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GEOLOGY AND MINERAL RESOURCES OF NORTH-CENTRAL CHOUTEAU, WESTERN HILL AND EASTERN LIBERTY COUNTIES MONTANA

BY

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CONTENTS

	Page
Abstract	225
Introduction	226
Location and extent of area	226
Field work and acknowledgments	226
Publications relating to this area	228
Geography	229
Surface features	229
Transportation	229
Culture and climate	230
Stratigraphy	231
Rocks exposed	231
Quaternary system	232
Recent series	232
Pleistocene series	232
Cretaceous system	232
Upper Cretaceous series	232
Judith River formation	232
Claggett shale	236
Eagle sandstone	242
Colorado shale	246
Rocks not exposed	248
Kootenai formation	248
Ellis formation	248
Madison limestone	249
Information from driller's log	249
Igneous rocks	251
Structure	253
Regional structure	253
Structure of the area	253
Faults	254
Mineral resources	258
Oil and gas	258
Results of drilling	258
Wells near Kremlin	258
Utopia wells	259
Other wells	260
Oil and gas possibilities of the region	260
Coal resources	261
Water resources	264

ILLUSTRATIONS

		Page
PLATE 36.	*A*, Cliffs of Judith River formation along Milk River; *B*, Cross-bedding in Judith River formation	236
37.	*A*, Exposure of Eagle sandstone; *B*, View looking up Marias River	237
38.	*A*, Distant view of dike; *B*, Dike cutting upward through Virgelle sandstone member of Eagle sandstone	252
39.	*A*, View along trace of fault, showing steeply dipping Colorado shale thrust over horizontal beds of Eagle sandstone; *B*, View looking west across plateau surface of Liberty County toward Sweetgrass Hills	253
40.	Faults exposed along Sage Creek, about 3 miles south of Gildford	256
41.	Interpretation of logs of wells drilled near Kremlin	260
42.	Coal in Judith River formation	260
43.	Geologic map of north-central Chouteau, western Hill, and eastern Liberty Counties, Mont	In pocket
FIGURE 57.	Index map of Montana showing location of the area described	227
58.	Lenticularity and cross-bedding of strata in upper part of Eagle sandstone in SW¼ sec. 1, T. 26 N., R. 7 E	246
59.	Lobe of Judith River formation in dike of porphyritic lamprophyre along Milk River near the northwest corner of sec. 2, T. 37 N., R. 8 E	251
60.	Coal in upper part of Eagle formation, T. 26 N., R. 12 E	262

GEOLOGY AND MINERAL RESOURCES OF NORTH-CENTRAL CHOUTEAU, WESTERN HILL, AND EASTERN LIBERTY COUNTIES, MONTANA

By W. G. Pierce and C. B. Hunt

ABSTRACT

This report describes a rectangular area of about 2,600 square miles in Chouteau, Hill, and Liberty Counties, Mont., adjacent to the international boundary. The area is a portion of the Missouri Plateau, a section of the Great Plains province, and lies between the Highwood Mountains, Bearpaw Mountains, and Sweetgrass Hills, of north-central Montana. The southern part of the area is drained by the Missouri River and its tributary Marias River, but the northern part is drained by the Milk River. These streams are trenched in narrow valleys several hundred feet deep. The land surface between them is a rolling plain interrupted by very broad, shallow valleys that probably were eroded during the Pleistocene epoch by large streams whose courses were doubtless diverted from time to time by the continental glaciers. These valleys are now occupied only by very small creeks.

The exposed rocks include sedimentary formations of Upper Cretaceous age, Pleistocene glacial deposits, and a few dikes of igneous rock. The exposed Upper Cretaceous formations from oldest to youngest are the Colorado shale, Eagle sandstone, Claggett shale, and Judith River formation. The Colorado shale, as shown by deep wells, is about 1,800 feet thick, but only the upper 500 feet is exposed in this area. The exposed parts of the formation consist mainly of dark-gray marine shale and some bentonite and calcareous concretions, and the upper 100 feet contains considerable sandstone and thus forms a transition zone between the Colorado shale and overlying Eagle sandstone. The Eagle sandstone, 200 to 225 feet thick, consists of a lower sandstone, the Virgelle sandstone member, overlain by sandstone, sandy clay, carbonaceous shale, and thin coal beds. The Claggett shale is a marine unit 400 to 500 feet thick that thickens eastward. The lower half of the formation is brownish-black fissile shale containing dark-gray calcareous concretions 4 feet or less in diameter. Four or more bentonite beds, 1 to 3 feet thick, occur in the lower 80 feet, and scattered pebbles of black chert are common in the lower 30 feet. The upper half of the Claggett is gray shaly sandstone with interbedded gray and black fissile shale and is transitional with the overlying Judith River formation. The Judith River formation, 500 to 600 feet thick, consists of continental and brackish-water sandstone, clay shale, carbonaceous shale, and coal. The lower 200 feet is made up of somber-colored beds with coal, generally most abundant at the top. The upper 300 to 400 feet consists of lighter-colored beds, non-coal-bearing in this area but containing coal where the top is exposed farther east.

Pleistocene gravel, loam, and glacial drift generally conceal the Upper Cretaceous rocks. The average thickness of these deposits is less than 15 feet, but the maximum thickness is 50 feet or more.

The igneous dikes that intrude the Upper Cretaceous rocks are composed of porphyritic lamprophyre.

The sedimentary rocks dip northeastward at the rate of about 35 feet to the mile, and their slope in this direction is modified by a few broad folds that plunge in the direction of the slope. The axis of the Utopia anticlinal nose, the most prominent fold of the area, is a few miles north of the main line of the Great Northern Railway. The Utopia nose plunges slightly north of east and has a structural relief of about 150 feet. The eastern extension of the Marias River syncline is just south of the Utopia nose and plunges east-northeast. Other folds that interrupt the regional dip have very little structural relief, and apparently none are closed folds. The rocks that are exposed in the vicinity of Kremlin have heretofore been regarded as having anticlinal structure, but they are interpreted by the writers as having been deformed by faulting. Here, as well as elsewhere in the eastern part of the area, there are numerous thrust faults of the type that are abundant in the region surrounding the Bearpaw Mountains, to the east.

Drilling has not revealed oil in commercial quantities, but small showings are present in several wells. Gas is apparently more abundant, for it was encountered in the Eagle sandstone in most of the wells.

Coal of subbituminous rank is present in lenticular beds, generally less than 3 feet thick, in the upper part of the Eagle sandstone and the lower 200 feet of the Judith River formation. In general, however, the coal is of poor quality. A large number of small mines supply the local market, but none are worked continuously.

The ground-water resources of the area are not entirely adequate for domestic supplies and for stock. A sufficient quantity of water can usually be obtained by drilling wells into the Judith River or the Eagle formation, but the mineral content of these waters is fairly high, generally ranging from 1,000 to 2,500 parts per million, and locally it may be as high as 5,000 parts per million. The principal mineral constituents of the water are sodium carbonate, sodium sulphate, and sodium chloride. The veneer of glacial drift, which covers most of the area, is generally too thin to yield water in shallow wells.

INTRODUCTION

Location and extent of the area.—The parts of north-central Chouteau, western Hill, and eastern Liberty Counties that are described in this report form a rectangular area of about 2,600 square miles in north-central Montana adjacent to the international boundary. (See fig. 57.) The area extends southward 72 miles from the international boundary and is 36 miles wide; it includes Tps. 26 to 37 N., Rs. 7 to 12 E.

Field work and acknowledgments.—The field work in this area was undertaken by the United States Geological Survey to obtain the information necessary for the classification of public lands and for the proper administration of the laws governing the development of mineral resources on public lands. The examination was made by the writers during July, August, and September 1932. Topographic maps of the Kremlin, Box Elder, Big Sandy (unpublished), and Lonesome quadrangles, prepared by the Geological Survey, were available for about one-fifth of the area and were used as base maps for field mapping. Sheets 26 and 27 of the international-boundary map, from the Gulf of Georgia to the northwesternmost point of the Lake of the Woods, furnished precise topographic base maps of a strip about a mile wide along the northern edge of the area. Plane-table sheets, prepared during a previous survey of the coal resources by the Geological Survey, were available for Tps. 35 to 37 N., Rs. 10 to 12 E., T. 26 N., Rs. 11 and 12 E., and T. 25 N., R. 12 E., comprising one-sixth of the area. For the remainder of the area township plats prepared by the General Land Office were used as base maps. Out-

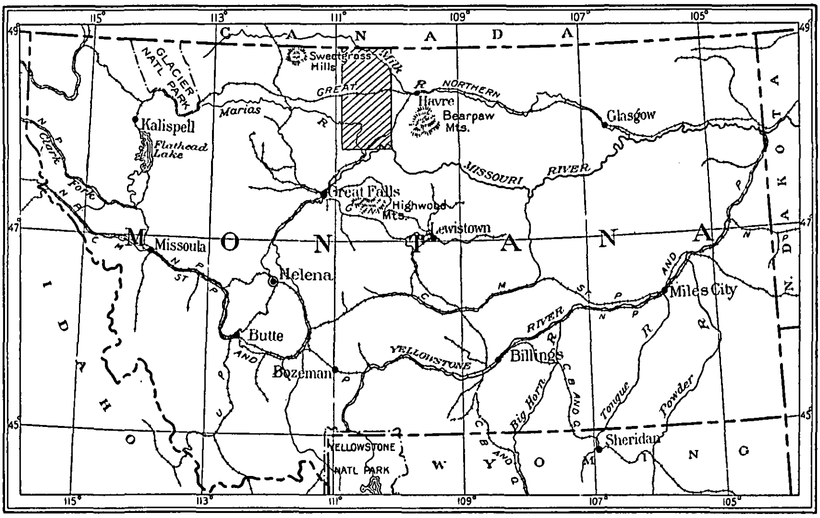

FIGURE 57.—Index map of Montana showing location of the area described (shaded area).

crops were located approximately with respect to section lines, and altitudes were determined by traverses with a surveying aneroid. Practically all parts of the area could be reached by car, except those parts along the Missouri and Marias Rivers, where examinations were made on foot.

Rock outcrops are not abundant in the area, and information obtained from water wells was very helpful in supplementing that obtained from outcrops. The use of this information involved the interpretation of the driller's or owner's descriptions of lithologic units encountered in drilling the well, and although these descriptions are not invariably accurate, the water wells were the source of much valuable information.

The portion of the present report that relates to coal resources includes the results of field work in 1915 by Eugene Stebinger, assisted by W. P. Woodring and J. D. Sears. This field work consisted of detailed areal mapping and tracing by plane-table methods of coal beds along the Milk River and Canada Coulee in Tps. 35 to 37 N., Rs. 10 to 12 E., and T. 37 N., R. 9 E. Similarly, in 1914 a party in charge of E. R. Lloyd made a detailed plane-table survey of T. 26 N., Rs. 11 and 12 E. No attempt was made during the earlier field work to determine the attitude of the strata and to map the geologic structure, but the present writers have used the earlier areal mapping as a basis for observations on the geologic structure of these townships.

The writers had a valuable and instructive field conference with their colleague C. E. Erdmann on the stratigraphy of the beds underlying the area considered in this report, which are exposed in the upturned beds of the Sweetgrass Hills. The project was under the supervision of H. D. Miser, and the writers are indebted to him and A. A. Baker for valuable suggestions and criticism of the report. The several oil companies furnished logs of their wells, and Mr. Lehfeldt, of Big Sandy, and the many residents of the region gave generous cooperation.

Publications relating to this area.—Although the geology of most of this area has not been described or mapped previously except for a brief statement[1] of the results of the present investigation, the regional geology of north-central Montana has long been known through the work of authors of geologic reports and maps of adjacent or nearby areas. Some of these reports and maps are cited below.

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

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[1] Pierce, W. G., and Hunt, C. B., Geology and mineral resources of north-central Chouteau, western Hill, and eastern Liberty Counties, Mont.: U. S. Dept. Interior Press Mem. 72308, June 1933.

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Stebinger, Eugene, The Montana group of northwestern Montana: U. S. Geol. Survey Prof. Paper 90, pp. 61–68, 1915.

Stebinger, Eugene, Possibilities of oil and gas in north-central Montana: U. S. Geol. Survey Bull. 641, pp. 49–91, 1917.

Weed, W. H., U. S. Geol. Survey Geol. Atlas, Fort Benton folio (no. 55), 1899.

GEOGRAPHY

Surface features.—The area here under consideration includes part of the Missouri Plateau and lies between three mountain groups—the Bearpaw Mountains on the east, the Highwood Mountains on the south, and the Sweetgrass Hills on the west. (See fig. 57 and pl. 39, *B*.) The surface of the plateau is gently rolling but is trenched by deep valleys that are occupied by the principal streams. The relief in the area is about 1,270 feet, the altitude above sea level ranging from 2,500 feet along the Missouri River to 3,770 feet on Goosebill Butte. However, most of the area is a plateau surface between 2,900 and 3,300 feet above sea level.

The Missouri River flows northeastward across the southeast corner of the area. Marias River flows southeastward across the southwestern part of the area and joins the Missouri south of the area. The Milk River enters the United States from Canada and flows across the northeastern part of the area. These three streams have cut steep-walled valleys 200 to 300 feet below the general plateau surface, which is otherwise gently rolling and little dissected. (See pl. 37, *B*.) Broad valleys, some of which are probably the abandoned courses of major streams but are now occupied only by small creeks, form a large part of the surface—for example, the valley of Sage Creek, which parallels the course of the Milk River; the valley of Lonesome Lake, in T. 29 N., Rs. 10 to 12 E.; and the valley of Big Sandy Creek, just east of the area.

Transportation.—The main line of the Great Northern Railway crosses the central part of the area, and a branch line from Havre to Great Falls crosses the southeastern part.

United States Highway 2 parallels the main line of the Great Northern Railway. It is a gravel road, in part oiled. State Highway 29, which extends southwestward from Havre through Big Sandy and Fort Benton to Great Falls, more or less follows the branch line of the railway. At the time of the field work this road was in part dirt and passable only with difficulty in wet weather. However, parts were being improved, and probably it will soon be serviceable in all weather.

Only the principal county roads are indicated on plate 43, but nearly all the section lines are traversable by automobile.

Culture and climate.—The towns within the area—Joplin, Inverness, Rudyard, Hingham, and Gildford—are closely spaced along the main line of the Great Northern Railway; each had a population of a few hundred inhabitants in 1930. Havre, 20 miles east of the area, is the largest commercial center serving this region. Its population in 1930 was 6,372. It is a division point on the Great Northern Railway, and the Great Falls branch joins the main line there. Fort Benton, on the north bank of the Missouri River 10 miles south of the area, was an important trading post in pioneer days, for it was at the head of navigation and was reached by steamers that slowly plied their way up the river. Its population in 1930 was 1,109. Big Sandy, on the east boundary of the area, had a population of 633, and Chester, 3 miles west of the area, had a population of 387.

The average annual precipitation in the area is about 11 inches, but through a period of a few years it may vary several inches. The annual mean temperature is about 42° F., but the extremes are great—generally between 105° in the summer and −45° in the winter. The prevailing winds blow from the west and southwest.

Practically all the inhabitants are engaged in raising wheat by dry-farming methods, though some livestock is raised in the northwestern part of the area. Good crops of wheat are usually obtained in years of more than average rainfall, but in the years when the rainfall is below the average the crops are very poor. Water supply for domestic use and for stock is a problem throughout the area. Surface water is available only along the major streams. Most shallow wells yield only small supplies of water and none in dry seasons. A sufficient yield for domestic use and for a few head of stock can usually be obtained by drilling a few hundred feet, but the water is mineralized and not entirely satisfactory. As water supply is a foremost problem in this region, some consideration of it is included in this report (p. 264).

STRATIGRAPHY

ROCKS EXPOSED

The rocks exposed in the area covered by this report are sedimentary deposits of Upper Cretaceous age, Pleistocene glacial deposits, and a few dikes of igneous rocks. The Upper Cretaceous rocks include sandstone, shale, and bentonite deposited in marine waters; sandstone and shale deposited in brackish waters; and continental deposits of clay, shale, sandstone, and coal. The sedimentary rocks can readily be separated into four formations, as described in the following table:

Upper Cretaceous formations exposed in the area

Age	Formation	Canadian equivalent	Thickness (feet)	Character
Upper Cretaceous.	Judith River formation	Pale beds Foremost formation	500–600	Mostly light-colored continental and brackish-water deposits of thin-bedded sandstone, thick massive sandstone, clay shale, carbonaceous shale, and coal. Most of the coal beds are found near the top of the formation and within 200 feet of the base. Locally there is a massive tan, probably marine sandstone about 50 feet thick at the base. Beds of oyster shells are common. The lower 200 feet, of more somber-colored beds, is equivalent to the Foremost formation, and the upper 300 to 400 feet, of a slightly lighter hue, to the Pale beds of the Canadian classification.
	Claggett shale	Pakowki formation	400–500	Upper half thin-bedded gray shaly sandstone, with interbedded gray and black fissile shale. Lower half brownish-black fissile marine shale containing dark-gray calcareous concretions 4 feet or less in diameter, which disintegrate into small angular pieces. Four or more bentonite beds 1 to 3 feet thick occur in the basal 80 feet. Contains scattered small black chert pebbles in the lower 30 feet.
	Eagle sandstone	Milk River formation	200–225	Upper half white and buff sandstone, sandy clay shale, carbonaceous shale, and thin coal beds. A thin bed of black chert pebbles in some places is present at or near the top. Contact with overlying Claggett shale is sharp. Lower half massive light-colored sandstone, the Virgelle sandstone member, which contains water and gas. The base is usually transitional into the Colorado shale.
	Colorado shale	Colorado shale	1,800±	Only the upper 500 feet is exposed in this area, consisting of interbedded tan sandstone and gray shale, which is more sandy in the upper 100 feet. The formation is composed principally of dark-gray marine shale with some beds of bentonite, sandstone, and calcareous concretions; the lower part is sandy and is known as the "Blackleaf sandy member."

Pleistocene gravel, silt, and glacial till, which were deposited by the continental glaciers, were not mapped in detail. These deposits, however, are present throughout the area and generally conceal the Upper Cretaceous rocks.

The dikes intruded into the Upper Cretaceous formations consist of porphyritic lamprophyre.

QUATERNARY SYSTEM

RECENT SERIES

The Recent deposits include flood-plain and alluvial deposits composed of clay, sand, and gravel. They lie unconformably on the earlier formations along the valleys of the principal streams of the area. The thickness is less than 25 feet.

PLEISTOCENE SERIES

The Pleistocene ice sheets deposited clay, sand, gravel, and boulders. This drift is generally less than 15 feet thick, except in morainal deposits or valley fill. The maximum observed thickness is 50 feet. This material covers nearly all of the area, except where it has been removed by streams, and unconformably overlies the earlier formations.

CRETACEOUS SYSTEM

UPPER CRETACEOUS SERIES

JUDITH RIVER FORMATION

The Judith River formation was named by Hayden [2] in 1871, but the stratigraphic position of the formation was not proved until 1903, when Stanton and Hatcher [3] determined that it is a part of the Montana group and a time equivalent of part of the Pierre shale. The Judith River and Eagle formations thicken westward in north-central Montana, and west of this area, where the Claggett thins out, they join. The combined series, exclusive of the Virgelle sandstone, is called the "Two Medicine formation", and the Virgelle is there treated as a distinct formation.

In the area here described the Judith River formation consists largely of sandstone and shale of fluviatile origin with some interbedded brackish-water deposits. The formation conformably overlies the Claggett shale; the contact is exposed at a few localities. The Bearpaw shale, which normally overlies the Judith River formation, has been completely eroded from the area.

The Judith River formation crops out in nearly all of the northern two-thirds of the area but has been eroded from the southern third. The formation attains a maximum thickness of about 600 feet in the northeast corner of the area.

The Judith River consists of very lenticular beds of sandstone, shale, and coal. (See pl. 36, *B*.) The lower 200 feet includes more

[2] Hayden, F. V., Geology of the Missouri Valley: U. S. Geol. Survey Terr. [4th Ann.] Preliminary Rept., p. 97, 1871.

[3] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, pp. 62-66, 1903.

coal, carbonaceous beds, shale, and in general more somber-colored deposits than the upper 300 to 400 feet, which consists predominantly of light-colored sandstones, generally friable, and which in this area contains little or no coal but to the east, near Havre, contains coal beds near the top of the formation. Ferruginous brown sandstone beds containing brackish-water fossils are common in the lower 200 feet but are rare in the upper 400 feet of the formation. On the other hand, vertebrate fossils are most common in the upper beds. Canadian geologists have long recognized these differences within the Judith River formation and have divided the strata into two formations—applying the name "Pale beds" to the upper part and "Foremost formation" to the lower part. (See pl. 36, *A*.) At many places it is difficult to draw a sharp boundary between these lithologic subdivisions.

Near the top of Goosebill Butte, in sec. 26, T. 27 N., R. 7 E., there is a prominent tan to buff massive sandstone about 50 feet thick, which in places has slumped so that now large blocks are lower than their original position. A few feet above this sandstone are beds of oyster shells and some thin coal beds in strata that consist predominantly of sandstone. These coal-bearing beds are undoubtedly Judith River, whereas the massive sandstone below is probably Claggett as originally defined (p. 236), but lithologically it is a part of the Judith River and consequently is mapped as a part of that formation and so treated in this report. Furthermore, this massive sandstone bed is not present everywhere at the base of the Judith River, and in some places a massive cross-bedded sandstone that contains a Judith River fauna occurs near the base of the formation.

The base of the Judith River is also exposed across the northeast sections of T. 30 N., R. 7 E., along Dobie Ridge, where, however, there is complete gradation through an interval of 160 feet from the shale of the Claggett to thin-bedded sandstone of the Judith River, as indicated by the following section:

Section of upper part of Claggett shale and lower part of Judith River formation in the E½ sec. 2, T. 30 N., R. 7 E.

	Ft.	in.
Judith River formation:		
Sandstone, friable, tan; contains lenses of cross-bedded sandstone and brown concretions in upper part	17	
Shale, gray, very thinly laminated; breaks into fine pieces	11	
Sandstone, tan, arkosic?	5	
Bed of oyster shells		4
Shale, sandy, brown, carbonaceous	1	

Section of upper part of Claggett shale and lower part of Judith River formation in the E½ sec. 2, T. 30 N., R. 7 E.—Continued

	Ft.	in.
Judith River formation—Continued.		
Sandstone, light green gray, cross-bedded, lenticular; forms irregular ledge	13	
Shale, hard, brown; contains plant fragments	1	6
Sandstone, friable, tan with orange-yellow streaks	12	
Shale, gray; contains plant remains and is carbonaceous in upper 6 inches; oyster shells at very top	2	6
Claggett shale:		
Shale, brown and tan, thinly laminated; weathers to purple along joint cracks; contains light-gray to tan cross-bedded sandstone concretions 1 to 4 feet in diameter; some thin sandy beds with oyster shells in upper part; black fissile shale at top	36	
Mostly concealed; sandy shale where exposed	33	
Sandstone, friable, tan; some clay with thin concretionary beds of buff sandstone	17	
Shale, tan to light gray, sandy; contains calcareous concretions that break into small conchoidal pieces	11	

The base of the Judith River is exposed in the fault blocks along the Milk River, in the center of T. 34 N., R. 13 E., just east of this area, where the contact with the underlying Claggett also is transitional. The transition beds consist of massive sandstone, 10 to 25 feet thick, separated by dark shale of approximately equal thickness, so that it is a matter of interpretation whether the contact should be drawn at the top of the highest shale or at the base of the lowest massive sandstone bed.

About 200 feet above the base of the Judith River there is a carbonaceous zone that contains coal at many localities. This zone crops out in Canada Coulee in T. 37 N., R. 9 E., where coal is mined from it. The same zone is poorly exposed along Sage Creek and Little Sage Creek in the northwestern part of the area but has been recognized in water wells as a persistent coal-bearing unit. Several shafts have been put down to the coal, and although most of the mines are now little used, they have supplied a considerable quantity of coal for the surrounding territory and can do so in the future. The general lithologic sequence in the faulted blocks of the Judith River formation along Sage Creek, south of Gildford, suggests that the coal exposed in the mines there is from the same zone at the top of the lower 200 feet of the Judith River formation.

The following section of the Judith River, measured along Milk River at the international boundary, is the most nearly complete section measured by the writers, but neither the base nor the top of the formation is present.

Incomplete section of the Judith River formation measured along Milk River at the international boundary, near north line of sec. 2, T. 37 N., R. 8 E.

	Ft.	in.
Glacial drift and soil.		
Judith River formation:		
Sandstone, pale pink at base, light yellow at top; badly weathered fossil bone at top	22	
Clay, light-colored	24	
Sandstone, friable, fine-grained; weathers light gray; forms slope	15	
Sandstone, light gray but weathers brown; fine to medium grain; considerable dark material in the sand, giving it a salt-and-pepper appearance; cross-bedded; forms ledge; lenticular	3	
Shale, gray, with thin beds of yellow sandstone	16	
Shale, carbonaceous, with streaks of coal	1	
Shale, gray, with thin beds of yellow sandstone	11	
Shell bed containing fragments of Unios(?) and other fossils		3
Shale, gray, with thin beds of yellow sandstone	15	
Shale, dark gray, fissile	1	
Shale, gray, with thin beds of yellow sandstone	8	
Shale, brown, carbonaceous	1	5
Shale, gray, with thin beds of yellow sandstone	16	
Shale, gray; some black carbonaceous shale near base but grades upward to lighter-colored shale with thin beds of sandstone	27	
Shale, carbonaceous, with thin streaks of coal	1	
Shale, gray and brown, locally carbonaceous	11	6
Bentonite		2
Shale, carbonaceous	1	6
Coal	2	8
Shale, dark gray, carbonaceous; contains a few fossil shells; grades upward to yellowish-brown shale	11	
Shell bed; lower part sandy shale, upper part dark-gray shale	3	
Coal, shaly	1	2
Sandstone, light gray, massive; contains some clay; dark-brown ferruginous concretions 1 foot thick and 3 to 15 feet long in zone about 6 feet above base of unit	22	
Clay, banded, tan, light gray, and chocolate brown; increasingly sandy toward the top	18	
Shell marl, mostly oyster shells		4
Shale, carbonaceous, with thin streaks of coal	1	
Sandstone, light gray, massive, resistant	10	
Shale, gray, silty, containing hard tabular concretions 1 to 4 inches thick, and banded clayey sandstone	27	
Shale, gray, sandy	35	
Shale, dark gray, with bands of dark-tan sandy shale	20	
Alluvium in valley of Milk River. Lowest exposed bed is less than 50 feet above base of Judith River.		
	326	

The uncertainties of recognizing horizons within the Judith River and the complete absence of the Bearpaw shale contribute to the difficulties of determining the thickness of the Judith River in this area. About 200 feet of somber-colored beds (Foremost formation of Canadian geologists) are exposed along Milk River, and an estimated thickness of 300 feet of the Pale beds of the Canadian classification overlies them. The Bearpaw shale, which is present a few miles east of the area, is probably not more than 100 feet stratigraphically above the highest Judith River beds within the area, so that the estimated total thickness of the Judith River is between 500 and 600 feet.

CLAGGETT SHALE

In 1905 Stanton and Hatcher [4] gave the name "Claggett shale" to the formation that overlies the Eagle sandstone and underlies the Judith River formation. The formation was named from the exposures near Judith (old Fort Claggett), on the Missouri River near the mouth of the Judith River. It consists chiefly of shale but includes more or less sandstone in the upper part. Elsewhere in Montana, where the formation contains a large percentage of sandstone, the name "Claggett formation" is applied to it.

The Claggett shale crops out in a broad belt in the southern part of this area and in fault blocks along Sage Creek and the Milk River. Good exposures are few and are confined mostly to the walls of large valleys and coulees. In places where there is no glacial drift there are local weathered exposures of the shale.

The Claggett is chiefly dark shale with a slightly brownish cast. The lower half contains calcareous concretions and beds of bentonite, but the upper half is progressively more sandy toward the top. The concretions are most common in the upper part of the lower half or shaly unit of the Claggett. They are isolated oblate spheroids from 1 to 4 feet in diameter, composed of dark-gray limestone. They are usually 10 feet or more apart horizontally but locally occur with a regularity that suggests definite beds or zones. Horizontally the individual zones merge with higher or lower zones and consequently cannot be used for precise stratigraphic horizon markers or "key beds." Individual concretions disintegrate into small, angular conchoidal pieces, but the whole concretion tends to maintain its unity through cementation by calcite. Cone-in-cone structure occurs at the top and base of many of the concretions. At each concretion examined the cone structure points toward the concretion—that is, the cones at the top point downward and those at the base point upward. The

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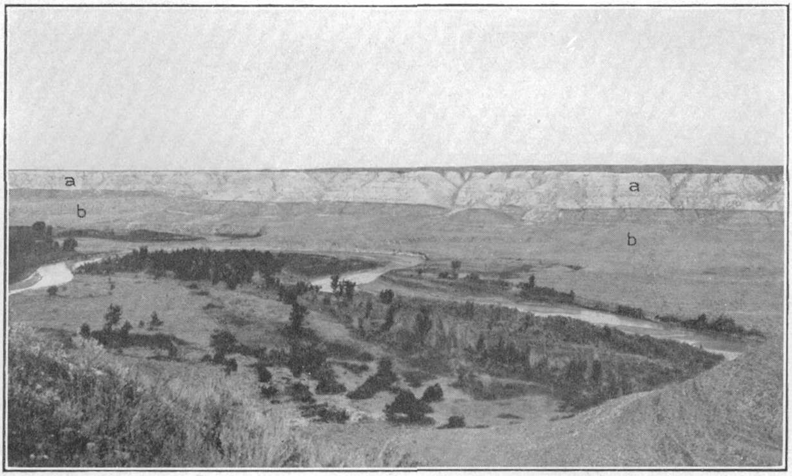
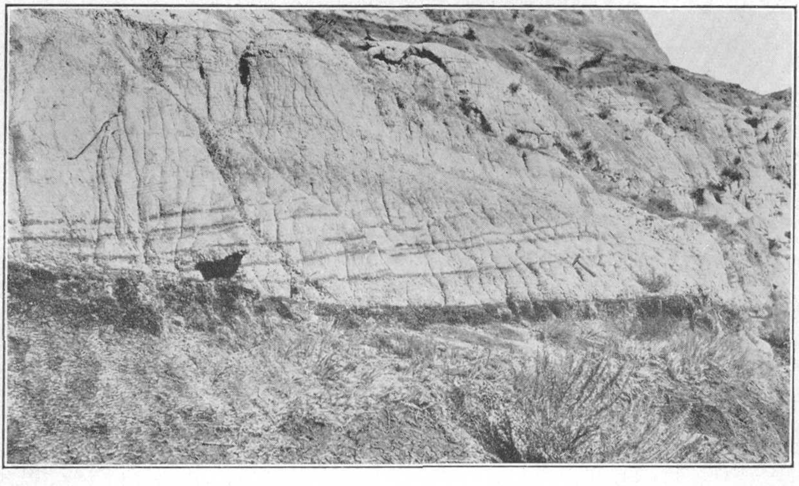
[4] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, p. 13, 1905.



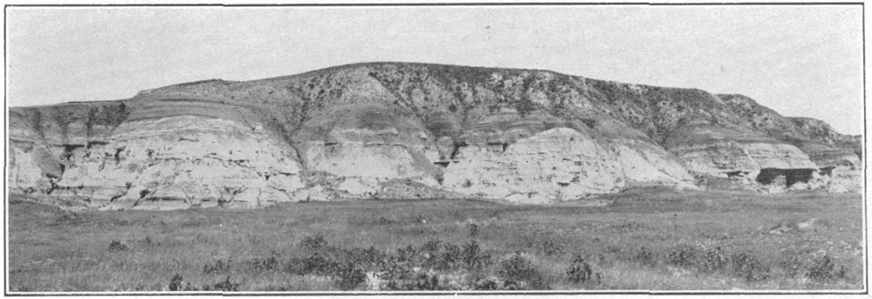
A. CLIFFS OF JUDITH RIVER FORMATION ALONG MILK RIVER, IN SEC. 3, T. 37 N. R. 9 E.

The lower third of the strata exposed (b) represents the Foremost beds of the Canadian classification, underlying the Pale beds of Canada (a). View looking north.



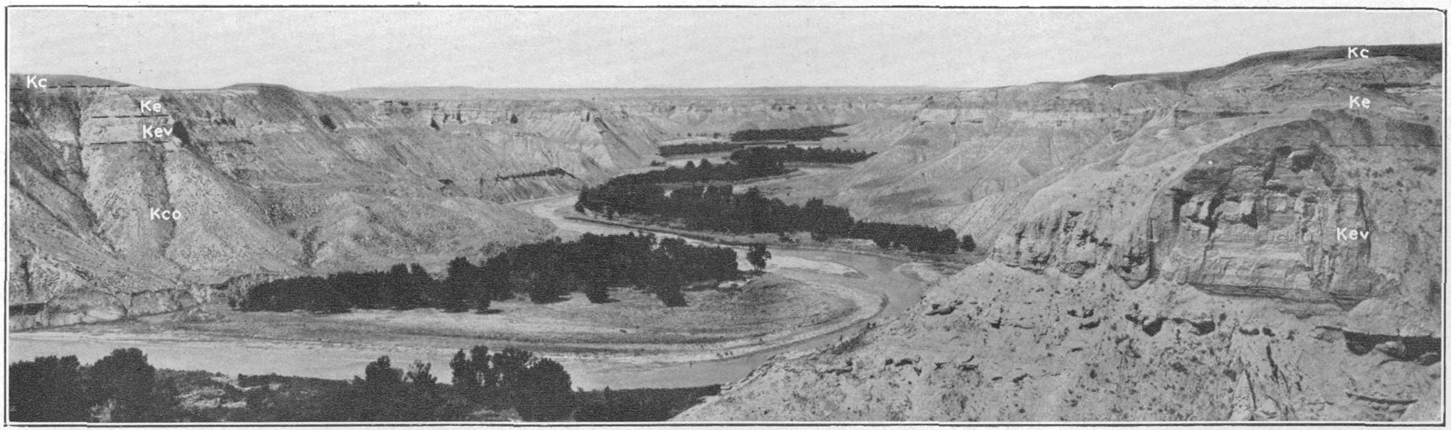
B. CROSS-BEDDING IN JUDITH RIVER FORMATION.

Due to overlap of shaly sandstone on a carbonaceous shale and coal bed. NW¼ sec. 28, T. 37 N., R. 9 E.



A. EXPOSURE OF EAGLE SANDSTONE.

Shows gradational contact between Virgelle sandstone member (white) and overlying dark beds of upper part of Eagle. Near center of west line of sec. 5, T. 26 N., R. 12 E., about 2 miles northeast of Virgelle.



B. VIEW LOOKING UP MARIAS RIVER IN CENTER OF S½ SEC. 23, T. 27 N., R. 8 E.

Shows Claggett shale (Kc) in extreme upper right and left, underlain by Eagle sandstone (Ke) with Virgelle sandstone member (Kev) at the base. The Virgelle grades downward through a transitional zone of shale and sandstone into Colorado shale (Kco) concretions are locally fossiliferous, with the fossils usually most abundant at the top of the concretion, just below the cone-in-cone structure if it is present.

Beds of bentonite from 2 inches to 3 feet thick are characteristic of the lower part of the Claggett. Eight beds of bentonite were found in the sections measured at Goosebill Butte and at the butte 5 miles northeast of it that is sometimes called "Middle Goosebill Butte." In one section the highest of the eight beds of bentonite is 90 feet above the base of the Claggett, and in the other section 71 feet above the base. Individual beds of bentonite in these two sections cannot be correlated either by intervals between the beds or by the thickness of the bentonite, but this may be due in part to inaccuracies in the measurements, for in the weathered exposures it is difficult to determine the thickness of the bentonite, and slumping, which is not uncommon, may have caused errors in recording the position and intervals between bentonite beds. In these two sections, however, four beds of bentonite, from 5 to 6 feet apart and from 8 to 21 inches in thickness, occur between 30 and 60 feet above the base of the Claggett. A similar succession of bentonite beds was also observed at several other localities within the area. These four bentonite beds are near the general stratigraphic position of the three beds of bentonite observed by Reeves,[5] but these may be higher if, as Reeves states, the triple bed is at the base of the Claggett.

The upper half of the Claggett in the vicinity of Goosebill Butte consists of buff or dark-gray sandstone and sandy shale containing various amounts of calcareous matter. At some horizons, where there is a large proportion of calcareous material, a ledge-forming sandstone a foot or two thick is produced. At other horizons, where there is irregular distribution of calcareous material, there are sandy calcareous concretions 18 inches or less in diameter. Beds of gray sandy shale 10 to 15 feet thick merge imperceptibly into predominantly sandstone units.

The massive marine sandstone about 50 feet thick near the top of Goosebill Butte is in this report included as a part of the overlying Judith River, as mentioned under that formation (p. 233).

In the northern half of the area the upper part of the Claggett is exposed only in fault blocks. These exposures show that the upper part is composed of sandstone and shale; the thicker sandstones are usually shaly and silty, and the thinner beds contain small sandy calcareous concretions. The upper part of the Claggett is more variable in lithology than the lower half, and in some of the fault blocks it is difficult to determine the top. This variability is

[5] Reeves, Frank, op. cit. (Bull. 751), p. 82.

to be expected, however, for the upper part of the formation represents a recession of the sea with sedimentation passing from marine to littoral and brackish-water and then to continental conditions. This change was repeatedly interrupted by minor oscillations.

Fossils, which are not abundant in either number or species, are most common in the limy concretions in the lower half of the Claggett and are scarce in the upper half of the formation. The principal species found have been identified by J. B. Reeside, Jr., as *Baculites ovatus*, *Baculites compressus*, *Inoceramus barabina* cf. *sagensis*, *Liopistha montanensis*, and *Corbula perundata*.

Apparently the Claggett thickens from about 400 feet in the western part of the area to about 500 feet in the eastern part. This thickening, however, is not determinable directly within this area but was estimated from well data and measured thicknesses in adjoining or neighboring areas.

The best exposure of the Claggett in this area is on the east side of Goosebill Butte in T. 27 N., R. 7 E., where the following typical section was measured:

Section of Claggett shale on east side of Goosebill Butte

	Ft.	*in.*
Glacial drift and gravel (to top of butte)	15±	
Judith River formation:		
Sandstone and shale, interbedded	50	
Sandstone, massive, cross-bedded, greenish gray; weathers brown; many oyster shells at top	6	
Shale, with thin beds of sandstone and carbonaceous shale	30	
Sandstone, massive, buff, capped by hard brown cross-bedded sandstone which on weathering forms cap rock of pillars; top is fossiliferous (oysters, clams)	50	
Claggett shale:		
Shale, gray, sandy, with some black shale	99	
Shale, gray, and sandstone, light gray	1	6
Shale, gray; lower part has purple hue on weathered fracture	20	
Sandstone, calcareous, buff, concretionary	1	
Sandstone and shale; dark-gray sandstone and olive-gray shale, interbedded	12	
Sandstone, buff, calcareous, irregularly bedded		6
Shale, gray	23	
Sandstone, friable, gray	6	
Sandstone, hard and calcareous in places	1	
Sandstone, gray, friable	1	2
Sandstone, buff, hard, calcareous	1	
Sandstone, gray, slightly nodular	3	
Sandstone, hard, fine-grained, buff, calcareous		7
Sandstone, drab, fine-grained, friable	15	
Shale, gray, slightly sandy	25	

Section of Claggett shale on east side of Goosebill Butte—Continued

	Ft.	in.
Claggett shale—Continued.		
Shale, dark gray; contains at least seven beds of limestone concretions; concretions are 4 feet in diameter, are composed of gray limestone, and disintegrate into small chunks; cone-in-cone structure common at both top and bottom of concretions	120	
Bentonite	1	3
Shale, olive gray, fissile	13	
Bentonite		2
Shale, gray; contains limestone concretions similar to those described above	16	
Bentonite, with 1-inch bed of gray shale, 2 inches above base		9
Shale, dark olive gray	1	
Bentonite		5
Shale, olive gray; contains limestone concretions similar to those described above	5	6
Bentonite	1	9
Shale, gray; contains limestone concretions similar to those described above	5	
Bentonite	1	6
Shale, gray, clayey	6	
Bentonite	1	
Shale, gray, fissile	15	
Sandstone, gray, shaly, crumbly		6
Shale, black, fissile; weathers to brownish cast	4	
Shale, olive gray	9	
Sandstone, friable, yellow, and interbedded shale	1	
Shale, brown, with plant fragments	1	6
Bentonite	3	
Shale, gray	3	
Eagle sandstone:		
Sandstone, friable, buff and gray; contains more or less clayey material; weathers white	10±	
Total section measured	581	1
Total thickness of Claggett	420	1

The Claggett is well exposed 5 miles northeast of the above section, and the following section was measured there. Although this section differs in detail from the section just given, the general character of the two is the same.

Section of Claggett shale measured at Middle Goosebill Butte, in the E½ sec. 1, T. 27 N., R. 7 E.

	Ft.	in.
Glacial drift and soil	10	
Judith River formation:		
Sandstone, gray and buff; sandstone concretions 5 feet or less in diameter; cross-bedded; irregular hard sandstone 5 feet thick at top	22	

Section of Claggett shale measured at Middle Goosebill Butte, in the E½ sec. 1, T. 27 N., R. 7 E.—Continued

	Ft.	in.
Judith River formation—Continued.		
Sandstone, cross-bedded, gray; weathers brown; resistant	1	6
Sandstone, gray to buff	12	
Claggett shale:		
Shale, olive green to gray, 2-inch bed of dark-gray concretionary limestone 10 feet above base; interbedded with argillaceous sandstone in upper part	55	
Shale, sandy; contains dark-gray limestone concretions 1 to 3 feet in diameter that weather to reddish brown	10	
Shale, brownish gray, fissile; becomes very sandy and olive gray upward	56	
Sandstone, light gray, calcareous in places	3	
Shale, some black and fissile, some gray and sandy, with some argillaceous sandstone	56	
Shale, sandy, gray and tan; concretionary calcareous sandstone at top	38	
Sandstone, gray, calcareous in part	2	
Partly concealed; probably brownish-gray shale, becoming sandy and less fissile upward	66	
Shale, brownish gray, fissile; zone of dark-gray to black limestone concretions at top; these concretions, from 1 to 4 feet in diameter, also occur downward from the top of the unit to a horizon within 30 feet of the base of the Claggett	55	
Bentonite	1	3
Shale, brownish gray, fissile	21	
Bentonite		8
Shale, brownish gray, fissile	6	
Bentonite		10
Shale, brownish gray, fissile	5	
Bentonite		11
Shale, brownish gray, fissile	5	
Bentonite	1	
Shale, brownish gray, fissile	13	6
Bentonite	1	
Shale, dark gray, fissile	3	6
Bentonite		3
Shale, brownish gray		10
Bed composed of a single layer of flat-lying black chert pebbles from ¼ to ½ inch in diameter		½
Shale, dark gray, fissile	9	
Bentonite		3
Shale, dark gray	1	
Eagle sandstone:		
Sandstone, light gray, laminated	4	
Shale, brown, carbonaceous	1	
Shale, gray	15	
Shale, dark gray, containing many plant fragments	3	

Section of Claggett shale measured at Middle Goosebill Butte, in the E½ sec. 1, T. 27 N., R. 7 E.—Continued

	Ft.	in.
Eagle sandstone—Continued.		
Shale, gray, grading upward into buff sandstone	5	
Shale, brown, carbonaceous		8
Sandstone, shale, and siltstone; locally contains a massive light-gray sandstone in the middle of the unit	60	
Total section measured	546	2½
Total thickness of Claggett	412	½

The base of the Claggett is fairly distinct and well exposed along Marias River in the southwestern part of the area. There is commonly a sharp lithologic break between the dark shale of the Claggett and the lighter-brown carbonaceous and plant-bearing beds at the top of the Eagle. Furthermore, the lower 30 feet of the Claggett contains scattered pebbles of black chert. These pebbles are locally present elsewhere in the section, but they are generally present and most abundant near the base of the Claggett. In the southeastern part of the area higher beds of the Claggett are only poorly exposed.

Along Sage Creek in T. 32 N., R. 11 E., the base of the Claggett is brought up by faulting. The following section was measured in the steeply dipping lower part of the Claggett exposed in sec. 15:

Section of lower part of Claggett shale in sec. 15, T. 32 N., R. 11 E.

	Ft.	in.
Top concealed.		
Shale	48	
Sandstone, bedded		5
Shale	15	
Bentonite		4
Shale	120	
Bentonite	1	8
Shale	6	
Bentonite	1	1
Shale	4	
Bentonite		8
Shale	4	
Bentonite	2	
Shale	8	
Base concealed.		
	211	2

The presence of four beds of bentonite with thin bands of shale separating them strongly suggests that the base of this section is very nearly the base of the Claggett shale. However, no black pebbles were found at this locality.

Along the Milk River in the center of T. 34 N., R. 13 E., just east of this area, steeply dipping beds in the Claggett are fairly well exposed in fault blocks, but minor faulting has disturbed the stratigraphic succession so that no reliable section could be measured. Four attempts to determine the thickness of the Claggett at this locality gave results ranging from about 350 feet to nearly 500 feet. This information is presented because the exposures are sufficiently good to encourage attempts to measure a section, and a single measurement would leave little doubt of its correctness. For example, Stebinger[6] gives the thickness of the Claggett as 285 feet in a supposedly complete section measured in sec. 8, T. 34 N., R. 13 E. It seems probable, however, that a concealed strike fault has cut out part of the Claggett in this section. In sec. 6 of the same township about 675 feet of Clagget is exposed, probably because of repetition of beds by one or more concealed faults.

EAGLE SANDSTONE

The name "Eagle sandstone" was first used by Weed[7] in 1899 for the beds of sandstone, shale, and thin coal that immediately overlie the Colorado shale at the mouth of Eagle Creek, along the Missouri River a few miles east of this area. In this area the formation is separable into a lower bed of massive sandstone and an upper series of sandstone and shale. Bowen,[8] in 1915, applied the name "Virgelle sandstone member" to the lower massive sandstone, which is exposed at the type locality near the town of Virgelle, in T. 26 N., R. 12 E., within the area considered in this report.

In the immediate vicinity of its type locality the Virgelle is a white argillaceous friable sandstone, but elsewhere in the area it is more commonly buff to light brown and massive. (Compare pl. 37, *A*, and pl. 37, *B*.) Over most of the area it is about 100 feet thick, and it generally crops out in cliffs or steep slopes. The upper part of the Eagle consists of massive sandstone, thin-bedded sandstone, clay shale, carbonaceous shale, and thin streaks of coal; it measures 100 to 150 feet in thickness. At places it contains thick massive beds of white sandstone that are similar to the Virgelle.

Although the Virgelle sandstone member contrasts sharply with the higher beds of the Eagle, it is impossible to determine precise stratigraphic boundaries of the Virgelle in this area. In the western part of the area 100 feet of interbedded sandstone and shale lies at the top of the Colorado shale, forming a zone transitional into the Eagle (pl. 37, *B*). Locally in this zone the sandstone beds thicken

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[6] Stebinger, Eugene, Possibilities of oil and gas in north-central Montana: U. S. Geol. Survey Bull. 641, p. 67, 1916.

[7] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Fort Benton folio (no. 55), p. 2, 1899.

[8] Bowen, C. F., The stratigraphy of the Montana group, with special reference to the position and age of the Judith River formation in north-central Montana: U. S. Geol. Survey Prof. Paper 90, p. 97, 1915.

and merge into the massive Virgelle, and the lithologic boundary is far below the top of the transition zone as developed elsewhere. Farther east, where the transition zone at the top of the Colorado is less sandy, the base of the Virgelle may be more definite. No regional trend or pattern of such changes could be determined. Similarly the boundary at the top of the Virgelle is arbitrary. The upper part of the Eagle locally becomes more sandy and the sandstones merge into the underlying Virgelle. These irregularities at the top and base of the Virgelle are well exposed along Marias River in the southwestern part of the area.

Few fossils were found in the Eagle in this area. Locally fragments of fossil wood are abundant, and elsewhere marine invertebrates are common.

Chert pebbles that have a black exterior are abundant in some places near the top of the Eagle. They are commonly flattened ellipsoids from one-fourth to 1 inch in length and are invariably very smooth or well rounded. Some of them are concentrated in thin beds, and others are scattered through a zone several feet thick. These chert pebbles have been regarded by some workers as a reliable indication of the top of the Eagle. In the area examined by the writers these pebbles are most abundant at the top of the Eagle, but they are not restricted to that horizon. In sec. 6, T. 34 N., R. 13 E., the upper part of the Colorado shale is exposed in a fault block. About 40 feet below the top of the Colorado shale is a 10-inch bed of reddish-brown limestone (with marine shale above and below) containing pebbles of green, gray, and black chert. The pebbles are from one-fourth to 1 inch in diameter and are most abundant near the center of the limestone bed. About 3½ feet above this bed is a similar bed, 5 inches thick, which also contains chert pebbles.

Chert pebbles are not uncommon in the basal part of the Claggett shale, although they may be widely scattered. They were found as high as 30 feet above the base of the shale. Chert pebbles similar to those in the Eagle and Claggett were found in glacial drift at several localities. Near the center of the west line of sec. 11, T. 30 N., R. 11 E., there are many chert pebbles lying on the surface of the ground. The Judith River formation is at the surface at this locality, and presumably the pebbles have weathered out from it, although possibly they were left there with a thin veneer of ground moraine. These pebbles are similar in appearance to those in the older formations—that is, they have the same range in size, all of them are dark gray or black on the outside but are composed of black, gray, white, yellow, or red chert, and all are smooth or well "rounded." Some of the pebbles from this locality were submitted to W. T. Schaller, of the United States Geological Survey, for a determination of the nature and origin of the black coating, and he reports as follows:

The black coating could not be removed by ignition; hence it is not organic. Treatment with various acids did not remove it; hence it is not due to a surface coating of iron or manganese oxides.

Examination of a thin section showed that the chert composing the pebbles is full of a black substance, much of it in rhombohedral crystals that suggest one of the rhombohedral carbonates (calcite, siderite, etc.). It also showed that the material of the black coating not only occurs on the surface but forms a narrow zone that penetrates each pebble a short distance and also is present in streaks, probably following healed fractures from the surface that penetrate the pebbles for greater distances than the thickness of the outer zone. * * *

It is suggested that the black coating on the pebbles is explainable as follows: Permeating solutions dissolved parts of the original carbonate mineral (magnesia-bearing siderite?) disseminated throughout the chert and on reaching the surface of the pebbles were oxidized and precipitated their load, probably chiefly iron, as black iron oxide in a narrow zone whose thickness would depend on the distance to which the oxidizing atmospheric conditions could operate and also, in lesser degree, along fractures (since healed) in which the same oxidizing conditions could operate. As this oxidized and precipitated iron oxide is embedded in the chert for a distance equal to the narrow zone of permeability of atmospheric oxidizing conditions, it cannot be removed by simple treatment with the common acids such as hydrochloric, sulphurous, or sulphuric.

Subsequent abrasion polished the outside surface of the zone containing the precipitated oxidized iron oxide and accentuated the black color.

The best exposures of the Eagle are in the southern and southwestern parts of this area, especially along the Missouri and Marias Rivers, but there are other exposures in the northeastern part of the area, in fault blocks along the Milk River.

Section of Eagle sandstone measured near south line of sec. 35, T. 28 N., R. 8 E.

	Ft.	in.
Claggett shale.		
Eagle sandstone:		
Shale, somber-colored, in lenticular beds, and carbonaceous dark shale; locally contains carbonized wood; some interbedded massive sandstone locally in thick beds	122	
Virgelle sandstone member:		
Sandstone, white, friable, massive, coarse-grained near top; locally dark bluish-purple ferruginous concretions	50	
Sandstone, buff orange, containing large iron-stained calcareous concretions; interbedded lenses of light-gray to white sandstone	11	
Colorado shale (top of transitional zone):		
Sandstone, gray; becomes increasingly arenaceous and less consolidated toward the top	32	
Sandstone, white to light gray	1	6

Section of Eagle sandstone measured near south line of sec. 35, T. 28 N., R. 8 E.—Continued

	Ft.	in.
Colorado shale (top of transitional zone)—Continued.		
Sandstone, dark gray, loosely consolidated, massive	13	6
Shale, very sandy, thin-bedded, with ¼- to 1-inch beds of loosely consolidated buff to gray sandstone	72	
Sandstone, calcareous		1
Shale, sandy, thin-bedded, dark olive gray	11	6
Sandstone, shaly, gray	1	
Sandstone, calcareous, gray		¾
Sandstone, shaly, gray, with some laminae of buff sandstone	3	
Sandstone, calcareous, gray		1
Sandstone, buff, with laminae of bluish-gray shale	1	
Shale, sandy, bluish gray, laminated, with buff sandstone beds as much as 2 inches thick; limestone concretions at base	6	6
Total section measured	325	2¾
Thickness of Eagle sandstone	183	

In the SW¼ sec. 1, T. 26 N., R. 7 E., the Eagle above the Virgelle sandstone member is well exposed. These upper beds are about 100 feet thick and consist largely of sandstone near the base but become increasingly shaly upward. The sandstone beds are strongly cross-bedded, and all the beds are very lenticular. (See fig. 58.)

The thickness and lithology of the upper part of the Eagle near the center of the south line of sec. 35, T. 28 N., R. 8 E., are shown in the preceding section.

Section of Eagle sandstone on Marias River in the SE¼ sec. 25, T. 29 N., R. 7 E.

	Feet
Glacial drift and soil	15
Claggett shale: Shale, dark gray, containing black chert pebbles; no bentonite beds observed	20
Eagle sandstone:	
Mudstone, gray, to somber-colored shale; brown and carbonaceous shale; thin hard light-gray sandstone beds; contact with the Virgelle sandstone gradational through 25 feet	132
Virgelle sandstone member: Mostly light gray, some buff; friable sandstone, weathering into fluted columns; contains lenticular gray and brown sandstone concretions; 60 feet above the base is an irregular but fairly persistent hard brown concretionary sandstone; the lower 15 feet of the Virgelle not exposed	115
Total thickness of section measured	282
Total thickness of Eagle sandstone	247

COLORADO SHALE

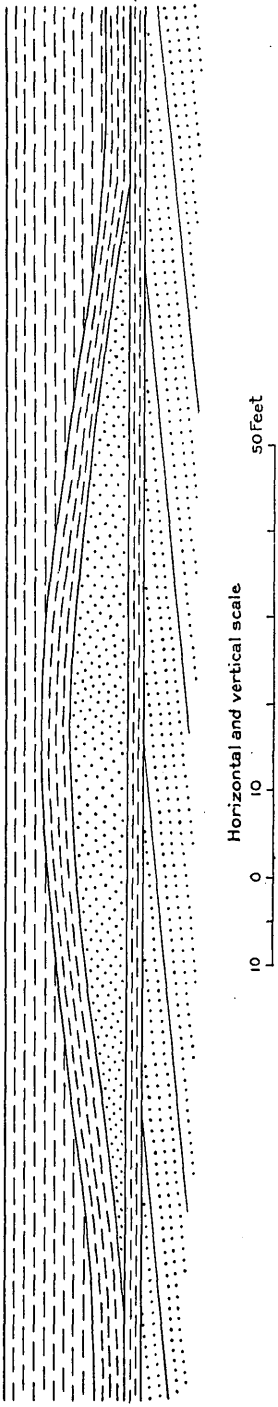


FIGURE 58.—Lenticularity and cross-bedding of strata in upper part of Eagle sandstone in SW¼ sec. 1, T. 26 N., R. 7 E.

The name "Colorado" was first used on one of the atlas sheets of the Fortieth Parallel Survey (published in 1876) and described in 1878 by King.[9] As originally designated, the group included equivalents of the †Fort Benton,[10] Niobrara and †Fort Pierre groups of Meek[11] and was a lithologic unit consisting almost entirely of shale. However, as paleontologic information grew, a marked break was recognized between the faunas of the Niobrara and Pierre (†Fort Pierre of Meek). In 1878 White[12] proposed, among other changes in nomenclature, that the term "Colorado group" be restricted to include only the †Fort Benton (Benton) and Niobrara. In 1899 Eldridge[13] strengthened the evidence for restricting the usage of the term, and in 1893 Stanton[14] used the term "Colorado formation" for only the †Fort Benton (Benton) and Niobrara. The present usage of the United States Geological Survey is threefold: (1) The term "Colorado group" is used where the rocks can be divided into distinct formations; (2) "Colorado formation" is used where there are sandstone and shale beds

[9] King, C. E., Systematic geology; U. S. Geol. Expl. 40th Par. Rept., vol. 1, p. 305, 1878.

[10] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the U. S. Geological Survey.

[11] Meek, F. B., A report on the invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, pp. 24, 25, 1876.

[12] White, C. A., Report on the geology of a portion of northwestern Colorado: U. S. Geol. and Geog. Survey Terr. 10th Ann. Rept., for 1876, pp. 3–60, 1878.

[13] Eldridge, G. H., Some suggestions upon the methods of grouping the formations of the middle Cretaceous and the employment of an additional term in its nomenclature: Am. Jour. Sci., 3d ser., vol. 38, pp. 313–321, 1889.

[14] Stanton, T. W., The Colorado formation and its invertebrate fauna: U. S. Geol. Survey Bull. 106, 1893.

that cannot be separated into mappable units; and (3) "Colorado shale" is used where the beds are chiefly shale that cannot be subdivided. In conformity with this usage, the name "Colorado shale" is used in the area considered in this report.

Only the upper 500 feet of the Colorado shale crops out in this area. These beds are well exposed in the southern part of the area along the Missouri River and Marias River. The upper 100 feet is a series of interbedded sandstone and shale that is transitional into the overlying Virgelle member of the Eagle sandstone. This sandy transition zone grades eastward into shale. In the southwestern part of the area the proportion of sandstone increases upward, and to locate consistently the base of the overlying Virgelle sandstone member of the Eagle is nearly impossible, whereas in the southeastern part of the area, although there is a sandstone in the upper 500 feet of the Colorado, it is less prominent than farther west, and the base of the Virgelle is fairly distinct. The lower 400 feet of the beds exposed consists almost entirely of dark-gray shale. The Colorado shale weathers into nearly vertical walls along the cliffs of the Missouri River. In contrast with the Colorado shale, the Claggett and Bearpaw shales commonly weather into slopes. In places the Colorado shale is slightly sandy, with some beds of yellow micaceous crumbly sandstone from one-fourth inch to 1 inch in thickness. Ovate concretions of black limestone from 6 inches to 2 feet in length, with septaria or veins of calcite, are common in the formation. The concretions apparently are not confined to specific horizons and occur sporadically, although locally they may be abundant.

In the northern part of T. 34 N., R. 12 E., several hundred feet of the upper part of the Colorado shale and part of the overlying Eagle sandstone and Claggett formation are exposed in a fault block. There the contact between the Colorado shale and the Eagle sandstone is sharp, with practically no transition zone, but possibly it is a fault contact. At 44 feet below the apparent top of the Colorado shale there is a peculiar reddish-brown bed of limestone containing pebbles of black, gray, and green chert from one-fourth to 1 inch in diameter. The bed is 10 inches thick and has a rough columnar jointing. Beds of this type were not observed elsewhere in the area, but similar chert pebbles occur in the overlying formations. (See pp. 241, 243.)

Fossils in the Colorado shale are most abundant in the concretions. Collections include *Scaphites ventricosus*, *Scaphites vermiformis*, *Baculites asper*, *Inoceramus grandis*, and *Ostrea congesta*. *Scaphites ventricosus* was found in the lower 25 feet of the sandy transition zone between the Colorado shale and the Virgelle sandstone, indicating that at least the lower part of this zone is of Colorado age. Possibly the uppermost 75 feet of the transition zone is of Montana age, equivalent to the beds that to the east contain the Telegraph Creek fauna, but in the absence of paleontologic data in this area the top of the Colorado is determined on the basis of lithology.

Partial section of upper part of sandy transition zone at top of Colorado shale in Skit Coulee, sec. 21, T. 26 N., R. 8 E.

Virgelle sandstone member of the Eagle sandstone.	
Colorado shale:	*Feet*
1. Sandstone, ferruginous and friable; very thin beds of shale	12
2. Sandstone, ledge-forming, laminated owing to thin films of shale along bedding planes	1
3. Sandstone (like no. 1)	4
4. Sandstone (like no. 2)	1
5. Shale, black, with a few beds of brown sandstone about an inch thick	7
6. Sandstone (like no. 2)	1
7. Shale (like no. 5)	7
8. Sandstone (like no. 2)	1
9. Shale and sandstone interbedded in irregular lenses one-sixteenth to one-fourth inch in thickness; proportion of sandstone increases upward by increase in number of sandstone lenses	2
10. Sandstone (like no. 2)	1
11. Shale and sandstone (like no. 9)	2
12. Sandstone (like no. 2)	1
13. Shale and sandstone (like no. 9)	36
Alluvium in Skit Creek.	
	76

The total thickness of the Colorado shale, determined from well logs and measurements made by others outside this area, is about 1,800 feet. Apparently it is of nearly uniform thickness over a wide area.

ROCKS NOT EXPOSED

Some information concerning the lower part of the Colorado shale and underlying rocks is available from drill records and outcrops in nearby areas.

Kootenai formation.—The Kootenai formation, of Lower Cretaceous age, consists of 350 to 500 feet of variegated red, green, and gray shale with lenticular cross-bedded sandstone and thin beds of limestone. Beds of gray sandstone, 50 feet or more in thickness, are present in places. To the west the base of the formation is marked by a sandstone known as the "Sunburst sand."

Ellis formation.—The Ellis formation, of Upper Jurassic age, is composed of 200 to 300 feet of dark-gray limestone, black limy shale, and some calcareous sandstone, with a sandstone locally present at the base. It rests unconformably upon the Madison limestone.

Madison limestone.—The Madison limestone, of lower Mississippian age, consists of about 1,000 feet of white to bluish-gray limestone, generally in thick massive beds but locally in beds 6 to 12 inches thick.

Information from driller's log.—An approximate section of these older rocks and the authors' interpretations of the formations penetrated is given in the following driller's log of a well drilled by the California Co. on the Utopia anticlinal nose, about 2 miles west of the area.

Log of the California Co.'s Ross No. 1 well, in the NE¼SE¼NE¼ sec. 3, T. 33 N., R. 6 E.

[Altitude 3,565 feet. Commenced drilling Nov. 9, 1931. Completed drilling Apr. 21, 1932]

	Feet
Judith River formation:	
Cellar	0- 13
Shale, yellow; shows coal	13- 36
Shale, dark gray	36- 81
Claggett formation:	
Shale, gray	81- 515
Eagle sandstone:	
Shale, gray, sandy	515- 530
Shale, gray	530- 590
Shale, gray, sandy	590- 600
Shale, gray	600- 605
Shell, sandy; little water	605- 610
Shale, gray, shelly	610- 625
Shale, gray, and sandy shells	625- 650
Shale, gray	650- 688
Virgelle sandstone member:	
Sand, water-bearing	688- 720
Shale	720- 725
Sand	725- 785
Colorado shale:	
Shale, sandy	785- 820
Shale, gray	820- 826
Shale, gray, sandy	826- 830
Shale, gray	830-1,015
Shale, black	1,015-1,050
Shale, blue	1,050-1,074
Shell, lime	1,074-1,077
Shale, blue	1,077-1,085
Shale, gray	1,085-1,120
Shale, black	1,120-1,190
Shale, gray	1,190-1,220
Shale, black	1,220-1,230
Shell, lime	1,230-1,235
Shale, black	1,235-1,740

Log of the California Co.'s Ross No. 1 well, in the NE¼SE¼NE¼ sec. 3, T. 33 N., R. 6 E.—Continued

	Feet
Colorado shale—Continued.	
Shell, lime	1,740–1,743
Shale, black	1,743–1,907
Shell, lime	1,907–1,910
Shale, black	1,910–2,050
Shell, sandy; show of gas	2,050–2,055
Shale, black	2,055–2,215
Shale, gray	2,215–2,240
Shale, black	2,240–2,320
Shale, gray, sandy	2,340–2,400
Sand, water-bearing	2,400–2,415
Lime, dark gray, sandy, hard	2,415–2,420
Shale, dark gray, sandy; shells	2,420–2,430
Shale, gray, sandy	2,430–2,535
Sand; water at 2,553 feet	2,535–2,565
Shale, gray, sandy	2,565–2,590
Shale, dark gray, sandy	2,590–2,595
Shale, black	2,595–2,608
Shale, gray	2,608–2,610
Sand; water, 1 bailer an hour	2,610–2,615
Shale, gray	2,615–2,660
Kootenai formation:	
Shale, gray, green, and red	2,660–2,725
Shale, brown	2,725–2,730
Shale, gray	2,730–2,955
Shale, brown	2,955–2,960
Red beds	2,960–2,970
Shale, gray, sandy	2,970–2,980
Shale, gray, sandy; lime shells	2,980–3,000
Shale, sandy	3,000–3,005
Shale, light gray, lime shells	3,005–3,015
Sand, dry ("Sunburst" of drillers)	3.015–3,060
Shale, brown	3,060–3,065
Ellis formation:	
Lime, black, hard	3,065–3,075
Shale, black, and lime shells	3.075–3,090
Shale, black	3,090–3,120
Lime, black	3,120–3,150
Shells, black, lime; gray shale	3,150–3,200
Shells, black, lime; gas at 3,202 feet when dumping bailer	3,200–3,210
Shale, dark gray, dry	3,210–3,215
Lime, sandy, gray	3,215–3,220
Shale, gray	3,220–3,226
Sand, water-bearing	3,226–3,265
Lime, white, sandy	3,265–3,280
Lime, brown, sandy	3,280–3,285
Lime, sandy	3,285–3,288
Madison limestone	3,288–3,337

IGNEOUS ROCKS

Dikes of igneous rock crop out at four localities in the area, but there may be many more similar dikes that are concealed by the glacial drift. The dikes are composed of porphyritic lamprophyre that is closely related in composition to the large bodies of igneous rocks in the adjacent Bearpaw and Highwood Mountains and the Sweetgrass Hills. All the dikes are deeply weathered and are only slightly more resistant to weathering and erosion than the Upper Cretaceous rocks which they intrude. The dikes crop out only in the valleys, where they generally protrude a few feet above the surrounding surface; no outcrops were observed on the old erosion surface, which forms a sort of tableland between the abrupt and narrow valleys of the present drainage system. (See pl. 38, *A*, *B*.) It is uncertain whether the dikes are irregular and discontinuous or

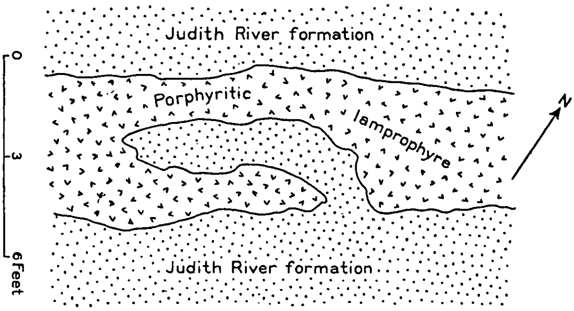


FIGURE 59.—Lobe of Judith River formation in dike of porphyritic lamprophyre along Milk River near the northwest corner of sec. 2, T. 37 N., R. 8 E.

simply concealed. The maximum width of the dikes is usually about 6 feet, but at one locality a width of 15 feet was observed. The intrusion of the dikes did not cause any alteration or disturbance of the adjacent sedimentary rocks except for a slight baking near the contact.

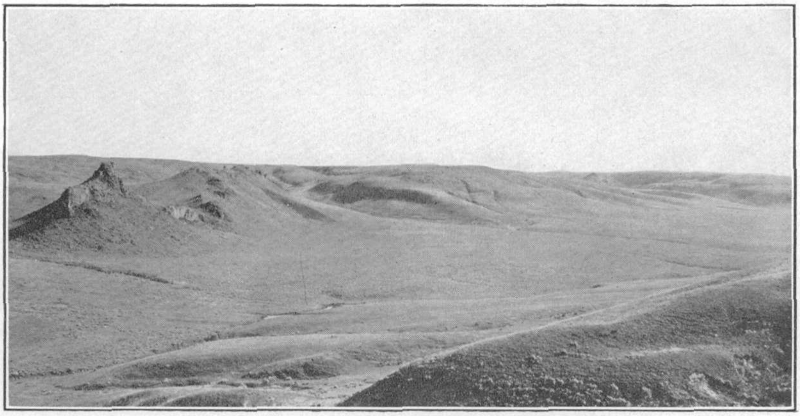
A dike that trends N. 60° E. emerges from a cover of glacial drift near the top of the bluff along the Milk River at the international boundary, near the northwest corner of sec. 2, T. 37 N., R. 8 E., and extends into Canada about 500 feet. The dike is 6 feet wide near the boundary but narrows northeastward to about 1 foot at the edge of the alluvium in the valley of Milk River. The contacts of the dike are irregular. At one point a lobe, about 2 feet wide, of Judith River sandstone and shale extends into the dike (fig. 59). The dike is broken by irregular joints developed at high angles to the contacts. The sedimentary rocks in the Judith River formation apparently are not baked at the contact beyond a zone about 1 inch wide, immediately adjacent to the igneous rock. The dike is a porphyritic lamprophyre that contains phenocrysts of biotite in an altered groundmass that consists chiefly of anhedral feldspar, probably mostly potash feldspar, and euhedral biotite. The flakes of biotite are clearly oriented, with trends roughly parallel to the trend of the dike.

A second dike, which also trends about N. 70° E., occurs about 100 feet northwest of the one just described. It is apparently of the same composition.

In the NE¼ sec. 15, T. 26 N., R. 9 E., a dike 3 feet wide trends N. 30° E. and dips 85° E. At the outcrop the dike intrudes the sandy transition zone at the top of the Colorado shale. The inner part of the dike is easily weathered and has no discernible jointing, but on each side of this part the rock is jointed in columns that are about 1 foot thick and nearly horizontal and normal to the contacts. No platy jointing was found along the contact. The central part of the dike contains phenocrysts of biotite and augite in a fine-grained groundmass whose index of refraction is higher than that of balsam. The biotite is more abundant than pyroxene. There is little parallelism of the phenocrysts. The columnar-jointed border zones are holocrystalline, with only a few phenocrysts of pyroxene (probably augite) in a groundmass of euhedral biotite, magnetite, and anhedral feldspar, probably potash feldspar.

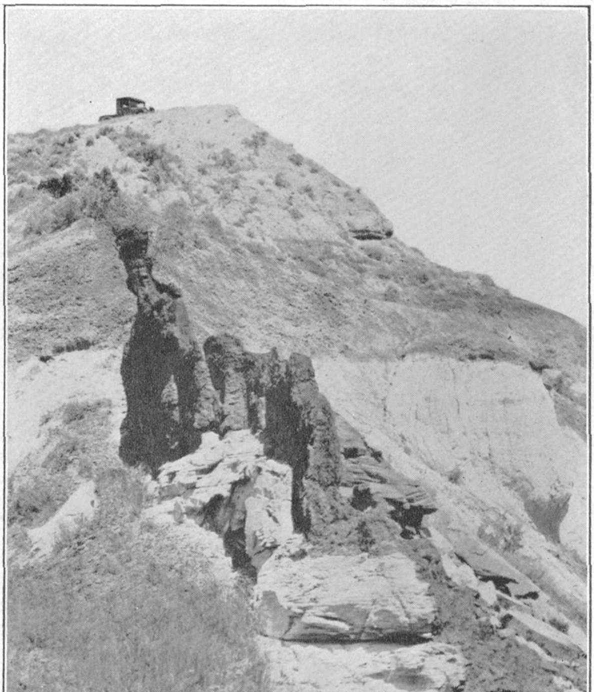
A dike in the SW¼ sec. 33, T. 26 N., R. 12 E., intrudes the upper part of the Eagle (pl. 38, *A*). It trends northeast, and its maximum width is 15 feet. It has outer zones about 1 foot thick that are broken into small plates by jointing parallel to the dike; the central zone is massive, with joints normal to its linear extent, a character which is typical of most of the dikes in this area. The rock is a porphyritic lamprophyre containing numerous large corroded phenocrysts of biotite and a few subhedral phenocrysts of augite. The groundmass is composed chiefly of augite and a nontwinned feldspar with an index of refraction lower than that of balsam. There is relatively little biotite in the groundmass. The phenocrysts of biotite are not only corroded but thoroughly leached and exhibit only a slight pleochroism or absorption. The phenocrysts have a nearly parallel orientation, but there is practically no parallelism of the minerals in the groundmass.

A dike of igneous rock trends N. 8° E. diagonally across a small valley in the SW¼ sec. 20, T. 26 N., R. 12 E., and is exposed for a distance of about 300 feet in the valley walls but does not protrude above the old erosion plain bordering the valley. (See pl. 38, *B*.) It intrudes the Virgelle sandstone and the upper part of the Eagle. The dike is 6 inches to 1 foot wide and is practically vertical. It contains abundant large phenocrysts of mica.



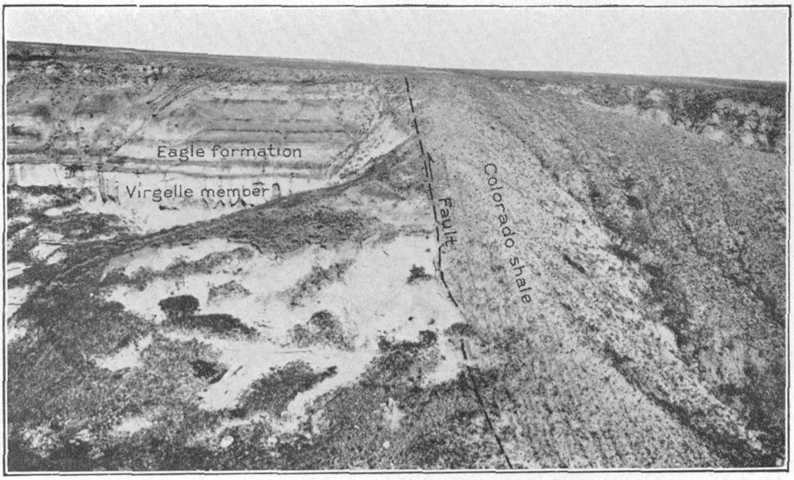
A. DISTANT VIEW OF DIKE IN SW¼ SEC. 33, T. 26 N., R. 12 E.

The dike does not protrude above the plateau surface.

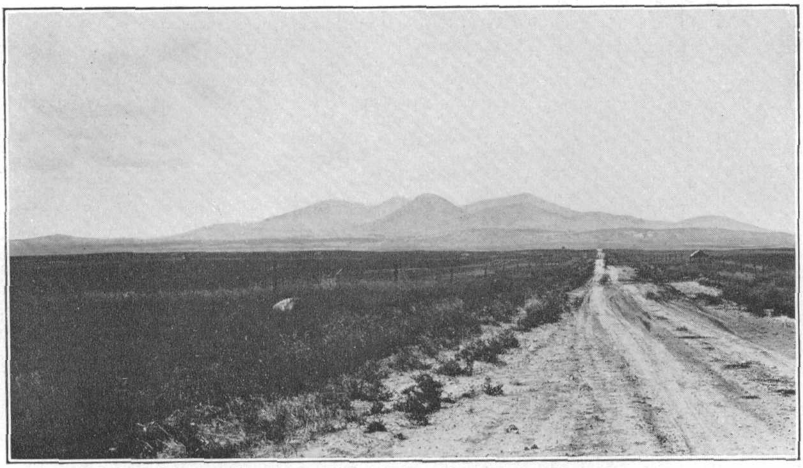


B. DIKE IN SW¼ SEC. 20, T. 26 N., R. 12 E.

Cutting upward through undisturbed and unaltered sandstone in upper part of Virgelle sandstone member of Eagle sandstone.



A. VIEW ALONG TRACE OF FAULT SHOWING STEEPLY DIPPING COLORADO SHALE THRUST OVER HORIZONTAL BEDS OF EAGLE SANDSTONE, SW¼ SEC. 4, T. 26 N., R. 11 E.



B. VIEW LOOKING WEST ACROSS PLATEAU SURFACE OF LIBERTY COUNTY TOWARD SWEETGRASS HILLS.

STRUCTURE

REGIONAL STRUCTURE

The principal structural feature in the north-central Montana region, including the area here described, is a northeastward- to eastward-dipping homocline, but the regional dip is modified by folding and faulting in some of the isolated mountain groups. The homocline rises to the southwest and west, continues for 40 miles or more west of the area, and forms the east side of the broad Sweetgrass arch, on the crest of which are the Kevin-Sunburst, Pondera, and other oil fields. The Bearpaw Mountains are circumscribed by a belt of thrust faults, some of which occur in the southeastern and eastern part of this area. The laccolithic intrusions of igneous rocks in the Sweetgrass Hills have domed up the sedimentary beds, so that they dip at high angles near the hills, but the dips flatten out and merge with the regional dip a few miles distant. The eastern limit of this doming is in the northwest quarter of the area. The igneous activity in the Highwood Mountains, to the south of this area, does not appear to have had any local structural effect, for the uniform northeastward dip continues through the area of igneous rocks in the mountains [15] and into the southern part of the area here described.

STRUCTURE OF THE AREA

The interpretation of the structure of the area is shown on plate 43 by means of contours drawn at intervals of 100 feet on the top of the Eagle sandstone. The contours are based in part on altitudes obtained at exposures of recognizable stratigraphic horizons; most of these altitudes were obtained at localities along the Missouri and Marias Rivers and Canada Coulee and in the northeastern part of T. 30 N., R. 7 E. In other parts of the area the contours are based on altitudes at outcrops of rocks whose position in the formation was not accurately known, on information obtained from about 100 wells drilled for water, and on the logs of 7 wells drilled for oil or gas in or near this area, exclusive of wells drilled west of Kremlin. Much of the information on which the contours are based is indefinite, but the maximum error in the altitude of the top of the Eagle sandstone, as indicated by the contours, probably does not exceed 100 feet, and for most of the area the error is believed to be less than 50 feet.

[15] Reeves, Frank, Thrust faulting and oil possibilities in the plains adjacent to the Highwood Mountains, Mont.: U. S. Geol. Survey Bull. 806, pl. 44, 1929.

The predominant structural feature throughout the area is a homoclinal dip; the rocks in the southern part of the area have a nearly uniform dip toward the northeast of about 35 feet to the mile, except in the immediate vicinity of faults; through the central and northern part of the area the homoclinal dip gradually swings to the east. Transverse to this general northeast or east homoclinal dip are several minor undulations. In the southwest a broad indistinct anticlinal nose plunges north-northeastward past Brinkman. About 10 miles to the southeast another nose parallels it. They are merely broad warps in which the structural relief, transverse to the axes, does not exceed 40 feet in 6 miles. The axis of a syncline that plunges east-northeast passes near Joplin, Inverness, and Rudyard. This syncline is the eastern extension of the Marias River syncline, which trends eastward across the Sweetgrass arch. An eastward-plunging anticlinal nose, commonly known as the "Utopia nose", lies a few miles north of the main line of the Great Northern Railway; its trend is slightly north of east. The Utopia nose is slightly asymmetrical, the southern flank being the steeper. The structural relief of the nose is about 150 feet, but the exposed beds do not show any closure on the west side. Possibly there are smaller anticlinal noses north of the Utopia nose and more or less parallel to it that are concealed by glacial drift and cannot be determined from the small and isolated outcrops of Judith River beds. The northeastern part of the area is concealed by glacial cover, except along the Milk River, and there practically all the exposed rocks are in the Judith River formation, in which there are no recognizable stratigraphic horizons; the beds, however, appear to be nearly horizontal. The so-called Kremlin "anticline" is interpreted by the writers as the result of faulting. The structure at that locality is described under the Kremlin wells. (See pp. 258–259.)

FAULTS

No normal faults were found in this area, but several thrust faults of an unusual type are exposed, principally along the Missouri River in the southeast corner of the area and along the Milk River in the northeastern part. Other faults are doubtless present in the area between these exposures, most of which is covered by glacial drift. No faults were observed in the western half of the area. A line indicating the western limit of known thrust faulting is shown on plate 43.

The faults are a part of the system of thrust faults that occurs in the region encircling the Bearpaw Mountains, to the east of this area. They have been noted by many geologists who have worked in this part of Montana and have been the subject of a special study by Reeves.[16]

In the published descriptions of the fault system Reeves presents evidence to show that the faulting is shallow and does not extend below the upper part of the Colorado shale. Briefly, this evidence consists of the following features: (1) Although some of the thrust faults show that a stratigraphic displacement of more than 1,000 feet may occur in faults of this type, none of the faults expose strata below the middle of the Colorado shale, even where faulting begins well below the top of the Colorado shale; (2) thrust faults of this type are absent where strata below the Colorado shale are at the surface; (3) the lowest beds exposed along the faults have approximately the same inclination as the fault plane, suggesting that the fault began as a movement along a bedding plane and passed upward along a curving surface; (4) the fault planes apparently flatten with depth; (5) well data indicate that the Kootenai formation below the thrust faults is in its normal position and not at a higher level on the upthrust side of the hypothetically extended fault; (6) mathematical calculation of the depth of faulting gives an average of 900 feet below the Eagle sandstone. The writers found no evidence that does not accord with Reeves' conclusions concerning the depth of the faulting.

The faults observed in this area are all of the reverse type, and the dip of the fault planes is 30° to 60°. The dip and strike of the strata on the upthrown side of a fault are about the same as the dip and strike of the fault plane—that is, the bedding planes within the upthrust block are parallel to the fault plane. The steep dip of beds in the upthrust block near a fault flattens to the regional dip within a quarter of a mile and locally within less than 1,000 feet from the fault. The strata on the footwall side of the fault appear to be undisturbed; they are nearly flat and conform with the regional structure. (See pl. 39, *A*.) So far as can be ascertained, that part of the area containing thrust faults is neither higher nor lower structurally than the adjoining region, and, except for the steeply upturned beds on one side of the fault, the structure continues with its

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[16] Reeves, Frank, Geology and possible oil and gas resources of the faulted area south of the Bearpaw Mountains, Mont.: U. S. Geol. Survey Bull. 751, pp. 97–103, 1924; Thrust faulting and oil possibilities in the plains adjacent to the Highwood Mountains, Mont.: U. S. Geol. Survey Bull. 806, pp. 165–185, 1929; Structure of the Bearpaw Mountains and adjacent plains, Mont. (unpublished manuscript); The structure of the Bearpaw Mountains, Mont.: Am. Jour. Sci., 5th ser., vol. 8, pp. 296–311, 1924; Shallow folding and faulting around the Bearpaw Mountains: Am. Jour. Sci., 5th ser., vol. 10, pp. 187–200, 1925; The landslide origin of the thrust faults around Bearpaw Mountains [abstract]: Washington Acad. Sci. Jour., vol. 17, no. 5, p. 127, 1927; Thrust faulting adjacent to the Highwood Mountains, Mont. [abstract]. Washington Acad. Sci. Jour., vol. 17, no. 9, p. 232, 1927. (See also other papers listed in bibliography, pp. 228–229.)

regional trend undisturbed through a faulted area. (See structure contours, pl. 43.)

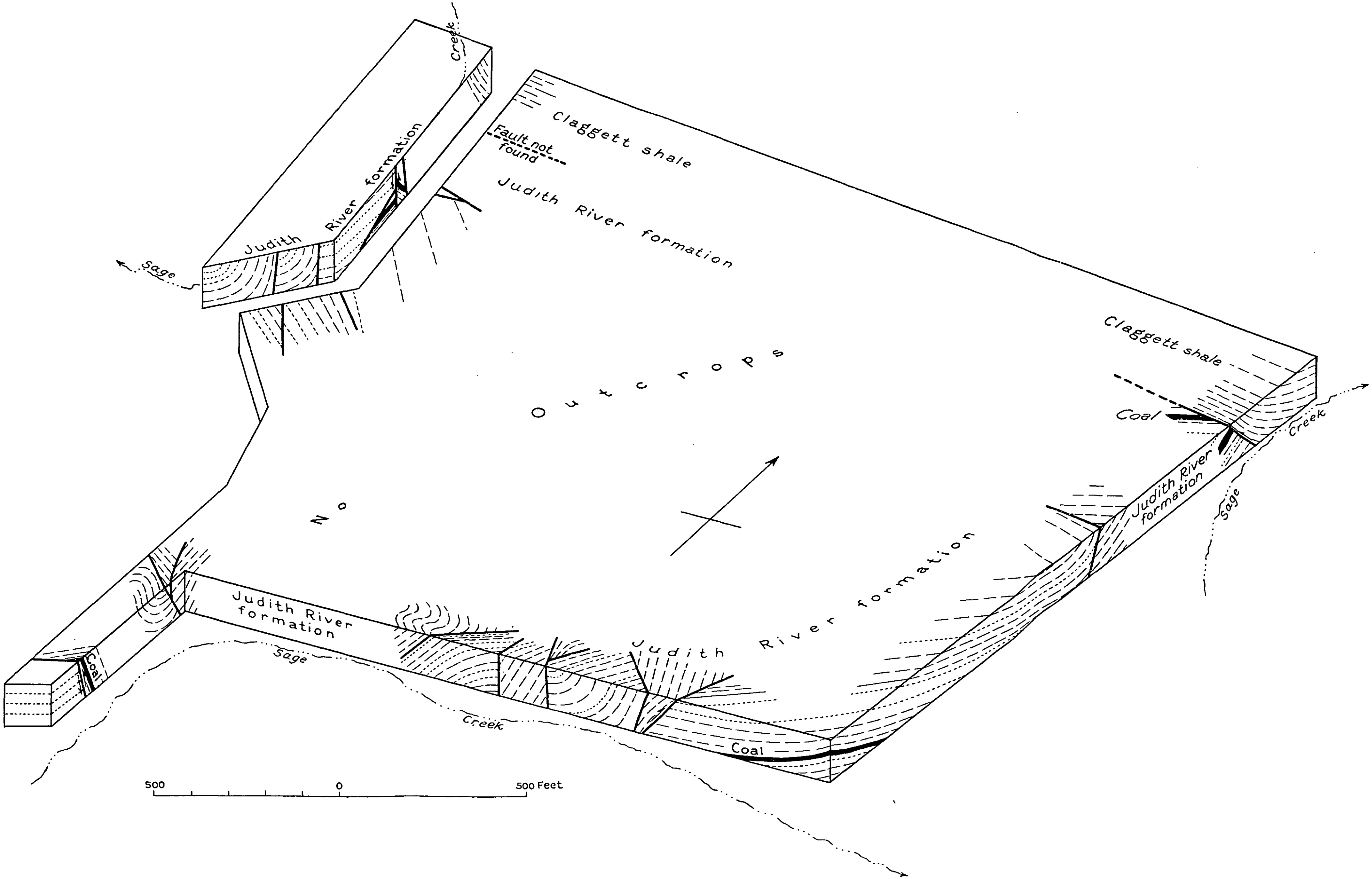
The three faults along the Milk River are roughly parallel, trending northeastward, and each is a thrust to the northwest. No such generalizations, however, can be made for the faults along the Missouri River in the southeast corner of the area, for about half of them strike northwestward and the rest strike northeastward. The thrust side in four of the northwestward-trending faults is on the southwest, and in one it is on the northeast. The thrust side in three of the northeastward-trending faults is on the northwest, and in three it is on the southeast. In the faults about 3 miles south of Gildford the principal fault seems to trend eastward, with the thrust side on the south.

Some of the thrust blocks are cut by several faults, so that the blocks are composed of a number of "slices." Measurements of stratigraphic sections across some of the thrust blocks showed rapid variation in the thicknesses of the stratigraphic units, which is ascribed to subsidiary faulting, although the faulting was not everywhere evident. A general picture of the complexity of some of the fault blocks may be obtained from the faults exposed in the banks of Sage Creek, south of Gildford. Plate 40 shows a block diagram of this area drawn from a detailed plane-table survey.

Most of the faults are not actually exposed for more than a mile or two, and it is possible that some of those that are mapped as extending 3 or 4 miles may be in reality more than one fault. The throw or stratigraphic displacement of the faults ranges from a few feet to hundreds of feet; the largest stratigraphic displacement observed is in the northeast corner of T. 34 N., R. 12 E., where beds below the top of the Colorado shale are thrust against strata above the base of the Judith River formation, representing a stratigraphic interval of about 1,325 feet. Sufficient data were not obtained to make estimates of the amount of horizontal movement.

That part of the map published with the report by Reeves[17] in 1924 based upon the earlier field work of Lloyd and Thom includes T. 26 N., R. 12 E., of the present report. Reeves shows a fault passing through secs. 9, 10, 16, and 17, with the upthrown side on the northwest. Faults are exposed in the S½ sec. 17 and the NW¼ sec. 16, and there are steeply inclined beds in the S½ sec. 3 that suggest the presence of a fault there; the displacement of the fault in the northwestern part of sec. 16 is in the opposite direction from that of the faults at the other two localities. The writers believe

[17] Reeves, Frank, Geology and possible oil and gas resources of the faulted area south of the Bearpaw Mountains, Mont.: U. S. Geol. Survey Bull. 751, pl. 13, 1924.



FAULTS EXPOSED ALONG SAGE CREEK, ABOUT 3 MILES SOUTH OF GILDFORD.

Based on plane-table survey.

that instead of a single fault there are three faults en échelon, and that as one fault dies out another fault with reversed thrust begins. Reeves [18] makes the following statement concerning faults mapped as scissors faults elsewhere in the fault belt adjacent to the Bearpaw Mountains:

As formerly mapped, some of the faults show a reversal in throw along their strikes. A special study of this feature in areas of good exposures during the later part of the field investigations revealed the fact that such a structure consists of two or more faults of opposite throw and ending in slightly offsetting positions.

The origin of the thrust faults has been discussed at length by Reeves in the previously cited papers, but his theory is stated very simply in the following abstract: [19]

The thrust faulting in the plains on the north and south sides of the Bearpaw Mountains is apparently confined to the weak Upper Cretaceous and early Tertiary formations. The trend and extent of the faults indicate that they were produced by a thrust force acting outward from the mountains. The slight plainsward inclination of the strata toward the faulted area suggests the possibility that during the mid-Tertiary period of volcanic activity in the mountains these formations, being buried under an enormous load of extrusive material and subjected to violent and frequent earthquake shocks, slipped plainsward on wet bentonite beds in the upper part of the Colorado shale, resulting in the compression and thrust faulting of these formations in the plains.

Two points which have not received consideration in the development of the theory, yet which seem to be logical accompaniments of such postulated movements, are: (1) Either all of the area between the central part of the Bearpaw Mountains and the outermost thrust fault probably would be underlain by a thrust fault or there must have been openings or gaps in the strata above the fault plane and to the mountainward side of the trace of the thrust fault on the surface equivalent to the amount of horizontal shortening involved in the thrust. Inasmuch as no evidence of gaps or large breaks is recorded, a more or less continuous fault seems a necessary part of this theory. Furthermore, there should be an area in the central part of the Bearpaw region that has been stripped of the strata above the fault plane equivalent in horizontal extent to the total amount of areal horizontal shortening in the thrust faults. (2) If the faulting is due to an outward movement of material from a "center", the further the material was moved the greater would become its circumference, so that gaps or openings should be produced having a radial trend from the "center." Such gaps apparently have not been observed.

[18] Reeves, Frank, Structure of the Bearpaw Mountains and adjacent plains, Mont. (unpublished manuscript).

[19] Reeves, Frank, The landslide origin of the thrust faults around Bearpaw Mountains [abstract]: Washington Acad. Sci. Jour., vol. 17, no. 5, p. 127, 1927.

MINERAL RESOURCES

OIL AND GAS

RESULTS OF DRILLING

Wells near Kremlin.—Six wells have been drilled in a small area about 3 miles west of Kremlin. Drilling of the Kremlin Petroleum well, in sec. 28, T. 33 N., R. 12 E., began in 1921, but the rest of the wells were drilled from 1927 to 1931. All the wells are located on a flat sod-covered plain of low relief, and the maximum difference in altitude of the tops of the wells is not over 20 feet. The Equitable-Perkins No. 1 well, in the SW¼SW¼ sec. 34, T. 33 N., R. 12 E., was drilled 3,765 feet, to the base of the Ellis formation, and was then plugged back to the Eagle sandstone at 1,080 feet, where gas had been found. The Perkins-Jones-Carruth well, a few hundred feet east of the Equitable-Perkins well, was drilled to a depth of 1,160 feet. Small flows of gas were encountered in the Eagle sandstone between 1,005 and 1,075 feet, but were not of commercial size, and the well was abandoned. The Flynn No. 1 well, in the NE¼NW¼ sec. 3, T. 32 N., R. 12 E., struck a flow of gas reported to be 1,650,000 cubic feet at 1,090 feet. Drilling was continued to 1,153 feet, where a strong flow of water was encountered that could not be shut off, and the well was abandoned. The Perkins-Robeck-Federal Bank well, in the NE¼SE¼ sec. 33, T. 33 N., R. 12 E., was drilled to a depth of 1,240 feet. Gas was reported at 1,095 feet, probably from the Eagle sandstone, and a water-bearing sand was encountered from 1,225 to 1,240 feet. The hole was plugged and abandoned. The Kremlin Petroleum well, in the NW¼SE¼ sec. 28, T. 33 N., R. 12 E., was drilled with a diamond drill to a depth of 3,131 feet. Gas was reported from a depth of 689 to 703 feet—probably from the Eagle sandstone—and also from 1,631 to 1,680 feet and 2,810 to 2,839 feet. A bluish-black shale heavily saturated with oil or a tar, which flowed into the hole and prevented further drilling, is reported at the bottom of the hole. The Robeck No. 1 well, also in the NW¼SE¼ sec. 28, T. 33 N., R. 12 E., was drilled to a depth of 750 feet. Gas, reported to be about 200,000 cubic feet, was struck at 610 feet. The hole was cased to this depth and capped.

A showing of oil was found in only one of these wells, but gas was found in all of them. The gas flows in the Robeck No. 1 and Flynn No. 1 wells apparently were the largest. The depth to the gas flows in four of the wells is between 1,005 and 1,095 feet, but in the Kremlin Petroleum and Robeck No. 1 wells gas was struck between 610 and 703 feet. Probably the gas in all the wells is from the same formation—that is, the Eagle sandstone. There is, however, a difference of several hundred feet between the depth at which it is encountered in the four wells and that in the two just mentioned. The logs of the wells, as interpreted by the writers, also place these two wells stratigraphically higher than the rest. The formations encountered and their depths below the surface, as interpreted from well logs, are shown in plate 41.

In the Kremlin Petroleum and Robeck No. 1 wells gas-bearing sandstone was encountered at about 600 feet. In the Kremlin Petroleum well deeper drilling encountered more sandstone at about 1,200 feet and the top of the Kootenai at about 3,100 feet (pl. 41). The sandstone encountered at 1,200 feet is probably the Eagle sandstone, undisturbed except for regional tilting, and the sandstone at 600 feet is probably also the Eagle in a thrust block. If the sandstone at 600 feet is correlated with the Eagle, and the sandstone at 1,200 feet is considered to be a sandstone in normal stratigraphic sequence in the Colorado shale, the Colorado shale would be more than 1,000 feet thicker here than elsewhere in this region, and the sandstone at 1,200 feet, which has not been recognized at other localities, would be a local lens in the upper part of the Colorado. Similarly, if the sandstone at 1,200 feet is correlated with the Eagle, and the sandstone at 600 feet is considered to be a sandstone in normal stratigraphic sequence in the Claggett, the thickness of the Claggett would be about 500 feet greater here than elsewhere in this region, and the sandstone at 600 feet would be a member not previously recognized in the shale.

The altitude of the surface at the six wells shown in plate 41 is about the same at each well, and the Eagle was encountered at about 1,000 feet in each well except the Robeck No. 1, where drilling ceased at 750 feet. Apparently the Eagle sandstone and the older formations have a nearly uniform dip. The Perkins-Robeck-Federal Bank well was probably drilled through an undisturbed stratigraphic sequence, but in the logs of the Equitable-Perkins, Perkins-Jones-Carruth, and Flynn No. 1 wells, as interpreted by the writers, the thickness of Claggett shale is abnormally great for this region. This unusual thickness may possibly be due to faulting that has repeated part of the Claggett, but because of the difficulty of recognizing the contact between the Claggett and Judith River formations, it seems probable that the apparent unusual thickness of the Claggett may be due to the inclusion of part of the Judith River.

Utopia wells.—The Mid-Rocky Federal Land Bank well, drilled in 1927 in the NW$\frac{1}{4}$ sec. 7, T. 33 N., R. 7 E., tested the Utopia anticlinal nose to a depth of 1,475 feet. It was abandoned in the upper half of the Colorado shale. Two other nearby wells, on the Utopia nose but outside of this area, were drilled to the top of the Madison limestone—in 1930–31 the Eleanor Association No. 1, in the SE$\frac{1}{4}$ sec.

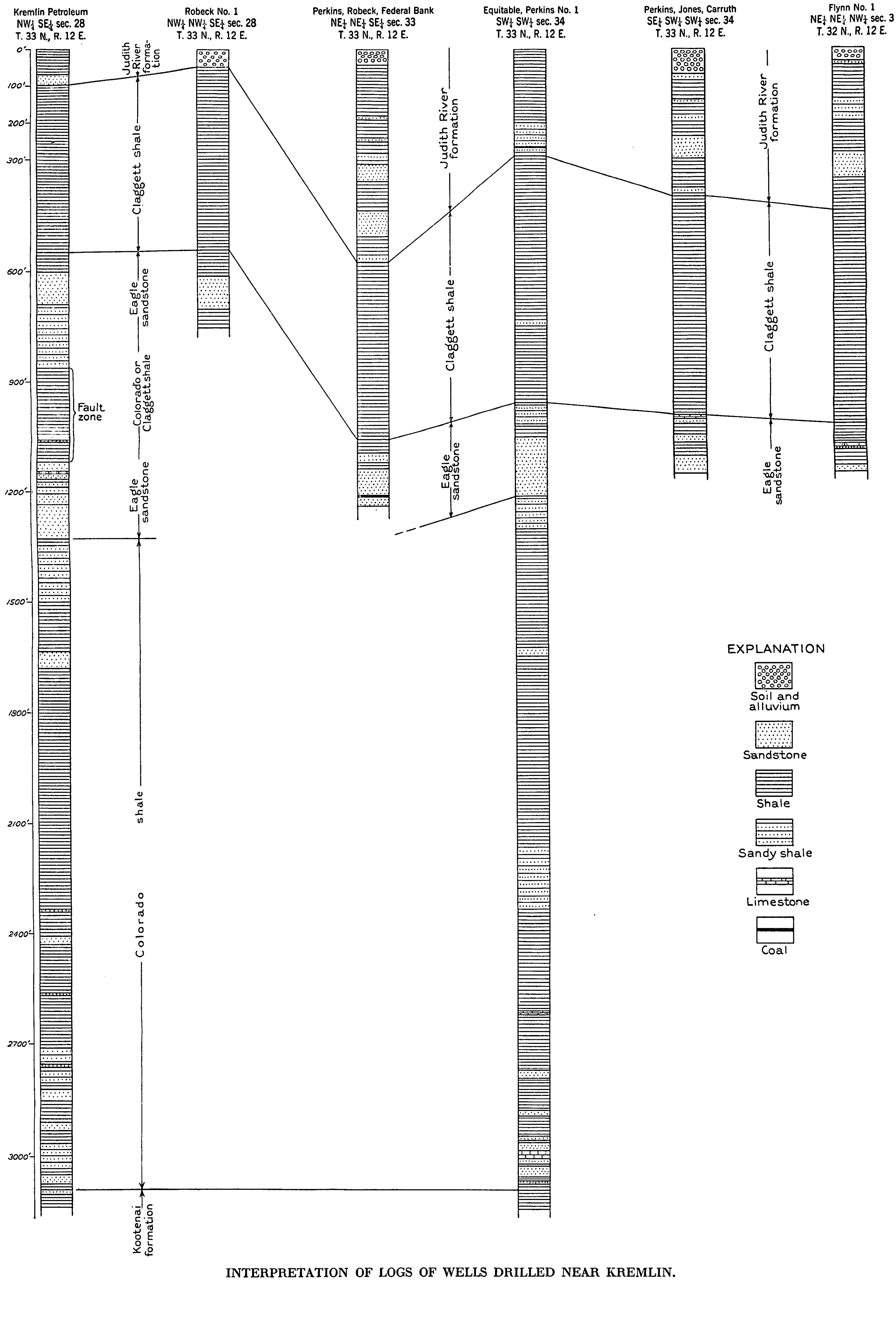
11, T. 33 N., R. 6 E., to a depth of 3,310 feet, and in 1931-32 the California Co.'s Ross No. 1, in the NE¼ sec. 3, T. 33 N., R. 6 E., to a depth of 3,337 feet. All three of these wells were dry holes.

The Newell well, in sec. 21, T. 35 N., R. 7 E., was drilled in 1926-27 to the base of the Colorado shale, at 2,600 feet, and is reported to have obtained a daily flow of 5,000,000 cubic feet of gas from a sand 500 feet above the base of the shale. The Square Deal Oil Co.'s well near Joplin was abandoned in the Madison limestone at a total depth of 3,710 feet. Gas is reported from a bed near the base of the Eagle sandstone and from the base of the Colorado shale, and a show of oil and gas at the top of the Madison.

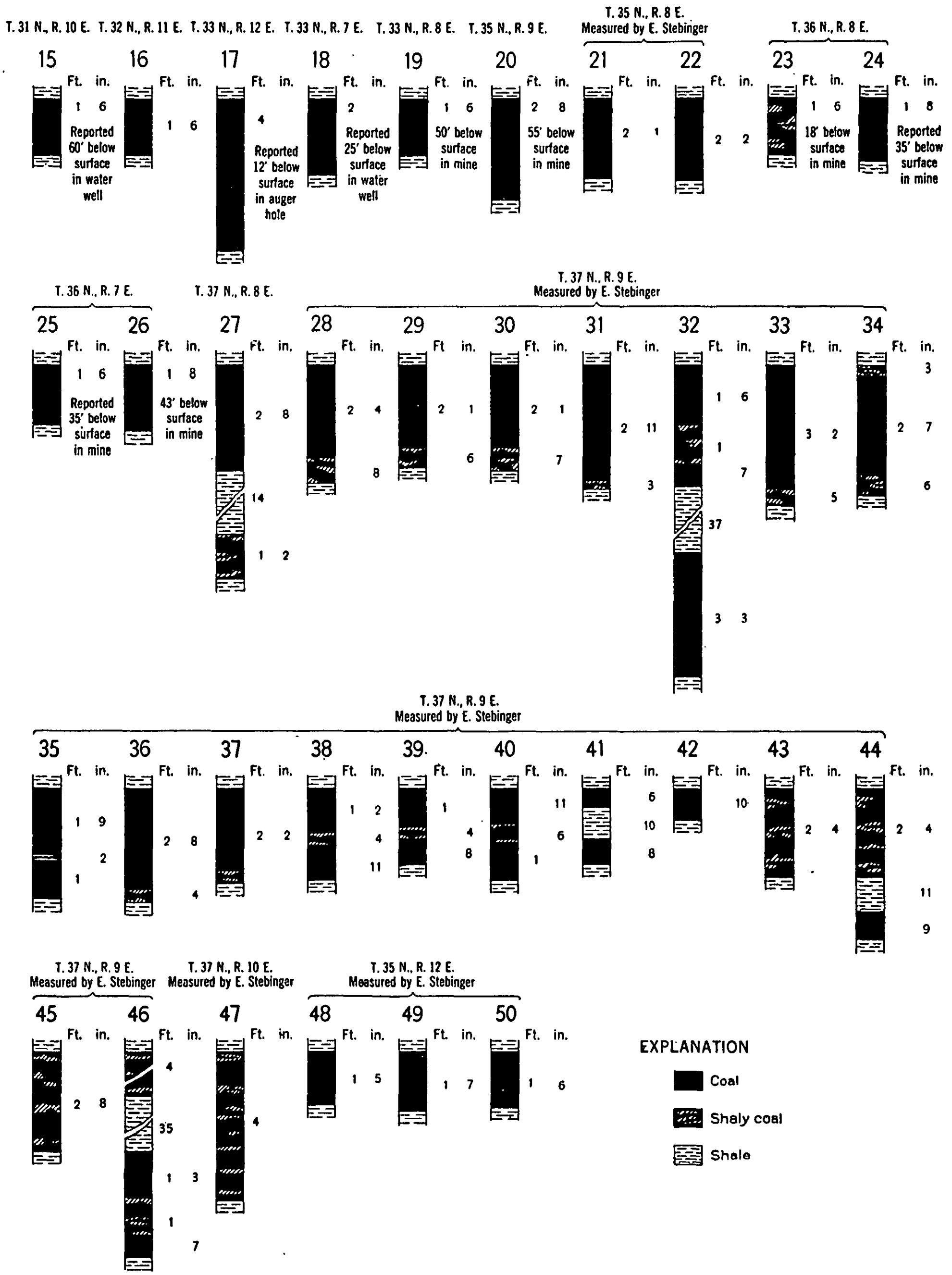
Other wells.—Drilling on the Williston-Shelby-Flack well, in the NE¼ sec. 12, T. 28 N., R. 11 E., began in 1928 and has progressed intermittently. The well is reported to have reached a depth of more than 2,615 feet and has probably penetrated the Kootenai formation. The well of the Bohy Oil Co., in the SW¼ sec. 26, T. 29 N., R. 9 E., was drilled to a depth of only about 600 feet and is now filled with cavings. The Register Life Insurance Co.'s well, in sec. 15, T. 30 N., R. 13 E., was a dry hole and was abandoned in 1928 at 2,230 feet, within the lower half of the Colorado shale. The Twenty Dollar Bill Syndicate's well, in the SE¼ sec. 9, T. 25 N., R. 9 E., penetrated the Madison limestone. Its total depth is 2,378 feet. The Cypress well, in the NW¼ sec. 36, T. 28 N., R. 6 E., likewise penetrated the Madison. It was drilled in 1928-29 to a depth of 2,789 feet. None of these wells struck oil, although several of them encountered some gas in the Eagle.

OIL AND GAS POSSIBILITIES OF THE REGION

Drilling has not revealed oil in commercial quantity, but small quantities are present in many wells. Gas has been found at several horizons, but the largest flows come from the Eagle sandstone. This formation crops out across the southern part of the area and dips regularly northward and eastward—factors which reduce the probability of a large gas field being discovered in this sandstone. Where thrust faults break the regular dip, reservoirs for oil and gas may be formed, but several structural features of this type have been drilled without commercial success. Lower beds that are possible sources of oil and gas and are productive on the Sweetgrass arch are the Blackleaf sandy member in the lower part of the Colorado shale, the Sunburst sand or similar sandstones in the Kootenai, and the basal Ellis or top of the Madison limestone, but the attitude of the strata at the surface does not indicate the presence of any structural feature suitable for trapping a large quantity of oil or gas. The merging of sandy beds into shale up a homoclinal dip, a feature which conceivably might occur in the Colorado shale or other



INTERPRETATION OF LOGS OF WELLS DRILLED NEAR KREMLIN.



COAL IN JUDITH RIVER FORMATION.

shale units, may possibly provide reservoirs for oil or gas; the location of such lithologic changes can be determined only by systematic drilling. It does not seem probable that sandstone beds in the Claggett would be sealed up the dip by a change to impervious shale, because the Claggett thins toward the west and the sandstones above and below it become thicker in that direction.

The Kremlin field, where gas has been encountered in the Eagle sandstone, contains but few rock outcrops, and those that were found seem to be in their normal position stratigraphically and to conform with the regional northeastward dip. The logs of the wells that have been drilled, however, show several anomalous features that can be explained on the assumption of thrust faulting. This interpretation is a logical one, for the field lies within the area of known thrust faulting that surrounds the Bearpaw Mountains. Other parts of the faulted area about the Bearpaw Mountains where thrust faults are exposed have been drilled, but most of them have not been productive, unless they form a part of a larger structural terrace or anticline. If there are thrust faults in the Kremlin field and they do not descend below the Colorado shale, then the strata below it would be no more likely to contain oil or gas than at any other place in the area.

The largest and most pronounced anticlinal fold in the area is the Utopia anticlinal nose, which rises toward the west without closure. Two wells on this fold, just beyond the west margin of the area here described, were drilled to the Madison limestone but failed to obtain commercial production of oil or gas.

COAL RESOURCES

In this area coal beds are present in the upper part of the Eagle and the lower 200 feet of the Judith River formation. The coal is of subbituminous rank and generally is present in thin beds of local extent. The coal beds in general are too thin and remote from convenient shipping points for profitable commercial mining at this time. A few mines supply local needs but are not worked continuously. Thicker coal beds, in part more conveniently located with respect to shipping points, are present 20 miles east of this area, in the upper part of the Judith River formation at Havre [20] and in the Fort Union formation 6 miles east of Big Sandy.[21] Mining at these two localities is much more extensive than in the area considered in this report.

[20] Pepperberg, L. J., The Milk River coal field, Mont.: U. S. Geol. Survey Bull. 381, pp. 82–107, 1910; The southern extension of the Milk River coal field, Chouteau County, Mont.: U. S. Geol. Survey Bull. 471, pp. 359–383, 1912

[21] Bowen, C. F., The Big Sandy coal field, Chouteau County, Mont.: U. S. Geol. Survey Bull. 541, pp. 356–378, 1912.

Where coal is exposed in the banks of coulees, as in T. 37 N., R. 9 E., or in steeply dipping fault blocks, as in T. 32 N., R. 11 E., mines are developed by tunneling along the beds. Where the beds lie nearly flat, and the coal is several feet below the surface, as in T. 36 N., Rs. 7 and 8 E., the coal is mined through shafts.

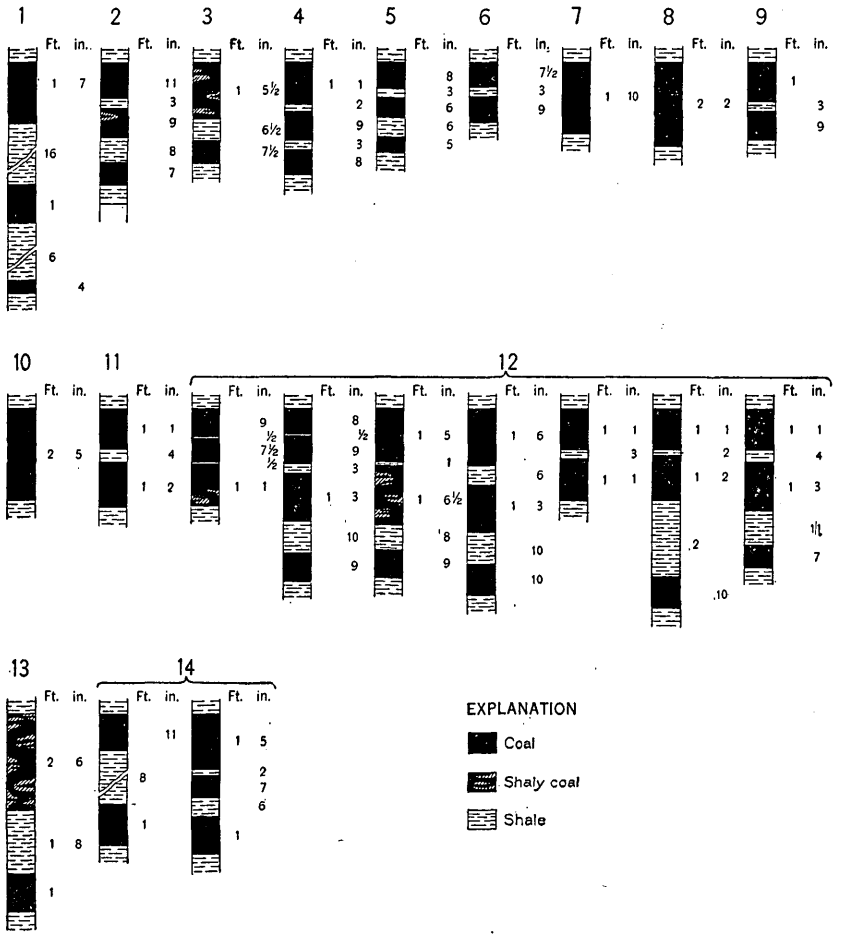


FIGURE 60.—Coal in upper part of Eagle formation, T. 26 N., R. 12 E. Numbers refer to locations shown on plate 43.

The following description of the coal resources is based largely on E. R. Lloyd's examination of the Eagle coal beds in 1914 and Eugene Stebinger's examination of the Judith River coal beds in 1913 and 1915. The writers made no attempt to study the coal beds in detail, but they visited most of the mines that have been opened since the earlier examinations.

Although the Eagle formation crops out extensively over the southern part of the area, potentially valuable coal beds are apparently confined to T. 26 N., R. 12 E. Other outcrops of the Eagle farther west were examined by the writers, but only very thin coal beds were seen. The average of two analyses of samples collected by Lloyd in 1914 from drift mines in T. 26 N., R. 12 E., gave a calorific value for the air-dried sample of 9,770 British thermal units. Coal was found at numerous places along the river bluffs and in the coulees. The beds are highly lenticular and contain many thin partings of shale and bone, so that it was necessary to measure numerous sections to show the true character of the coal. Thicknesses range from a few inches to 2½ feet. Measured sections of the coal beds are shown in figure 60, and the locations are recorded on plate 43. Seven measurements on a coal bed exposed near locality 12 and two measurements on another bed at locality 14 illustrate the variable lithology of the coal beds in the Eagle of this area.

The Judith River formation covers the northern two-thirds of the area, and locally coal beds are exposed where the lower 200 feet of the formation is the surface rock. A fairly persistent zone of carbonaceous shale, containing somewhat lenticular beds of coal, occurs about 200 feet above the base of the Judith River formation. This zone is particularly well developed in the northwest quarter of the area. The thickness of the coal beds is generally about 1 to 1½ feet, although locally it exceeds 3 feet.

The following analyses of fresh coal from mines in secs. 2 and 28, T. 37 N., R. 9 E., were made in the laboratory of the United States Bureau of Mines at Pittsburgh, Pa.:

Analyses of mine samples of coal in the Judith River formation, from Hill County, Mont.

Laboratory no.	Form of analyses	Proximate				Ultimate					Heating value	
		Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	British thermal units
17841F	A	24.1	29.2	37.4	9.28	1.15	5.98	50.03	1.02	32.54	4,705	8,470
	B		38.5	49.3	12.23	1.52	4.35	65.95	1.34	14.61	6,205	11,170
	C		43.9	56.1		1.73	4.96	75.14	1.53	16.64	7,065	12,720
17892	A	31.4	30.4	23.8	14.4	1.35						
	B		44.4	34.7	2.09	1.97						
	C		56.2	43.8		2.49						

17841F, sample from NW¼NW¼ sec. 28, T. 37 N., R. 9 E. 17892, sample from SW¼ sec. 2, T. 37 N., R. 9 E.

Forms of analyses: A, analysis of sample as it comes from the mine; B, analysis after all moisture has been eliminated; C, analysis after all moisture and ash have been theoretically removed.

Most of the coal beds measured are probably near the top of the lower 200 feet of the Judith River formation. Plate 42 shows the measured coal beds, and plate 43 shows the locations.

WATER RESOURCES

Surface water and shallow wells do not furnish an adequate supply of water in this region, and consequently drilled wells are generally a necessary source of water supply for domestic use and livestock. The two formations that yield the greatest amount of water are the Judith River formation and the Eagle sandstone. Apparently water can be obtained at several horizons in the Judith River, but the amount is usually not large and may vary a great deal even locally. Several wells drilled for water in the Judith River formation have been dry holes. The water is confined under artesian pressure, but the pressure is not great enough to produce flowing wells. The wells drilled to the Eagle sandstone usually furnish an abundant supply of water, probably from the Virgelle sandstone member near the base of the formation. It is likewise confined under artesian pressure, but the wells do not flow. The Claggett shale, which lies between the Judith River and Eagle formations, does not yield water.

In that part of the area in which the Claggett shale is at the surface, or where there is not a considerable thickness of Judith River strata, the objective for water wells is the Eagle formation. The structure contours on plate 43 will be of value in such areas in determining the depth to the top of the Eagle, if the altitude of the ground at the proposed drilling site is known, for the depth to the top of the Eagle at that locality is the difference between the surface altitude and the altitude of the top of the Eagle as shown by the contours.

The waters from the Judith River and Eagle formations are in most places not entirely satisfactory for drinking and may be unsuitable for irrigation. The total dissolved solids are about the same in each formation, generally from 1,000 to 2,500 parts per million but locally as high as 5,000 parts per million. Considerable variation in the amount of dissolved solids may occur within either formation. The principal mineral constituents of the water from both formations are sodium bicarbonate, sodium sulphate, and sodium chloride.

INDEX

A

Page

Abbott mine, work at 146
Abstracts of reports 1, 43–44, 121, 175, 189, 225–226
Acknowledgments for aid 2, 46–47, 123, 191, 227–228
Alice mine, features of 33
Allen no. 2 claim, ore deposit of 25
Alluvium in Rosebud coal field, Mont., character and distribution of 66, pl. 11
Alma gas field, production from 220
Antelope mine, features of 29
Arizona mine, features of 37
Arkansas coal field, accessibility of 194
- climate of 193
- coal of, analyses of 210–213
- drainage of 192–193
- geography of 191–194
- geologic work in 190–191
- land forms in 191–192
- location of 190
- population of 194
- vegetation of 193
- western part of, age and character of rocks in 194–196
  - coal of, analyses of 210–213
  - coal of, production of 203–205
  - coal of, rank, quality, and uses of 209
  - coal beds of, distribution and thickness of 205–208
  - field work in 190
  - geology of 194–203
  - map of, showing geologic structure and mineral resources pl. 35
  - mining methods in 209
  - natural gas in 214–221
  - road material in 224
  - sand and gravel in 224
  - shale for making brick in 224
  - structural features favorable for accumulation of gas in 221–224

Atoka formation, character, distribution, and thickness of 196–198
- correlation of 196
- fossils in 197–198
- natural gas from 215

Avon area, Mont., geologic map and structure sections of pl. 32
- *See also* Maxville, Philipsburg, and Avon areas.

B

Page

Ballbrach mine, work at 146
Barnes mine, development workings at 188
Bee Bluff fault, possibility of gas in closure against 222
Bellevue mine, features of 23–24
Benton group, equivalent of 246
Big Dirty coal bed, occurrence of, in Richey-Lambert coal field, Mont 139–140, pls. 22, 27
- occurrence and thickness of, in Rosebud coal field, Mont 77–78, pl. 10
- quantity of coal in, in Rosebud coal field, Mont 83

Biswell Hill anticline, possibility of gas in 221
Blackleaf sandy member of Colorado shale, possibility of oil and gas in 260
Blanchard Mountain area 38, pl. 3
Blue Bell mine, development workings at 188
- section of phosphate beds in pl. 34

Blue Bird mine, features of 28–29
Blue Lode claim, ore deposits of 33–34
Boggy shale, character and thickness of 200
- correlation of 196

Boller mine, work at 146
Bonanza mine, features of 35, pl. 3
Boston mine, features of 41, pl. 3
Brooklyn property, features of 19–22, pl. 3
Bryan mine, features of 29
Budka coal bed, occurrence of 141, pls. 22, 27
Burley coal bed, coal mined from 84
- occurrence and thickness of 79, pl. 10
- outlook for mining of 84
- quantity of coal in 83

Butterfield coal bed, occurrence of 140, pls. 22, 27
Butterfield mine, work at 146

C

Carroll coal bed, occurrence of 140, pls. 22, 27
Carroll mine, work at 146
Cavanal coal bed, occurrence of 208
Cecil anticline, possibility of gas in 223
Charleston coal bed, occurrence and thickness of 207–208, pl. 35

Page
Chinaman mine, development workings at____________ 37, pl. 3
Chouteau, Hill, and Liberty Counties, Mont., coal resources of___________ 261–263, pl. 43
field work in______________ 226–228
geography of__________ 226, 229–230
geologic map of_______________ pl. 43
geology of________________ 231–257
oil and gas in_____________ 258–260
possibilities of_________ 260–261
publications relating to_____ 228–229
water resources of___________ 264
Claggett shale, bentonite beds in___ 237
character, thickness, and correlation of______ 231, 236–242
fossils in___________________ 238
oil and gas in_____________ 259, 261
sections of_________ 234, 238–241, 249
Coal beds of Chouteau, Hill, and Liberty Counties, Mont., general features of___ 261–263, pl. 43
Coal beds of Richey-Lambert coal field, Mont., clinker formed by burning of_ 145, pl. 25
details of, by townships______ 148–174, pl. 22
distribution and correlation of_ 139–142
Coal beds of Rosebud coal field, Mont., coal clinker in_ 81–82, pl. 11
details of, by townships________ 85–120, pls. 11–21
general features of__ 75–76, pls. 10, 11
sections of______________ pls. 12–21
stratigraphic relations and correlation of__________ 74–75, pls. 9, 10
Coal beds of western part of Arkansas coal field, distribution and thickness of____________ 205–208
Coal of Chouteau, Hill, and Liberty Counties, Mont., analyses of_____________ 263
mining of_________________ 261–262
rank of____________________ 261
resources of_______________ 261–263
sections of______________ 262, pl. 42
Coal of Richey-Lambert coal field, Mont., analyses of____ 144
mining of_________________ 145–147
nature and occurrence of____ 139–143
physical and chemical character of _________________ 142–143
Coal of Rosebud coal field, Mont., occurrence of____ 73–74, pl. 9
outlook for mining of________ 84–85
physical and chemical properties of______________ 80–81
quantity of_________________ 82–84
Coal of western part of Arkansas coal field, analyses of____ 210–213
mining of____________________ 209

Page
Coal of western part of Arkansas coal field, production of__ 203–205
rank, quality, and uses of_____ 209
Collier, A. J., correlation of formation divisions by____ 195–196
Colorado shale, character, thickness, and correlation of____ 231, 246–248, pl. 39
fossils in____________________ 247
oil and gas in______________ 259–261
sections of_____________ 248, 249–250
Contact mining district, Nev., claim map of______________ pl. 3
geology of_______________ 5–12, pl. 2
history of___________________ 4–5
location of___________________ 2
mineral deposits in, oxidation and enrichment in____ 17–18
types of________________ 13–17
mines and prospects in________ 18–41
outlook for__________________ 18
production of________________ 4–5
topography of________________ 2–4
Copper, production of, in Contact district, Nev_________ 5
Copper King no. 2 claim, geology and ore deposits of_______ 25
Copper Shield group, work on____ 37, pl. 3

D

Delano no. 1 claim, geology of_____ 25
Delano no. 2 claim, ore deposits of_ 26
Detweiler mine, work at__________ 29
Dissett Bros., production of phosphate rock from mine of __________________ 177
Dissett mine, development workings on__________________ 188
section of phosphate beds in___ pl. 34

E

Eagle sandstone, character, thickness, and correlation of __________________ 231, 242–245, pls. 37–39
coal beds in________________ 261–263
fossils in____________________ 243
oil and gas in______________ 258–261
sections of_____________ 244–245, 249
water in_____________________ 264
Edgar, Omer, mine of, development at __________________ 188
mine of, production of_________ 177
section in_______________ pl. 34
Effie Fay group, work on_________ 37, pl. 3
Ellis formation, character and thickness of____________ 248–249
oil and gas in______________ 258, 260
section of____________________ 250
Elvirio coal beds, occurrence of____ 141–142, pls. 22, 27
Elvirio mine, work at______________ 146
Empire mine, work at_____________ 22
Eplin & Horton, development workings on property of___ 188
Erna gas field, production from_____ 218

F

Page

Field work----- 46, 123, 176, 190, 226–228
Flaxville (?) gravel, Richey-Lambert coal field, Mont., character and thickness of- 132–133, pl. 26
Florence group of claims, features of----------------- 37, pl. 3
Flowers coal bed, occurrence and thickness of------- 80, pl. 10
 outlook for development of----- 84
Fort Benton group, equivalent of--- 246
Fort Pierre group, equivalent of---- 246
Fort Smith formation, correlation of ----------------- 196
Fort Union formation in Richey-Lambert coal field, Mont., distribution, character, and thickness of-------------- 129
Fort Union formation in Rosebud coal field, Mont., coal beds in---- 78–80, pls. 10, 11
 occurrence and character of---- 57–64, pls. 5, 8–11
 quantity of coal in------------ 83–84
Foster coal bed, occurrence and thickness of------- 79, pl. 10
 quantity of coal in------------ 83

G

Gaines coal bed, occurrence of----- 141, pls. 22, 27
Game Hill anticline, possibility of gas in-------------- 222
Gas. *See* Natural gas.
Geologic maps:
 Arkansas coal field, structure in western part of------ pl. 35
 Avon phosphate area, Mont---- pl. 32
 Chouteau, Hill, and Liberty Counties, Mont., parts of ----------------- pl. 43
 Contact mining district, Nev--- pl. 2
 Maxville phosphate area, Mont- pl. 28
 Nevada-Bellevue mine--------- pl. 4
 Philipsburg phosphate area, Mont---------------- pl. 29
 Richey-Lambert coal field, Mont- pl. 22
 Rosebud coal field, Mont------- pl. 10
Geomorphology of Rosebud coal field, Mont---------------- 71–73
Gold, production of, in Contact district, Nev------------ 5
Graveley, C. A., mine of, features of---------------- 187–188
 mine of, production of--------- 176
 section of phosphate beds in ----------------- pl. 34
Gravels in Rosebud coal field, Mont., character and distribution of-------- 64–66, pl. 11
Gray Copper Corporation properties, features of------ 32–35, pl. 3

H

Page

Haddow coal bed, occurrence and thickness of------- 80, pl. 10
Haddow Creek mine, production of-- 85
Hartshorne sandstone, character and thickness of---------- 198
 correlation of ---------------- 196
 distribution of---------------- 198
 fossils in-------------------- 198
Helen B. Smith claim, features of--- 34–35
Hell Creek member of Lance formation, distribution and character of- 53–54, pls. 9–11
Hendricks, T. A., and Parks, Bryan, Geology and mineral resources of the western part of the Arkansas coal field- 189–224, pl. 35
Hice mine, features of------------- 38
Hickey mine, geology and ore deposits of-------- 30–31, pl. 3
Hill County, Mont. *See* Chouteau, Hill, and Liberty Counties, Mont.
Hunt, C. B., with Pierce, W. G., Geology and mineral resources of north-central Chouteau, western Hill, and eastern Liberty Counties, Montana---- 225–264, pls. 36–43

I

Ilo tunnel, dike in-------------- 25, pl. 4
Ivy Wilson group, production of---- 35–36

J

Jones mine, geology and ore deposits of------------------ 30–31
Jordan mine, work at------------ 146
Judith River formation, character, thickness, and correlation of-------- 231, 232–236
 coal beds in-- 232–235, 261–263, pl. 42
 sections of--- 233–234, 235, 249, pl. 36
 water in--------------------- 261

K

Kootenai formation, character and thickness of---------- 248
 oil and gas in-------- 259, 260, pl. 41
 section of------------------ 250
Kratz mine, geology and ore deposits of------------ 39–40
Kremlin, Mont., wells near----- 258, pl. 41

L

Lance formation, coal beds in------ 75–78, pls. 10, 11
 occurrence and character of---- 53–57, pls. 6, 8, 11
 quantity of coal in---------- 83–84

Page
Lane coal bed, occurrence of 140, pls. 22, 27
Lane mine, work at 146
Lavaca gas field, production from 218–219
Lead, production of, in Contact district, Nev 5
Lead-Silver mine, features of 30–31
Lebo shale member of Fort Union formation in Richey-Lambert coal field, Mont., character and thickness of 129–130, pls. 22, 24, 27
Lebo shale member of Fort Union formation in Rosebud coal field, Mont., coal beds in 77–78, pls. 10, 11
correlation of 60–61
occurrence and character of 57, pls. 5, 8–9, 11
quantity of coal in 83–84
relations of 58–59
sections of 57–59
thickness of 59, pl. 10
Lena shaft, ore body in 22
Liberty County, Mont. *See* Chouteau, Hill, and Liberty Counties, Mont.
Lower Hartshorne coal bed, analyses of coal from 210–213
coal below, occurrence of 205
occurrence and thickness of 205–206, pl. 35

M

McAlester shale, character, distribution, and thickness of 199
coal beds in 199
correlation of 196
fossils in 199
McKay coal bed, occurrence and thickness of 80, pl. 10
quantity of coal in 83
Madison limestone, character and thickness of 249, 250
oil and gas in 259–261
Magnolia mine, lodes of 33
Mammoth claim, deposits of 33–34
Manitou anticline, possibility of gas in 222–223
Mansfield gas field, history and production of 217–218
Massard Prairie gas field, production from 219
Maxville, Philipsburg, and Avon areas, Mont., field work in 176
geology of 177–183, pls. 28–32
phosphate rock in 183–188, pl. 34
surface features of 177
Mill Creek fault, possibility of gas in closure against 223
Miller mine, work at 146
Mulberry fault, possibility of gas in closure against 223–224

N

Page
Natural gas in Chouteau, Hill, and Liberty Counties, Mont., occurrence of 258–260
possibilities of 260–261
results of drilling for 258–260
Natural gas in western part of Arkansas coal field, analyses of 216
occurrence of 214–216
production of 216
Nevada mine, ore of 36
Nevada-Bellevue mine, geology, ore deposits, and workings of 22–26, pl. 4
New Hope mine, development work at 188
Northwest Development Co., sections of phosphate rock on property of pl. 34
Northwestern Improvement Co., development workings on property of 187–188
production of phosphate rock from mine of 176–177
Niobrara group, equivalent of 246

O

Oil. *See* Petroleum.

P

Palo Alto mine, features of 26–28
Pardee, J. T., Phosphate rock near Maxville, Philipsburg, and Avon, Mont 175–188, pls. 28–34
Paris coal bed, analyses of coal from 211–212
occurrence and thickness of 208, pl. 35
Paris shale, correlation of 196
Parker, Frank S., The Richey-Lambert coal field, Richland and Dawson Counties, Mont 121–174, pls. 22–27
Parks, Bryan, with Hendricks, T. A., Geology and mineral resources of the western part of the Arkansas coal field 189–224, pl. 35
Petroleum in Chouteau, Hill, and Liberty Counties, Mont., occurrence of 258–260
possibilities of 260–261
results of drilling for 258–260
Philipsburg area, Montana, geologic map of pl. 29
sections of phosphate beds in pl. 34
structure sections and profile in pl. 31
See also Maxville, Philipsburg, and Avon areas.

Page
Phosphate rock, beneficiation of 185–186
columnar sections of pl. 34
composition of 184–185
development workings on 187–188
markets for 177
occurrence of 183–184
production of 176
reserves of 186–187
Pierce, W. G., The Rosebud coal field, Rosebud and Custer Counties, Mont 43–120, pls. 5–21
and Hunt, C. B., Geology and mineral resources of north-central Chouteau, western Hill, and eastern Liberty Counties, Mont 225–264, pls. 36–43
Pierre group, equivalent of 246
Pierson mine, production of coal from 84
Pleistocene gravel, occurrence and character of 133–135, pls. 22, 24–26
Prittegurl coal bed, occurrence of 142, pls. 22, 27
Pust coal bed, occurrence of 142, pls. 22, 27
Pust mine, work at 146

Q

Queen of the Hills mine, features of 31–32, pl. 3

R

Rattler mine, features of 32–33
Red Metal mine, work at 37, pl. 3
Reeside, J. B., Jr., fossils identified by 238
Richey-Lambert coal field, Montana, coal of, physical and chemical character of 142–143
coal of, reserves of 147–148
coal beds in, by townships 148–174, pl. 27
T. 19 N., R. 50 E 148, pl. 27
T. 20 N., R. 50 E 148–151, pl. 27
T. 21 N., R. 50 E 151–152, pl. 27
T. 22 N., R. 50 E 152, pl. 27
T. 23 N., R. 50 E 152–153, pl. 27
T. 21 N., R. 51 E 153–154, pl. 27
T. 22 N., R. 51 E 154–155, pl. 27
T. 23 N., R. 51 E 155–156, pl. 27
T. 24 N., R. 51 E 156–158, pl. 27
T. 21 N., R. 52 E 158–159
T. 22 N., R. 52 E 159, pl. 27
T 23 N., R. 52 E 159–160, pl. 27
T. 24 N., R. 52 E 160–162, pl. 27
T. 21 N., R. 53 E 162, pl. 27
T. 22 N., R. 53 E 162–163, pl. 27
T. 23 N., R. 53 E 163–164, pl. 27
T. 24 N., R. 53 E 164–166, pl. 27
T. 21 N., R. 54 E 166, pl. 27
T. 22 N., R. 54 E 166–168, pl. 27
T. 23 N., R. 54 E 168–169, pl. 27

Page
Richey-Lambert coal field—Continued.
coal beds—Continued.
T. 24 N., R. 54 E 169–171, pl. 27
T. 21 N., R. 55 E 171–172, pl. 27
T. 22 N., R. 55 E 172–173, pl. 27
T. 23 N., R. 55 E 173, pl. 27
T. 24 N., R. 55 E 173–174, pl. 27
drainage of 126–127
field work in 123
geography of 125–128
geomorphic history of 136–139, pls. 22, 23, 26
land forms in 125–126
location of 121–122
mining in 145–147
previous geologic work in 124–125
settlements in 127–128
stratigraphy of 128–135, pls. 22–25
structure of 135–136
transportation in 127–128
water supply of 126–127
Rosebud coal bed, coal mined from 84
occurrence and thickness of 80, pl. 10
outlook for mining of 84
quantity of coal in 83
Rosebud coal field, coal of, physical and chemical properties of 80–81
coal of, quantity of 82–84
coal beds in, by townships 85–120, pls. 12–21
T. 2 N., R. 42 E 90–92, pl. 12
T. 3 N., R. 42 E 88–90
T. 4 N., R. 42 E 88–89
T. 5 N., R. 42 E 86–88
T. 6 N., R. 42 E 85–86
T. 2 N., R. 43 E 96–97, pl. 14
T. 3 N., R. 43 E 95–96, pl. 13
T. 4 N., R. 43 E 94–95
T. 5 N., R. 43 E 93–94
T. 6 N., R. 43 E 92–93
T. 2 N., R. 44 E 102–103, pl. 16
T. 3 N., R. 44 E 101–102, pl. 15
T. 4 N., R. 44 E 99–101
T. 5 N., R. 44 E 97–99
T. 6 N., R. 44 E 97–98
T. 2 N., R. 45 E 106
T. 3 N., R. 45 E 105–106, pl. 18
T. 4 N., R. 45 E 103–105, pl. 17
T. 5 N., R. 45 E 103–104
T. 3 N., R. 46 E 109–110
T. 4 N., R. 46 E 108–109
T. 5 N., R. 46 E 106–108
T. 3 N., R. 47 E 112–113, pl. 21
T. 4 N., R. 47 E 111–112, pl. 20
T. 5 N., R. 47 E 110–111, pl. 19
T. 3 N., R. 48 E 116–117
T. 4 N., R. 48 E 113–116
T. 5 N., R. 48 E 113–114
T. 3 N., R. 49 E 120
T. 4 N., R. 49 E 119–120
T. 5 N., R. 49 E 116–119
drainage and water supply of 48–51
faults in 68–69
field work in 46–47
geomorphology of 71–73
location of 45

Page

Rosebud coal field, Mont., magnetic declination in 47
outlook for development of 84–85
population of 51
previous geologic work in 45–46
stratigraphy of 53–66, pls. 7–10
structure in 66–71, pls. 7, 8, 10, 11
topography of 47–48, pls. 5, 6, 11
transportation in 52
vegetation in 51, pl. 5

S

Salmon River Mining Co., claims of 22, pl. 3
Salt Lake group, inactivity of 37, pl. 3
Savanna sandstone, character and thickness of 199–200
coal beds in 199–200
correlation of 196
fossils in 200
Schaller, W. T., quoted 244
Schrader, F. C., The Contact mining district, Nevada 1–41, pls. 1–4
Sheckles mine. *See* Truro-Sheckles mine.
Shibley gas field, production from 220
Silkworm mine, ore deposit of 40–41
Silver, production of, in Contact district, Nev 5
Silver Circle mine, geology and ore deposits of 31–32, pl. 3
Silver King mine, geology and ore deposit of 39–40
Skylark claim, work on 37
Snyder mine, production of 84
Solack coal bed, occurrence of 141, pls. 22, 27
Spadra shale, correlation of 196
Squires mine, work at 146
Standard prospect, features of 35, pl. 3
Stark mine, work at 146
Stillson coal bed, occurrence of 142, pls. 22, 27
Stillson mine, work at 146
Sue group, development work on 35–36, pl. 3
Sunburst sand, possibility of oil and gas in 260

T

Terrace gravels in Rosebud coal field, Mont., character and distribution of 64–66, pl. 11
Terret coal bed, coal mined from 84
occurrence and thickness of 79–80, pl. 10
outlook for mining of 84
quantity of coal in 83
Tongue River member of Fort Union formation in Richey-Lambert coal field, Mont., character and thickness of 130–131, pls. 22, 23
Tongue River member of Fort Union formation in Rosebud coal field, Mont., coal in, outlook for mining of 84
coal in, quantity of 83
coal beds in, features of 62–64, 78–80, pls. 9–11
distribution and character of 61, pls. 5, 8, 11
fossils in 61
sections of 62–64
thickness of 61
Tongue River syncline, features of 68
Trail Creek coal bed, quantity of coal in 83
Trail Creek coal zone, occurrence and thickness of 78–79, pl. 10
Truro-Sheckles mine, features of 37
Tullock member of Lance formation, coal beds in 55–56, 76–77, pls. 10, 11
coal beds in, quantity of coal in 83
distribution and character of 54–56, pls. 6–11
fossils in 56
section of 56
thickness of 55–56, pl. 10

U

United States Bureau of Mines, coal analyses by 263
Upper Hartshorne coal bed, occurrence of 206–207
Utopia anticline, drilling on 259–261

V

Vache Grasse anticline, possibility of gas in 221
Vesta gas field, production from 218
Virgelle sandstone member of Eagle sandstone, correlation of 242–243
sections of 244, 249
water in 264
Vivian Tunnel Co., plans for development work by 30
Vulcan mine, geology and ore deposit of 38–39

W

Washington Phosphate & Silver Co., development workings on property of 188, pl. 33
production of phosphate rock from mine of 177
Water resources of Chouteau, Hill, and Liberty Counties, Mont 264
Wells, logs of, interpretation of pl. 41
Wright coal bed, quantity of coal in 83
thickness of 76, pl. 10

Y

Yellow Girl mine, inactivity at 37