township but was not mapped. A measurement at locality 184 shows a thickness of 16½ inches. This may be continuous with the local bed 60 feet above the Solack bed mapped in T. 21 N., R. 52 E. The Stillson(?) bed occurs in the high buttes in the southern part of the township. It contains 6 feet 5 inches of coal with two partings at locality 185, and the average thickness is probably more than 5 feet. A bed occurring at locality 166, 70 feet above the Stillson (?) bed, containing 2 feet 8 inches of coal with a 2-inch clay parting, may be the equivalent of the Pust bed found in the townships to the east. (See fig. 40.)

A small amount of coal has been taken from the Solack bed at locality 182, but the mine is now abandoned. No other mining has been attempted in the township.

T. 22 N., R. 51 E.—With the exception of a few small badland areas near the right bank of Pasture Creek, the surface of T. 22 N., R. 51 E., is gently rolling. The ridges and hills are strewn with glacial boulders, and some of the surface is covered by thin deposits of glacial till.

The Carroll bed crops out along Pasture Creek in the northwestern part of the township. At the Carroll mine (locality 146) the bed contains 7 feet 3 inches of good coal. The Carroll bed is thick and persistent in neighboring townships and probably extends under this township with an average thickness of at least 5 feet 6 inches. A local bed 30 to 40 feet above the Carroll bed at locality 147 contains 3 feet of good coal with a 1-inch clay parting near the base. Beds at approximately the same stratigraphic position were found at localities 144 and 168. Because of the thinness of this bed no attempt was made to map it. The Lane bed consists of two benches separated by 4 to 22 feet of sandy shale. The lower bench, which is the one shown on plate 22, has a maximum observed thickness of 4 feet 5 inches at locality 148 and an average thickness of about 3 feet. The upper bench has a maximum observed thickness of 3 feet 8 inches at locality 150 and an average thickness of about 3 feet 3 inches. Both benches are thin west of locality 170 and could not be traced to the boundary of the township. (See fig. 41.)

Coal is obtained from the Carroll bed at the Carroll mine (locality 146). This mine supplies some of the coal used in Richey, 7 miles east of it, and most of the coal used in this township. There is a small prospect pit on the Lane bed at locality 151.

T. 23 N., R. 51 E.—This township includes parts of the valleys of Lisk and Redwater Creeks. The valleys are flat and open, and the ridges wide and rolling. The surface is broken here and there by small badland areas,

entrenchments of the streams, and buttes and benches formed by clinkered rocks and concretionary layers. The ridges are strewn with many glacial boulders and a few small deposits of glacial till.

The Carroll bed crops out on the valley sides of the northeastern and southwestern parts of the township, but in the valley of the South Fork of Lisk Creek the outcrop is buried by alluvium. The coal is irregular in thickness and quality. It is burned in only a few places. The thickness ranges from 3 feet 2 inches at locality 141 to 6 feet 4 inches at locality 142. Measurements were

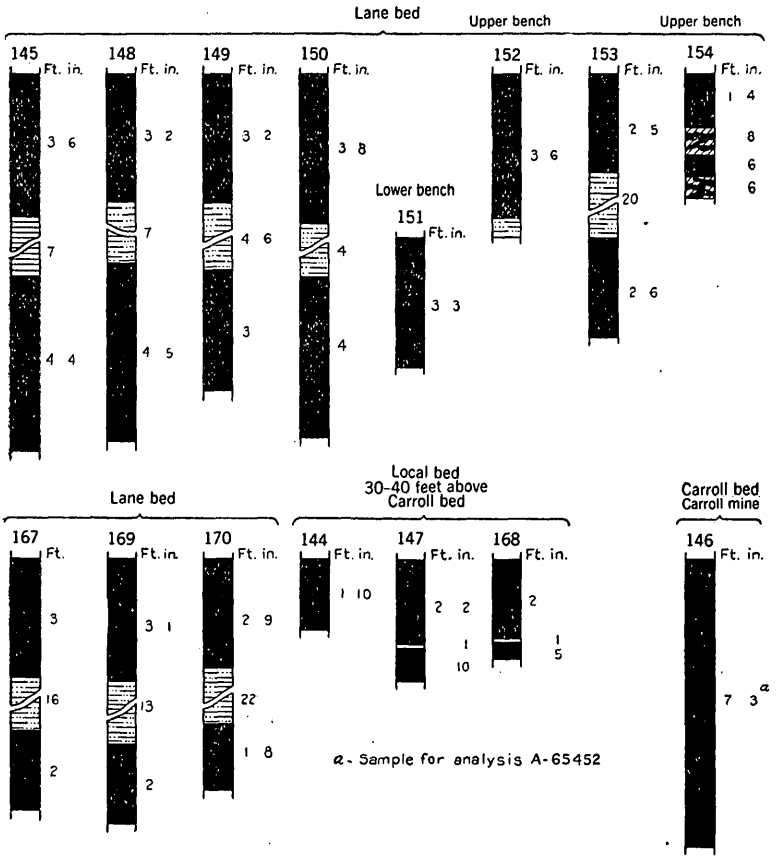


FIGURE 41.—Sections of coal beds in T. 22 N., R. 51 E. (For explanation see fig. 35, p. 149.)

made also at localities 127, 129, and 137, but the measurement at locality 127 is incomplete.

The Lane coal bed crops out on the valley slopes and is readily traced by its massive and conspicuous clinkers. Measurements were made at localities 125, 126, 128, 132, 135, 136, 138, and 140, and the thickness of coal was found to range from 2 feet 6 inches to 10 feet 11 inches. Small entries on this bed, known collectively as the "Abbott mine," have been opened at localities 132 and 135. They are rather inaccessible, and the coal has been used only by ranches in the immediate vicinity.

A local bed 20 feet above the Lane is 16 inches thick at locality 124 but could not be traced far enough to warrant mapping. Two local beds below the Lane

are exposed in the eastern part of the township. One bed 60 feet below the Lane bed is 15 inches thick at localities 131 and 134; the other, 75 feet below the Lane bed, is 22 inches thick at locality 130 and 20 inches thick at locality 133. Neither bed was mapped, because of their thinness, but thin coals near these horizons were noticed elsewhere in the township. There is a local bed 30 feet below the Carroll at locality 139, where it is 4 feet 5 inches thick, but it is lenticular and could be traced only a short distance. (See fig. 42.)

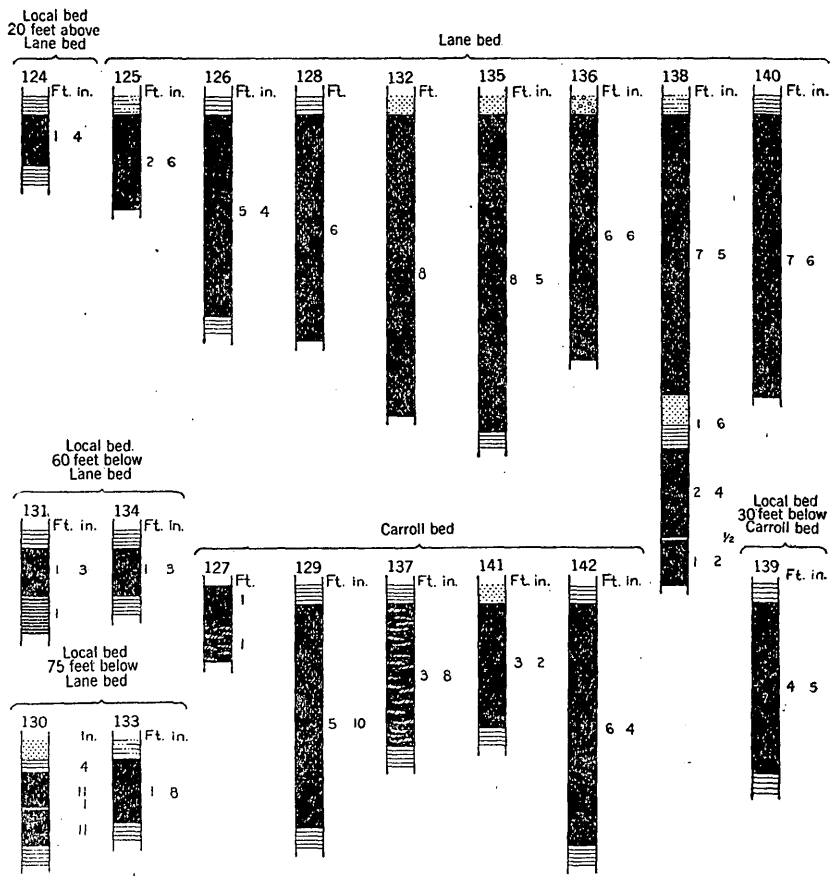


FIGURE 42.—Sections of coal beds in T. 23 N., R. 51 E. (For explanation see fig. 35, p. 149.)

T. 24 N., R. 51 E.—T. 24 N., R. 51 E., includes parts of the valleys of Redwater, Lisk, and East Redwater Creeks. Steep cliffs border Redwater Creek, and the surface near it has been dissected into badlands. In the southwestern part of the township a wide sloping terrace between Redwater and Lisk Creeks rises 30 to 60 feet above the streams. The surface of the remainder of the township is rolling but here and there broken by small badlands resulting from rapid headward erosion of small streams, or by buttes and benches capped by clinkers or concretionary layers that are resistant to erosion. Glacial erratic boulders are strewn over the ridges and valley slopes of the township.

The upper 350 feet of the Lebo shale member, which is barren of valuable coal, forms the surface of more than half the township. It is in this formation that the badlands are most extensively developed.

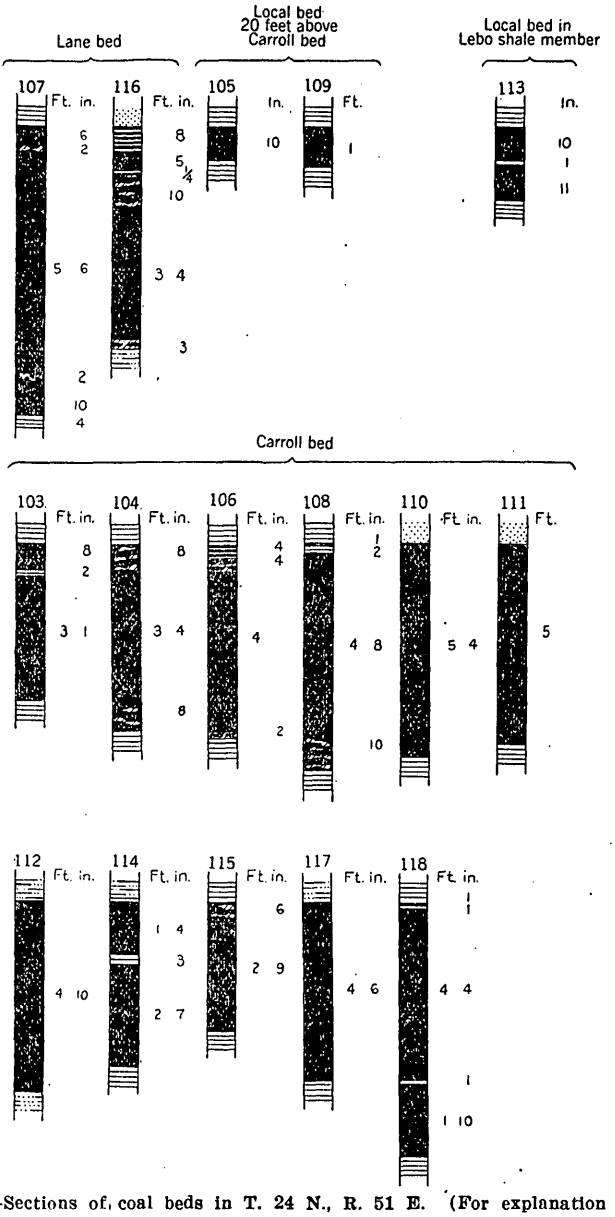


FIGURE 43.—Sections of coal beds in T. 24 N., R. 51 E. (For explanation see fig. 35, p. 149.)

The Big Dirty bed was measured at a mine in sec. 26, T. 25 N., R. 50 E. It does not crop out in this area, as its stratigraphic position is below the lowest horizon exposed. It is known to be extensive in this part of Montana, and therefore it is probably present beneath the Richey-Lambert field with a thickness and quality comparable to the following section:

Section of coal in Big Dirty bed at mine in sec. 26, T. 25 N., R. 50 E.

	Ft.	in.
Sandstone.		
Coal		3+
Shale		2
Coal		8
Gypsum		⅛
Coal	5	9
Shale		¼
Coal	2	7
Shale		¼
Coal	2	
Shale.		

The Carroll bed crops out on the hill slopes in the east half of the township. The coal is not extensively burned at the outcrop but is commonly covered by thick soil. Measurements of the bed were made at localities 103, 104, 106, 108, 110, 111, 112, 114, 115, 117, and 118. The maximum thickness observed is 6 feet 2 inches with a 1-inch parting at locality 118, and the minimum is 3 feet 3 inches including 6 inches of bony coal at locality 115.

The Lane coal bed crops out on the high ridge in the east-central part of the township. Because of extensive burning along the outcrop there are few places where the coal is exposed. It was measured at localities 107 and 116, where it is 7 feet 2 inches and 4 feet 7 inches thick respectively but contains partings of bony coal. The cover over the coal is less than 80 feet but is sufficient to prevent weathering, and probably the entire amount of unburned coal in this bed, amounting to nearly 2,000,000 tons, could be readily mined by open-pit methods.

A local bed 20 feet above the Carroll bed was not mapped but was measured at localities 105 and 109, where it is only 1 foot or less in thickness. The bed is persistent and was found elsewhere in the township. A local bed in the Lebo member, about 280 feet below the Carroll bed, is 22 inches thick at locality 113. This bed was not observed elsewhere in the township. (See fig. 43.)

T. 21 N., R. 52 E.—The divide between the Missouri and Yellowstone Rivers crosses T. 21 N., R. 52 E., near the southeast corner, and practically all of the township is drained by Lisk and Pasture Creeks, tributaries of the Missouri.

The land surface south of the divide is part of a tableland of moderate relief, but immediately north of the divide the surface is rugged and deeply dissected by narrow canyons. Farther north it is rolling, and the streams flow in wider valleys. Near the divide the clinkered rocks formed by burning of the Pust bed cap prominent buttes and benches.

The Solack bed is the lowest bed exposed in this township. It contains many partings and coal of poor quality, as shown by sections measured at locality 155, in sec. 5, T. 21 N., R. 52 E., and at locality 163, in sec. 25, T. 21 N., R. 51 E.

A local bed 60 feet above the Solack bed was mapped in the southwestern part of the township, where the measurements at localities 161 and 162 showed it to be over 2 feet thick. The bed is thinner to the north and was not traced beyond sec. 30.

The Stillson (?) bed is 2 feet 10 inches thick at locality 158, but the upper part of the bed contains bony coal. The bed thins to the east, and probably it does not constitute a valuable reserve of coal in this township. It is this bed that has formed the clinkered rock in the southwest corner of the township.

The Pust bed crops out in the southern and eastern parts of the township. Sections measured at localities 156 and 159 show it to be 14 to 16 feet thick with one or more thin beds below it. The coal is burned at the outcrop almost everywhere in this township, and in places it is buried beneath outwash from the steep cliffs near the divide. The coal is of good quality and contains only two thin partings. (See fig. 44.) Two small tunnel mines—the Squires mine, at locality 156, and the Boller mine, at locality 159—have been opened on the outcrop of the bed. The coal from these mines is used only in the immediate vicinity.

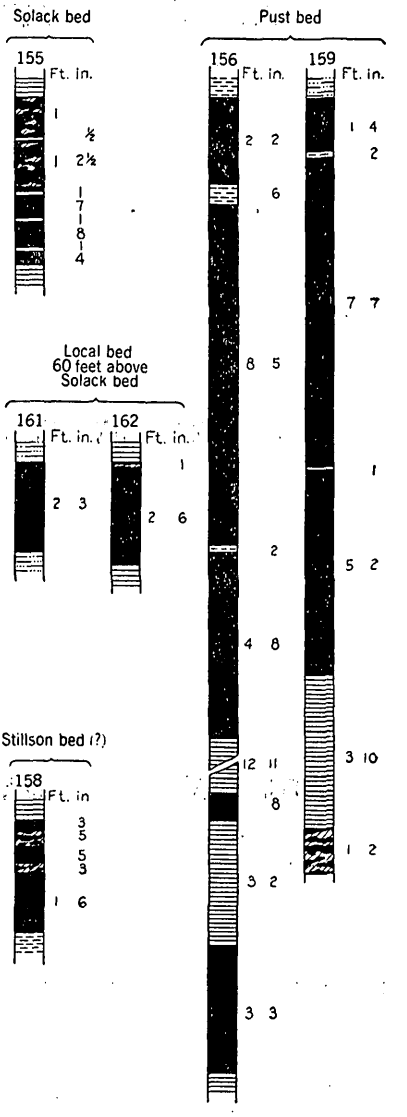


FIGURE 44.—Sections of coal beds in T. 21 N., R. 52 E. (For explanation see fig. 35, p. 149.)

The Lane bed was encountered at a depth of about 180 feet in a deep well in the town of Richey. About 10 feet of coal was found, but no data are available concerning its quality. It is probable that the Lane bed extends beneath this township with an average thickness of at least 6 feet. There has been no mining or prospecting in this township.

T. 23 N., R. 52 E.—The greater part of T. 23 N., R. 52 E., is drained by two forks of Lisk Creek, but the northeastern part is drained by tributaries of East Redwater Creek. The alluvium-filled valleys are wide and flat-bottomed, but the alluvium has been incised to a depth of 5 to 15 feet by the meandering streams. Most of the surface is rolling, but at many places it is cut into badlands at the headwaters of small streams; or layers of concretions or beds of clinkered rock form the resistant cap rock of small buttes and benches. Glacial

T. 22 N., R. 52 E.—T. 22 N., R. 52 E., is somewhat basinlike in that the boundaries of the township for the most part lie on high ground, whereas the central part consists of flat or rolling agricultural land. This depression is drained by tributaries of Pasture, Lisk, and East Redwater Creeks. The crests of the high ridges are rolling; but locally they have been dissected in many places to such completeness that only buttes and badlands remain.

Richey, the terminus of the Richey branch of the Great Northern Railway, is in the south-central portion of the township.

No unburned coal beds thicker than 2 feet crop out in the area, but the highest points on the ridges in the southern and eastern part of the township are capped by thick clinkers formed by burning of the Pust bed. No coal remains unburned in the Pust bed in this township.

boulders are strewn on the surface of the ridges and hill slopes. A linear concentration of boulders through secs. 5, 8, 9, and 16 suggests a moraine, but no glacial till was found, possibly because of the lack of exposures.

The Carroll bed crops out in the northwestern part of the township in the valley of the North Fork of Lisk Creek. The outcrop is close to the stream level and is buried beneath alluvium east of secs. 7 and 18. A measurement made by use of a soil auger at the spring at locality 119 shows the bed to be 6 feet 6 inches thick. Where it crops out in the townships to the west the bed is rather irregular but averages about 5 feet in thickness, so it is probable that the bed is as much as 5 feet thick where it underlies this township.

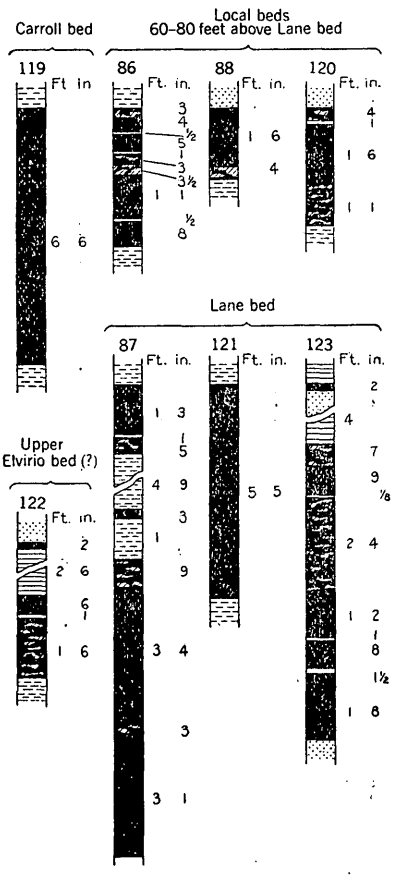


FIGURE 45.—Sections of coal beds in T. 23 N., R. 52 E. (For explanation see fig. 35, p. 149.)

The Lane bed crops out along the valleys of East Redwater Creek and both forks of Lisk Creek. The coal at the outcrop is either burned or concealed by soil nearly everywhere in this township, and sections could be measured only at localities 87, 121, and 123. At locality 121 there is 5 feet 5 inches of clean coal, and at locality 87 there is 6 feet 5 inches of clean coal with 3 inches of bony coal near the middle, but at locality 123 the coal is impure and is split by many partings.

Local beds of small areal extent, 60 to 80 feet above the Lane bed, were measured at localities 86, 88, and 120, but because of their thinness and impurity, they were not mapped. (See fig. 45.)

The highest coal bed mapped in the area crops out on the high ridge in sec. 25, 160 feet above the Lane bed. This bed is tentatively correlated with the Upper Elvirio bed on the basis of the interval between it and the Lane bed. The bed is irregular in both thickness and quality and in places pinches out entirely. At locality 122 the bed is 2 feet 1 inch thick and contains but little clean coal. Measurements in T. 23 N., R. 53 E., show that the bed thickens to the east.

Four prospects have been opened on the Lane bed, but only small amounts of coal have been removed, and none of them have been worked in recent years. At the small prospect south of locality 123 the coal was burning at the time of the examination. A small quarry in the clinker on the ridge in sec. 16 furnishes road metal, which is used in nearby stream crossings.

T. 24 N., R. 52 E.—East Redwater Creek flows northwestward across T. 24 N., R. 52 E., through a wide valley. The meandering stream has trenched the alluvial fill of the valley floor to a depth of 10 to 20 feet. The valleys of the tributaries are broad, but in the higher parts of the area the streams have dissected small areas of the surface into gullies and badlands. A pro-

nounced bench is capped by the clinkered rocks formed by the burning of the Lane bed, and in some places a lower bench is capped by the clinkered rocks formed by the burning of the Carroll bed. Glacial erratic boulders are very common on the ridges and hill slopes.

About 50 feet of the upper part of the Lebo shale member is exposed in the valley of East Redwater Creek in the northwestern part of the township.

The Carroll bed crops out along the valley of East Redwater Creek and its North Fork. In this township it is thinner and of poorer quality than the Lane bed and is commonly concealed by thick soil, but in places it has burned at the outcrop, causing clinkers scarcely less massive than those caused by the

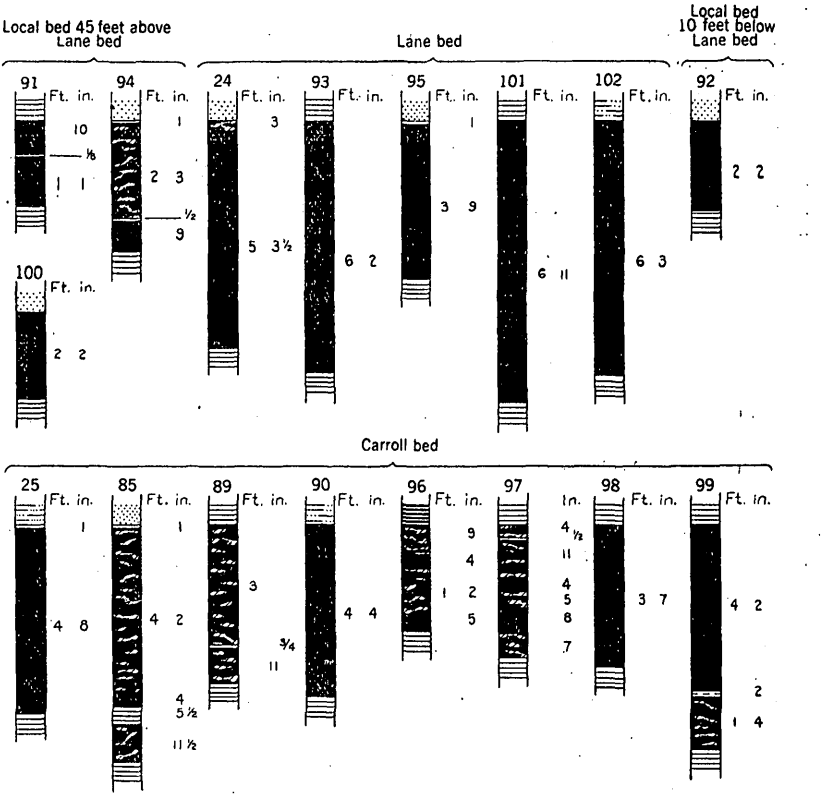


FIGURE 46.—Sections of coal beds in T. 24 N., R. 52 E. (For explanation see fig. 35, p. 149.)

Lane bed. Measurements of the thickness of the bed at localities 25, 85, 89, 90, 96, 97, 98, and 99 show an average thickness of about 4 feet, but the presence of bone and partings impairs the value of the bed through much of its extent.

The Lane coal bed crops out high on the hills in the southern part of the township and near the top of a small hill in the northeast corner. Sections of the coal measured at localities 24, 93, 95, 101, and 102 show it to be of good quality. The maximum observed thickness is 6 feet 11 inches at locality 101, and the minimum is 3 feet 9 inches at locality 95. The Lane coal has been burned at the outcrop nearly everywhere in this township. The ridge in secs. 27 and 28 is underlain by the Lane bed, which is about 5 feet thick with a cover of 50 feet or less and may offer opportunities for open-cut mining.

A thin discontinuous local bed 45 feet above the Lane bed was measured at localities 91, 94, and 100, but it could not be traced continuously between these points. A local bed 10 feet below the Lane bed is 2 feet 2 inches thick at locality 92. This bed was not found elsewhere in the township. (See fig. 46.)

There has been no mining or prospecting in this township.

T. 21 N., R. 53 E.—The divide between the Yellowstone and Missouri Rivers trends northeastward across the central part of T. 21 N., R. 53 E. Southeast of the divide the upland surface, known locally as the Retah Table, is flat except for scattered gravel-capped hills projecting 30 to 100 feet above the general surface. This portion of the township is drained by Burns Creek and Thirteenmile Creek. Northwest of the divide the surface breaks sharply downward over steep cliffs to rolling ridges and deeply incised stream canyons and thence to the flat valley of Lisk Creek.

The Pust bed is the only thick bed in the township. It crops out along the northwest side of the divide and in sec. 34. The bed is thick, but the extensive burning along the outcrop in the Lisk Creek Valley prevents actual measurement of the coal. The following incomplete section of the bed was measured at locality 258:

Section of Pust bed at locality 258, in sec. 34, T. 21 N., R. 53 E.

	Ft.	in.
Shale		9
Bony coal		3
Clean coal	2	7
Bone		3
Clean coal (base concealed)	12	10

To judge from measurements made in adjoining townships the minimum thickness in this township is 12 feet. A small mine at locality 258 is active only during the fall and winter and supplies coal for use in the immediate vicinity.

T. 22 N., R. 53 E.—The divide between the Yellowstone and Missouri Rivers crosses the southeast corner of T. 22 N., R. 53 E. Southeast of the divide the flat upland surface has been dissected by the headwaters of Burns Creek into rounded ridges separated by many small valleys that preserve their depth and distinctness almost to the divide. Northwest of the divide are steep cliffs and deeply incised stream canyons. Farther northwest the hills are rolling and the stream valleys are wider. The higher part of this rolling land is known locally as the "T-Bone Hills."

The Richey branch of the Great Northern Railway crosses the northwest corner of the township.

The Upper Elvirio (?) bed was mapped in the northeastern part of the township. Measurements at localities 67, 68, and 71 show the bed to be over 3 feet in thickness, but the coal is of little commercial value because of the impurities and partings in it.

A local bed 100 feet above the Upper Elvirio (?) bed was mapped in the northeastern part of the township and was measured at locality 72. The bed is about 2 feet thick at that place, but this probably represents its maximum thickness in this area. There has been some burning of the outcrop near locality 72, but elsewhere the outcrop is unburned and the coal is of poor quality.

The Pust bed crops out in the southern and eastern parts of the area, and the clinkers formed by the burning of the coal form prominent benches and

cap many small buttes and mesas. Measurements made at localities 75, 76, 78, and 79 show the bed to have a thickness of 8 to 14 feet. The coal is of good quality, although partings and bone are present in some of the sections. (See fig. 47.)

Several small local beds were observed but were not mapped. The thickest one of these, 20 feet below the Pust bed, was measured at locality 80, where it is 2 feet 3 inches thick. Elsewhere in the township it is much thinner or entirely absent. It is possible that this bed might correspond to the lower split of the Pust bed found in the township to the east.

Several prospects have been opened on the Pust bed, but the only mine operated in recent years is the Ballbrach mine, in sec. 35. This mine consists of several wide entries, none over 50 feet in length, driven into the bed at the outcrop. Coal from this mine is used locally for domestic fuel.

T. 23 N., R. 53 E.—East Redwater Creek flows northwestward through the central part of T. 23 N., R. 53 E., and drains all of the township except the parts of secs. 19 and 30 drained by Lisk Creek. The channel of East Redwater Creek is bordered by a wide alluvial flat, into which it is entrenched to depths of 10 to 25 feet. Southwest of the creek the surface is hilly, and there is little flat land suitable for cultivation. The clinkers formed by the burning of the Lane bed cap buttes and benches in this portion of the township. In the northwestern part of the township they cap small mesas and ridges surmounting rugged slopes. Near Lane and Manrock gravel-covered stream terraces rise 30 to 50 feet above the alluvial flat. Glacial erratic boulders are strewn over the ridges and hills in the northern part of the township.

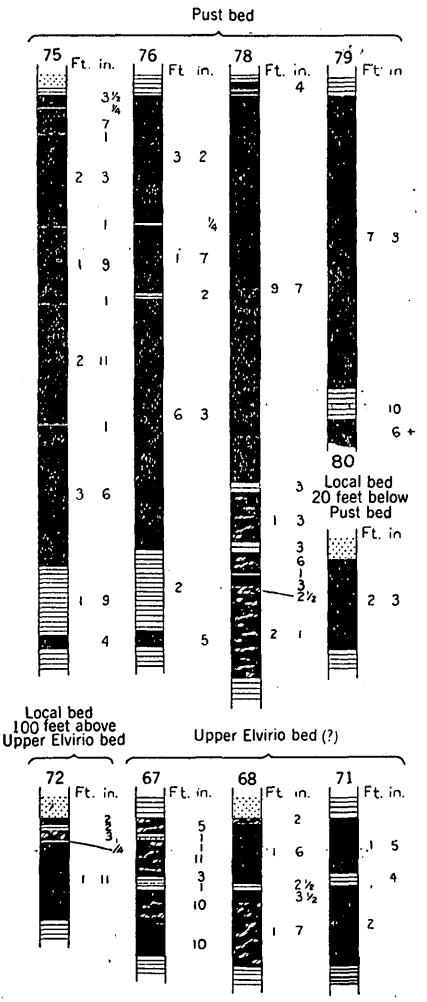


FIGURE 47.—Sections of coal beds in T. 22 N., R. 53 E. (For explanation see fig. 35, p. 149.)

The Richey branch of the Great Northern Railway crosses the southern part of the township. Lane, in sec. 36, is a small settlement on this railroad.

The Carroll bed crops out near the edge of the alluvium in the valley of East Redwater Creek in the northwest corner of the township. There are two patches of clinker along the southwest bank of the stream, but no coal is exposed. About 1¼ miles north of sec. 6, at locality 49, a measurement shows the Carroll bed to have a thickness of 4 feet 3 inches. The bed is

persistent elsewhere in the Richey-Lambert field, and it is probable that the bed extends beneath T. 23 N., R. 53 E., with a thickness of at least 3 feet.

The Lane bed crops out along the valley of East Redwater Creek and on the ridges in the northwestern part of the township. Nearly everywhere the coal has been burned at the outcrop and has formed massive clinkers. Measurements of the thickness of the coal ranged from 8 feet at locality 53 to 10 feet 8 inches at locality 57. The Lane mine (locality 57), described on page 146, and several smaller mines derive their coal from this bed. The open-cut mine at locality 53 is used only to supply domestic fuel to the neighboring ranches, and the tunnel mine at locality 55 has been abandoned because of fire. A local bench with 23 inches of coal occurs 13 feet above the Lane bed at locality 84.

The Budka bed was mapped in the north-central part of the township. The bed is reported to contain 4 feet of bony coal at the Updegraff mine, in sec. 2, but where it is exposed elsewhere in the township it does not exceed 2 feet in thickness, and south of sec. 10 the bed is split into small layers of coal and carbonaceous clay, separated by layers of sandstone and shale. This carbonaceous horizon is present as far south as Lane. At locality 77, in sec. 28, the bed at this horizon is 2 feet 4 inches thick.

The Upper Elvirio bed crops out near the eastern border of the township. The thickness of coal in this bed ranges from 2 feet 4 inches at localities 46 and 54 to 6 feet 4 inches at locality 59, but partings of shale, sandstone, and bone are common, and much of the coal is impure. A bed 160 feet above the Lane bed crops out in the high ridge in the southwestern part of the township. Because of its stratigraphic position this bed is tentatively correlated with the Upper Elvirio bed. This bed contains 4 feet of coal at locality 81 and 2 feet 4 inches of coal at locality 82. Thick partings are present at both localities. Many thin local beds occur near this horizon, and it is possible that the Upper Elvirio bed is not a distinct and continuous bed but rather a series of lenses of coal near the same horizon. (See fig. 48.)

The Lane bed is the source of most of the coal mined in this township. The Updegraff mine, which was flooded at the time of the examination, consists of an open cut on the Budka bed from which a small amount of coal has been taken for domestic use.

T. 24 N., R. 53 E.—East Redwater Creek drains all of T. 24 N., R. 53 E., except a small area in the northeast corner, which is drained by West Charley Creek. The North Fork of East Redwater Creek flows westward through the central part of the area in a wide flat-bottomed valley between rolling ridges, which are broken here and there by small badlands. Glacial boulders are strewn over the rolling surface of the ridges and hill slopes.

The Carroll bed crops out in the lowland in the western part of the township. A measurement of this bed at locality 28 shows a thickness of 5 feet 10 inches, but the bed thins to 4 feet 3 inches at locality 49, in the southwest corner. At locality 26 an incomplete measurement of the bed where it was partly burned shows a thickness of 2 feet 8 inches.

The Lane bed probably has a greater average thickness than any other bed in the township. The coal is but rarely exposed because of burning at the outcrop and the thick soil cover. The coal horizon intersects the surface along East Redwater Creek and its North Fork and near West Charley Creek, in the northeast corner of the township. At locality 27 the bed is 5 feet 9 inches thick. The uniform thickness of the clinkers in the southern two-thirds of the township and sections measured in adjoining townships indicate that where the bed underlies the southern part of this township it is thick and of good quality. The thinner clinkers in the northern part of the township indicate

that there the bed is probably somewhat thinner. The stratigraphic interval between the Lane bed and the Budka bed is 60 feet, so the area underlain by the Lane bed where the cover is less than 60 feet is shown on plate 22 between the outcrop lines of the two beds. At several places in the township

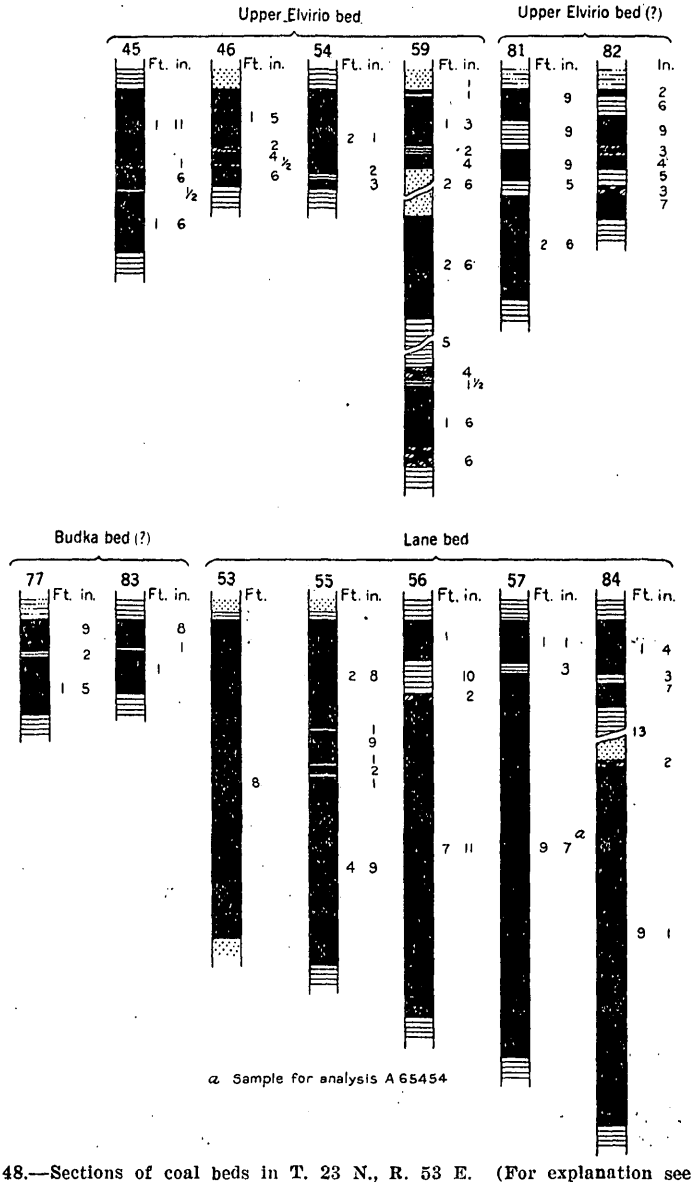


FIGURE 48.—Sections of coal beds in T. 23 N., R. 53 E. (For explanation see fig. 35, p. 149.)

where there is a local widening of this band there is a large amount of coal within the reach of open-cut mining.

The Budka bed crops out in the southern and eastern parts of the township. The observed thickness of the bed ranges from 2 feet 5 inches at locality 47 to 4 feet at locality 39, but the bed contains considerable bony coal.

The Lower Elvirio coal bed underlies part of the ridge in secs. 13 and 24, but the outcrop is concealed beneath thick soil and slope wash. A measurement of this bed at locality 29, in sec. 18, T. 24 N., R. 54 E., indicates that the bed is probably about 4 feet thick and rather dirty where it underlies T. 24 N., R. 53 E.

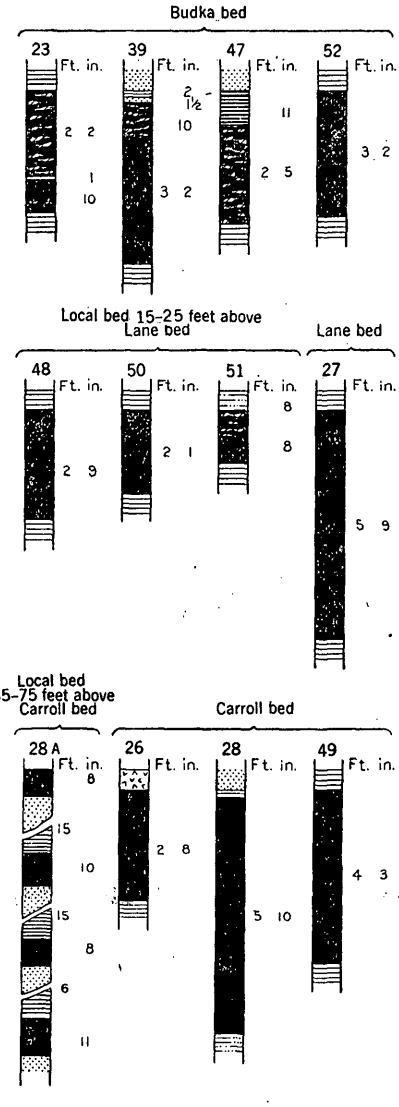


FIGURE 49.—Sections of coal beds in T. 24 N., R. 53 E. (For explanation see fig. 35, p. 149.)

A thin local bed containing dirty coal, 15 to 25 feet above the Lane bed, crops out in the southwestern part of the township, and its thickness was measured at localities 48, 50, and 51. Several local beds less than 1 foot in thickness were found at locality 28a, in a zone extending from 35 to 75 feet above the Carroll bed. (See fig. 49.)

T. 21 N., R. 54 E.—T. 21 N., R. 54 E., lies east of the divide between the Missouri and Yellowstone Rivers. The northern part of the township includes the rugged badlands and valleys of the North Fork of Burns Creek, and the remainder of the township includes the flat surface of the eastern part of the Retah Table, which is drained by the shallow valleys of the Middle and South Forks of Burns Creek.

The Pust bed, the only thick coal bed cropping out in the township, comes to the surface only along the North Fork of Burns Creek. The coal is everywhere burned at the outcrop, forming thick masses of clinker. The thick clinker and measurements of this bed in adjoining townships indicate that the bed is thick where it underlies the surface in this township. Its thickness is probably not less than 12 feet. There has been no mining or prospecting in this township.

T. 22 N., R. 54 E.—The divide between the Yellowstone and Missouri Rivers crosses the northwestern part of T. 22 N., R. 54 E., and separates the drainage basins of Burns and Fox Creeks to the southeast from that of East Redwater Creek to the northwest. Most of the township southeast of the divide is a dissected upland. This part of the township is rugged, with many deep canyons and large buttes. In the northeastern part of the township a high ridge forms the divide between Fox and Burns Creeks. The surface north of this ridge slopes gently to the wide valley of Fox Creek, broken only by stream valleys and the benches and buttes caused by thick clinkers of the Pust bed.

The Richey branch of the Great Northern Railway and the highway from Richey to Sidney cross the northern part of the township.

The Upper Elvirio (?) bed crops out in the northwestern part of the township. A measurement at locality 66 shows a thickness of over 5 feet, but there

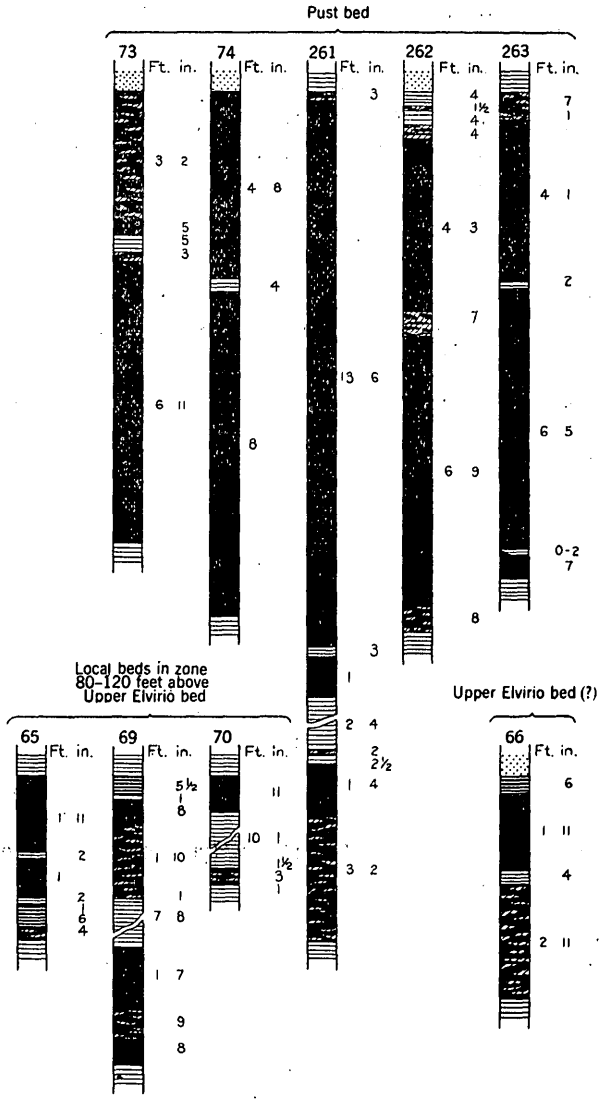


FIGURE 50.—Sections of coal beds in T. 22 N., R. 54 E. (For explanation see fig. 35, p. 149.)

is a 4-inch clay parting near the middle of the bed, and the lower 3 feet of coal is impure. The bed is much thinner to the north and west. A well in sec. 30, T. 22 N., R. 55 E., shows 6 to 8 feet of coal at the Upper Elvirio (?) horizon, so it is possible that the bed thickens to the south and east and may be of commercial value beneath the southeastern part of the township, although that exposed at the outcrop is of doubtful value.

The Pust coal bed crops out on the slopes north of the high ridge and in the valley of the North Fork of Burns Creek, but is so thoroughly burned at the outcrop that there are few exposures of the coal, except in the canyons where erosion has removed the burned material. Measurements were made at localities 73, 74, 261, 262, and 263 in this township and at locality 270 in sec. 33, T. 23 N., R. 54 E., and the thickness of coal was found to range from about 6 feet to 14 feet 6 inches. Ash of a bed that is possibly a bench of the Pust bed was found 15 feet below the main Pust bed in the northern part of the township, but no exposures of coal were found. At locality 269, in sec. 28, T. 23 N., R. 54 E., the lower bed is 3 feet thick, but as this bed is absent in the southern part of T. 22 N., R. 54 E., it either pinches out or merges southward into the main bed.

A local bed 80 to 120 feet above the Upper Elvirio(?) bed was mapped in the northwestern part of the township. Sections at localities 69 and 70 show, in a zone 38 feet thick, 4 small and usually impure beds separated by thick layers of gray clay. The thickest of these, the uppermost, is the one shown on the map. It contains about 3 feet of rather impure coal. At locality 65 the upper bed is the only one present. This bed is over 4 feet thick, but contains numerous partings. (See fig. 50.)

A small mine on the Pust bed is operated by a Mr. Miller at locality 263.

T. 23 N., R. 54 E.—The divide between the Yellowstone and Missouri Rivers crosses T. 23 N., R. 54 E. Fox Creek, a tributary of the Yellowstone, drains the part of the township east of the divide, and East Redwater Creek, a secondary tributary of the Missouri, drains the part west of the divide. East of the divide, in the northern part of the township, the surface is rolling, with a few gravel-capped buttes rising above the general surface level, but toward the south the surface is more irregular, and the streams have cut deep valleys almost to the divide. Along the south border of the township the surface slopes regularly southward. West of the divide a rolling surface deeply dissected by stream channels rises to an irregular line of cliffs that border the highland surface at the divide. The valleys west of the divide, except at the headwaters, have at one time been filled with alluvium, and the present streams are entrenched into this material to a depth of as much as 25 feet. Glacial erratic boulders are strewn over the ridges and hill slopes of the northwestern part of the township.

The Richey branch of the Great Northern Railway crosses the southwest corner of the township.

The Upper Elvirio coal bed crops out in the western part of the township. Two measurements of the thickness of the bed in the northwestern part of the township at localities 41 and 44 showed a main bed 5 feet 4 inches, and 3 feet 6 inches thick, respectively. A measurement at locality 60 showed an upper bench 2 feet 9 inches thick and a lower bench 1 foot thick separated by 5 feet of shale. A measurement of the bed at locality 40 showing a thickness of 13 inches may represent only the thin upper bench that occurs at localities 41 and 44. Because of the poor exposures there is some doubt that any of these measurements represent either the maximum or the minimum thickness of the bed in this township.

The Pust coal bed crops out extensively in this township but is poorly exposed on the grass-covered slopes. The coal in this bed has been burned at the outcrop only in the southern part of the township. The thickness of the coal measured ranges from 22 inches at locality 43 to 6 feet 2 inches at locality 268. A lower bench 15 feet below the main Pust bed is 3 feet thick at locality 269 but could not be traced for more than a few miles from this locality. In gen-

eral, the thickest and cleanest coal in this bed is in the southern part of the township. (See fig. 51.)

Coal is mined from the Pust bed in the short entries and small open cuts of the Painter mine (localities 267, 268, and 270), and from the lower split

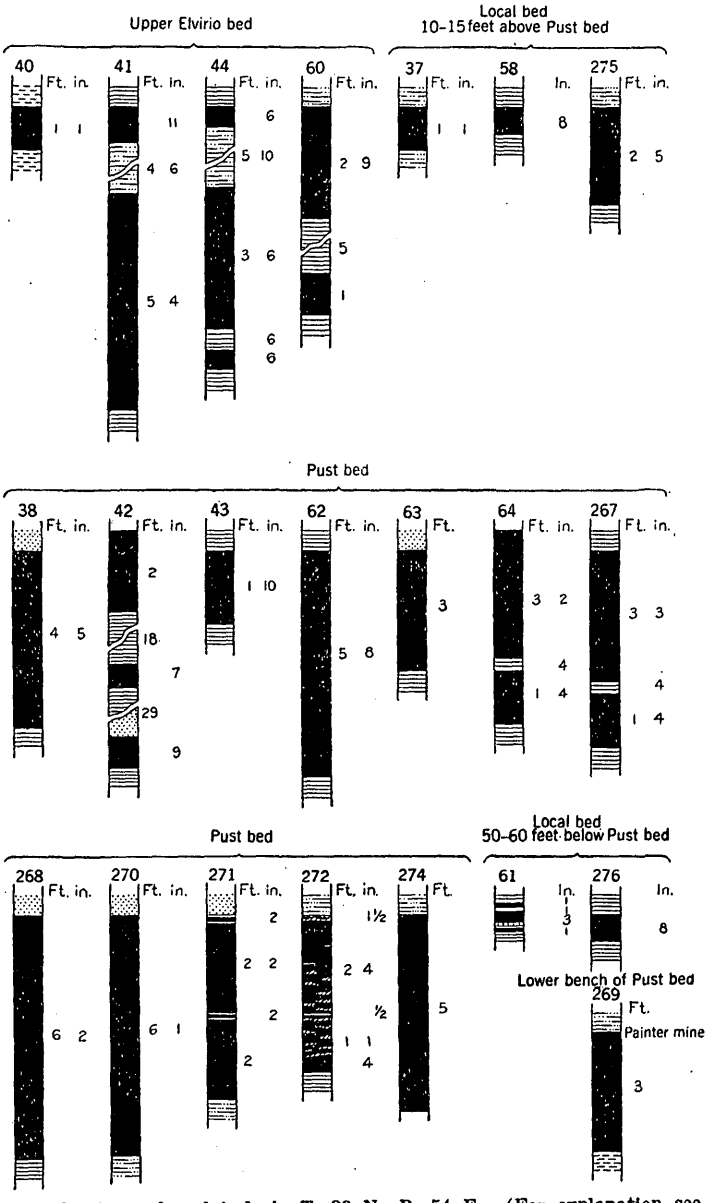


FIGURE 51.—Sections of coal beds in T. 23 N., R. 54 E. (For explanation see fig. 35, p. 149.)

of the Pust bed at locality 269, to supply coal to nearby ranches and the town of Enid. There are small prospects on the Pust bed at localities 38 and 274.

T. 24 N., R. 54 E.—The divide between the Yellowstone and Missouri Rivers crosses the southeastern part of T. 24 N., R. 54 E. The surface southeast of

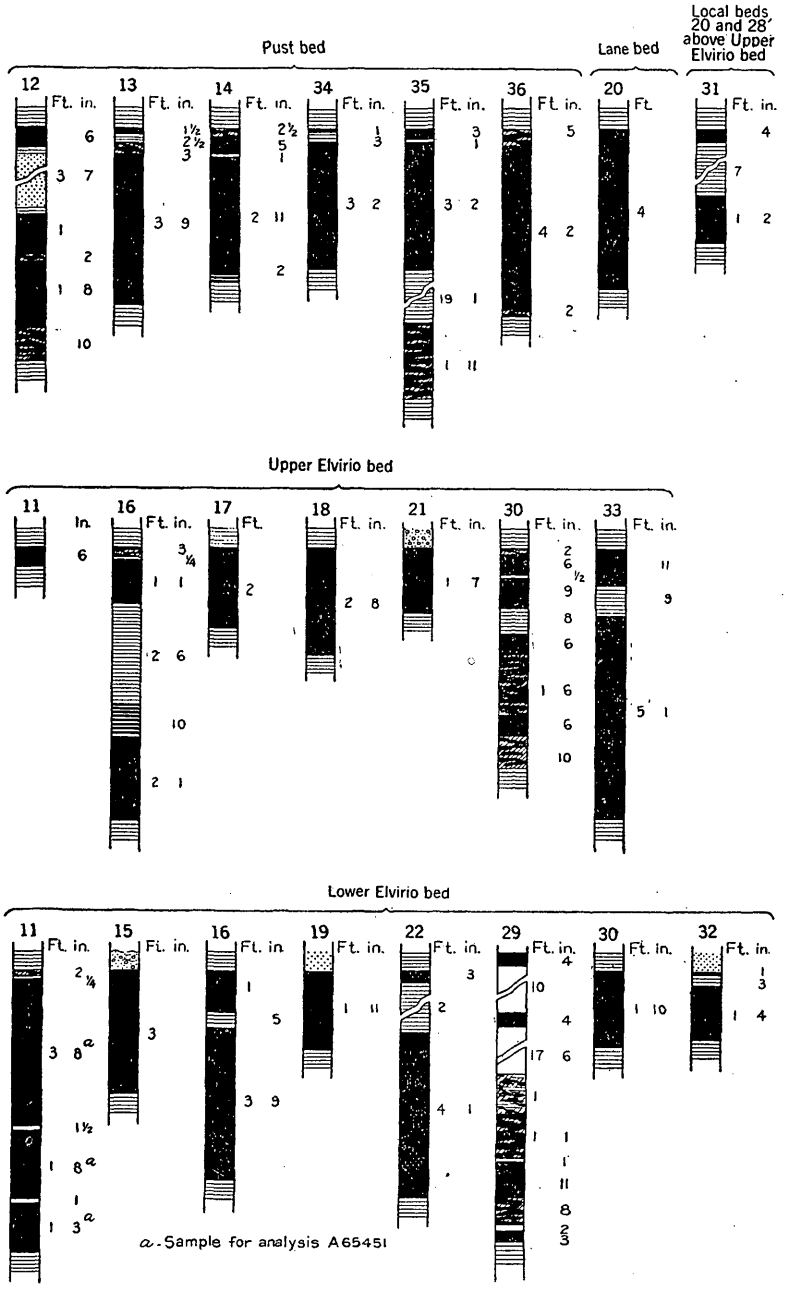


FIGURE 52.—Sections of coal beds in T. 24 N., R. 54 E. (For explanation see fig. 35, p. 149.)

the divide is gently rolling, with a few projecting gravel-covered hills and wide, shallow valleys. A line of cliffs near the divide faces a slightly dissected rolling surface extending north and west to the limits of the township. Glacial erratic boulders are very common north and west of the divide except on the surface of the alluvial flats.

The Lane bed crops out in the northwest corner of the township and was measured at locality 20. At this point only 4 feet of coal was found, but from measurements made in Tps. 23 and 24 N., R. 53 E., the writer believes that the bed may be thicker to the south.

No coal crops out in sec. 7 of this township, where the horizon of the Budka bed is exposed, but a well in sec. 18 penetrated 5 feet of good coal near the Budka horizon. At locality 39, in sec. 25, T. 24 N., R. 53 E., the Budka bed is 4 feet thick, so it is probable that this bed underlies the southwestern portion of the township, but no accurate estimate can be made of its thickness or value.

The Lower Elvirio bed was not mapped in the southwest corner of the township because of its thinness and impurity. In the north half of the township it is a persistent bed of variable thickness, as shown by the measurements at localities 11, 15, 16, 19, 22, 29, 30, and 32. It is nearly 7 feet thick with three thin partings at the Elvirio mine (locality 11) but is thinner elsewhere in the township. The 4-inch bed 17 feet above this bed at locality 29 may be the equivalent of the Upper Elvirio bed.

The Upper Elvirio bed was mapped only in the west half of the township. Although in some places there is a distinct bed of coal, this bed is usually represented by a zone of coal and carbonaceous shale. The observed maximum thickness is 6 feet 9 inches including a parting of 9 inches of shale, at locality 33. The bed could not be definitely traced north or northeast of the Jordan mine.

The Pust bed crops out near the base of the cliffs northwest of the divide. The bed is variable in quality. The observed thickness ranges from 3 feet 2 inches at locality 34 to 4 feet 9 inches at locality 36. The local bed of bony coal 23 inches thick, 19 feet below the Pust bed at locality 35, may represent a local thickening of the lower split of the Pust bed which was found 6 miles to the south.

Two thin local beds, 20 and 28 feet above the Upper Elvirio, were found at locality 31. Neither of these beds could be identified elsewhere in the township. (See fig. 52.)

The Elvirio mine (locality 11), on the Lower Elvirio bed, supplies domestic fuel in this vicinity. Several other prospects and small mines have been opened on the Lower Elvirio and Upper Elvirio beds, but none were in use at the time of the examination.

T. 21 N., R. 55 E.—The surface of T. 21 N., R. 55 E., is a broad, nearly flat upland trenched by the broad U-shaped valley of the North Fork of Burns Creek, which trends southeastward across the township. A low pass near the northwest corner of sec. 5 forms part of the divide between Burns Creek and Fox Creek.

The Pust bed, the only coal bed mapped in this township, crops out along the base of the cliffs bordering Burns Creek. The coal is burned or covered along most of the outcrop, but measurements of the thickness of the bed were obtained at localities 259 and 260. The thickness of coal including a few thin partings at these two localities was found to be 21 feet and 12 feet, respectively. There had been prospecting but no active mining at both of these localities. Local beds less than 1 foot thick and of no commercial value occur above the Pust, but these are not shown on the map. (See fig. 53.)

T. 22 N., R. 55 E.—T. 22 N., R. 55 E., is drained by forks of Fox Creek which occupy wide, flat valleys. Part of the valley of one fork is occupied by Fox Lake, a small body of stagnant water almost hidden by marsh grass. A wide alkali flat borders the lake and extends over a large part of the valley floor. A broad, low ridge extends northeastward from the middle of the west border of the township toward Fox Lake. In the southwestern part, except for the wide pass into the Burns Creek Valley, the land is rugged and dissected into breaks and badlands. In the southeastern part are remnants of an upland surface bordered by steep slopes and breaks.

Lambert, on the Richey branch of the Great Northern Railway, is in sec. 11.

The Pust bed crops out along the sides of the valleys in the western part of the area. It is commonly burned or covered at the outcrop, but massive clinker benches and buttes mark its presence. The Pust bed becomes thinner toward the east, and the outcrop is largely concealed beneath the valley alluvium and gravel terraces. It could not be traced definitely east of locality 264, in sec. 26. At that point 2 feet 7 inches of coal is present, but farther west, at localities 265 and 266, the bed is about 11 feet thick. At locality 266 an irregular parting of clay about 2 feet thick divides the bed into two benches. (See fig. 54.)

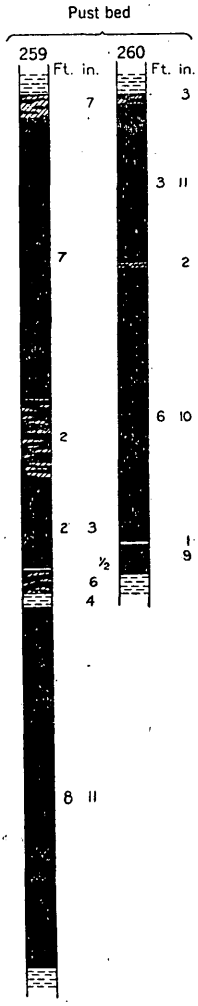


FIGURE 53.—Sections of the Pust coal bed in T. 21 N., R. 55 E. (For explanation see fig. 35, p. 149.)

The Upper Elvirio bed, or another coal bed near that horizon, was encountered in a well drilled in sec. 30. According to the owner of the well, 6 to 8 feet of coal was found at a depth of about 100 feet. The Upper Elvirio bed is variable in thickness and quality at the outcrop in the townships west of this one, so estimates of the value of the bed beneath this township are most uncertain.

Thin local beds of small areal extent were found above the Pust bed but were not mapped or measured.

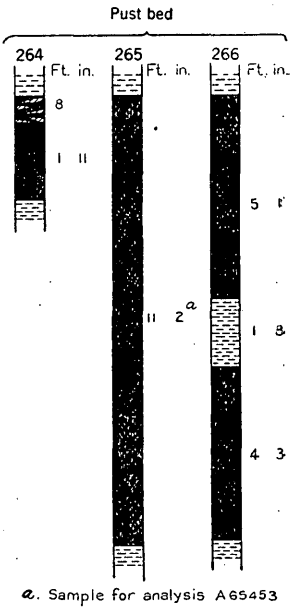


FIGURE 54.—Sections of Pust coal bed, T. 22 N., R. 55 E. (For explanation see fig. 35, p. 149.)

Two mines have been opened on the Pust bed. The August Pust mine, at locality 266, is a small open-cut mine from which only a little coal has been removed. In addition two entries have been driven about 50 feet on the bed, but no drifts or rooms have been opened from them. The Otto Pust mine, at locality 265, consists of a tunnel 200 feet long with ventilating shafts and rooms. This mine supplies coal for most of the residents of this neighborhood.

The broad low ridge in the west-central part of the township is underlain by the Pust coal bed at a maximum depth of 95 feet. It is estimated that this ridge is underlain by about 9,000,000 tons of coal that could be mined by open-cut methods.

T. 23 N., R. 55 E.—T. 23 N., R. 55 E., is rolling, with wide valleys occupied by tributaries of Fox Creek. A few small areas of badlands or projecting gravel-capped hills interrupt the rolling surface. The streams are bordered by alluvial flats, which are, in turn, bordered in places by gravel-covered stream terraces. The stream terraces, which are 20 to 30 feet above the present stream channels in the southern part of the township, converge and finally merge upstream with the valley bottom. The highest of the gravel-covered hills is probably correlative with the upland of the Retah Table.

The Pust bed crops out on the ridge in secs. 30, 31, and 32. The following section of the bed was measured at locality 273:

Section of Pust bed at locality 273, T. 23 N., R. 55 E.

	Ft.	in.
Clay		4
Clean coal		11
Bony coal		2
Coal with thin clay partings	1	5
Clay		2
Clean coal	1	
Clay		4

Elsewhere in the southeastern part of the township the coal outcrop is buried beneath terrace gravel or concealed by thick soil. At other places in the township where the horizon of the Pust bed is exposed only thin coal beds and carbonaceous shale beds occur.

The Prittegurl bed, 100 feet above the Pust bed, is thin and poorly exposed in this township. Its outcrop is concealed by thick soil and gravel through most of the area; consequently only its approximate position is shown on plate 22. A good exposure was found in a badland area at locality 278, where three beds, each less than 1 foot thick and separated by 10 to 15 feet of shale and sandstone, are present.

T. 24 N., R. 55 E.—South of the divide between the Yellowstone and Missouri Rivers, which crosses the southern part of T. 24 N., R. 55 E., the surface has low relief except for isolated gravel-capped hills. North of the divide, there are cliffs and badlands adjacent to the divide, but in the north half of the township the surface is rolling with a few badlands and entrenched stream channels. Glacial erratic boulders are common on the surface north of the divide except in the stream channels and on alluvial flats.

The Lower Elvirio bed crops out in the northern part of the township, but because of a cover of thick soil it is exposed in few places. Measurements made at localities 1, 5, and 9 show thicknesses of coal ranging from 2 feet 8 inches to 5 feet. This bed underlies extensive areas with shallow cover but is usually thin and contains coal of poor quality.

The Pust bed could not be traced east of sec. 19. A measurement at locality 10 shows a thickness of only 2 feet.

In the southeastern part of the township the Prittegurl coal bed crops out in the cliffs and badlands north of the divide but is concealed beneath gravel and thick soil south of the divide. Measurements show a maximum observed thickness of 5 feet 8 inches of coal in one bed, with thin beds in a zone 10 feet above it, at locality 2, at the east border of the township, and a minimum

observed thickness of 21 inches of coal at locality 7, in sec. 28, the bed thinning westward. The bed is thinner also toward the south, as shown by the absence of thick coal beds near this horizon in the good exposures at locality 278, in T. 23 N., R. 55 E.

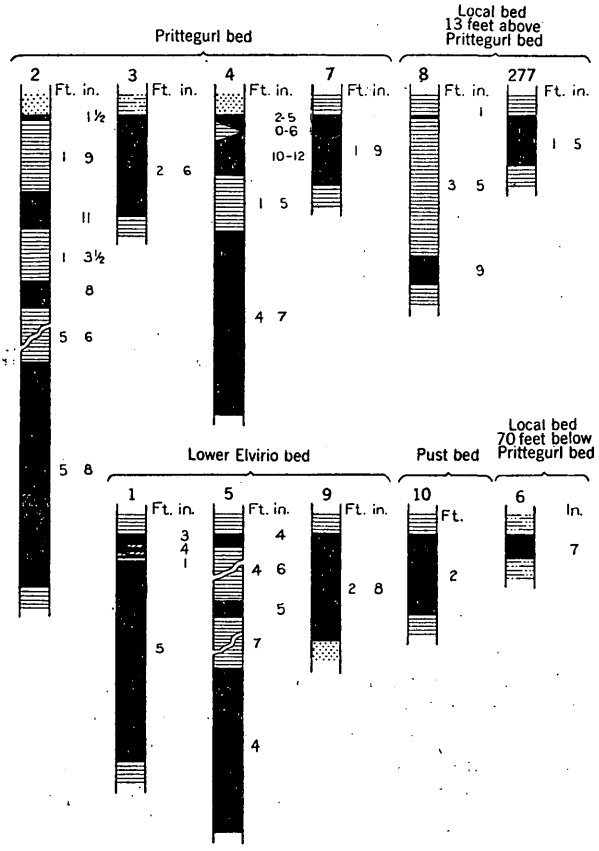


FIGURE 55.—Sections of coal beds in T. 24 N., R. 55 E. (For explanation see fig. 35, p. 149.)

A thin coal bed 13 feet above the Prittegurl bed was measured at localities 8 and 277, and a thin local bed 70 feet below the Prittegurl bed was measured at locality 6, but both beds are too thin to be a valuable source of coal. (See fig. 55.)

A small amount of coal has been taken from the Prittegurl bed at the Prittegurl mine (locality 4). Most of the coal used in this township is obtained from mines in adjacent townships.