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GEOLOGY

OF THE

LEWISTOWN COAL FIELD

MONTANA

BY

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GEOLOGY OF THE LEWISTOWN COAL FIELD, MONTANA.

By W. R. Calvert.

INTRODUCTION.

That coal-bearing rocks occur in the vicinity of Lewistown, Mont., has been known for many years. In 1882 the geologists of the Northern Transcontinental Survey visited the region in the course of a general reconnaissance of the Northwest, the chief object of the exploration being to secure information concerning the coal resources. The evidence obtained during that cursory examination seemed to be unfavorable to the supposition that coal was present in quantity in the Lewistown field, although the occurrence of valuable coal deposits in the Great Falls region, somewhat farther west, was clearly recognized. A number of years later Weed and Pirsson[a] made a study of the geology and mineral resources of the Judith Mountains, and in their report gave a short discussion of the coal in the immediate vicinity of the uplift. Various other geologists have made brief reference to the field.

In order to obtain more definite information concerning the coals of the Lewistown field, chiefly for land-classification purposes, a survey of the district was made by the United States Geological Survey during the summer of 1907, and this report embodies the results of the work.

In conjunction with the economic and geologic investigation of the field the accompanying map (Pl. I, in pocket) of the area was prepared. Since land classification was the prime object of the investigation, it was necessary wherever possible to follow land lines in map making. The method employed was to meander from land corners, pacing along section lines and using the section corners found in these meanders as a basis for horizontal control. Where the coal outcrop could not be mapped accurately from the section lines it was traced separately and the meanders tied to section corners. In unsurveyed areas, or where the nature of the topography was such as to render the following of land lines impractical, location was obtained by triangulation to known points.

[a] Weed, W. H., and Pirsson, L. V., Geology and mineral resources of the Judith Mountains of Montana: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 438-616.

Vertical control was obtained by aneroid barometer readings based in the western half of the field on elevations given by railroad profiles, and in the eastern and northern districts on elevations determined by the United States Geological Survey. Since aneroid barometers are often unreliable, it is not claimed that the contours on the map are other than approximately correct, except possibly in the immediate vicinity of known elevations, such as lines of railroad or bench marks placed by the Survey. In general the horizontal control presents a higher standard of accuracy than the vertical, especially where land corners could be found, and where distances recorded in the township plats agree with the measured distances on the ground. In the mountain tracts the topography, denoted by broken contours, is taken from the maps of the Northern Transcontinental Survey. The topography is represented on these maps by a 200-foot contour interval, but, in order to be consistent with the body of the present map, additional contours have been interpolated.

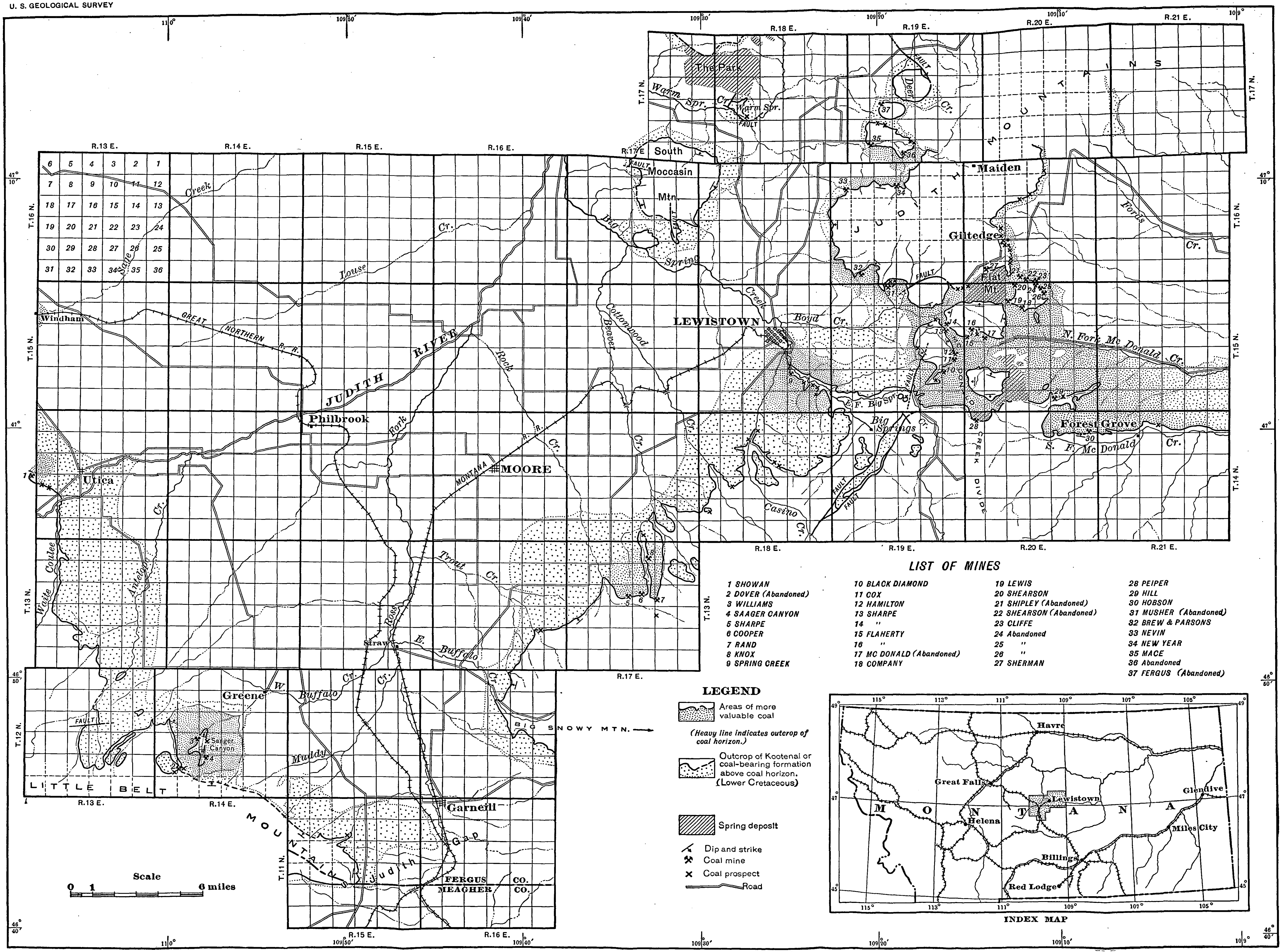
The positions of the parallels and meridians are likewise only approximate. The astronomic location of a point at Lewistown, determined by the United States Geological Survey, furnished the basis for the placing of latitude and longitude lines in other parts of the map. More precise work may change slightly the relation of land areas to these lines.

The writer wishes to express his appreciation of the field assistance and hearty cooperation of Eugene Stebinger, J. B. Umpleby, J. R. Hoats, and C. P. Fordyce. The final preparation of the map and much of the compilation of other data have been done by Mr. Stebinger. The entire work, both in field and in office, has been under the general supervision of C. A. Fisher, to whom the writer is indebted for many helpful suggestions. To many other persons, miners, ranchers, and business men, the author is grateful for kindness shown in the field. Among these, O. F. Wasmansdorff, the county surveyor of Fergus County, deserves special mention for his valuable aid and unfailing courtesy.

GEOGRAPHY.

LOCATION AND EXTENT.

The area investigated lies between longitude 109° and 110° 15′ west and is divided by the forty-seventh parallel into two nearly equal portions. (See Pl. II.) It is thus located in central Montana, including the west-central part of Fergus County and a few square miles in the northeastern portion of Meagher County. It contains an area of about 1,500 miles, although a considerably greater territory is represented on the map. The greater part of the



ECONOMIC MAP OF LEWISTOWN COAL FIELD, MONTANA.

district lies in Judith Basin, a name applied to the upper drainage basin of Judith River.

The boundaries of the Lewistown coal field are arbitrary rather than natural, for they are based on land lines rather than on geologic or geographic districts. Work similar in character to that pursued during the season of 1907 was carried on the previous year in the Great Falls coal field[a] to the west, and as the eastern limit of that investigation was the line between Rs. 12 and 13 E., the survey of the Lewistown field was made to connect with that of the Great Falls field.

SURFACE FEATURES.

A considerable diversity in character of topography is presented in the Lewistown field. Broadly viewed, the area is a part of the great plains province, which extends in unbroken continuity for many miles to the east. It is on the western border of the plains, however, where the monotony is varied by local mountains which lie contiguous to or within the field.

A broad and shallow depression, termed Judith Basin, comprises the western half of the area treated. This part of the field is characterized by extensive terraces, which in certain localities are trenched by streams, although there are large areas where the surface is unbroken. The slope of these terraces is so gentle that it is scarcely perceptible.

To the southwest Judith Basin merges into the uplift of the Little Belt Range, whose eastern end extends into the field, as shown on the map. This eastern extension presents a bold northern face along which in places there is a comparatively narrow transitional zone, between the plains and mountain types of topography. In other localities to the north of this uplift the plains extend to the very base of the mountains. The southern slopes of the Little Belt Mountains are much more gradual, and viewed from the south the range is a much less striking topographic feature than when seen from the north.

Lying to the east of the Little Belt Range and with a similar east-west trend are the Big Snowy Mountains, whose western end barely enters the field. Although this uplift lies largely outside the area mapped, it influences much of the topography in the southern part of the field. Unlike the Little Belt Range, the Big Snowy Mountains have longer and more gradual slopes to the north, which are much more deeply trenched. Between the Little Belt and the Big Snowy mountains there is a depression about 8 miles wide, termed Judith Gap. This constitutes a watershed between two drainage

[a] Fisher, C. A., The Great Falls coal field, Montana: Bull. U. S. Geol. Survey No. 316, 1907, pp. 161-173.

systems, and is also a natural passageway for travel in and out of Judith Basin.

There are three mountain groups in the northern part of the field. The Judith Mountains lie wholly within the area mapped. They are irregular in outline, with axis trending in a general northeast-southwest direction, and include an area of about 100 square miles. West of the Judith Mountains are two minor groups, known as the North Moccasin and the South Moccasin mountains. The former uplift is practically outside the area mapped, though the flat-topped, mesa-like form designated on the map as The Park is a southern extension of the North Moccasin Mountains.

The Judith and Moccasin mountains are very similar in general appearance and structural relations. Unlike either the Little Belt Range or the Big Snowy Mountains they possess numerous individual peaks, hence the crest line is much more serrate. The rise from the plains is rather abrupt, and, being isolated, the mountains stand out boldly, like islands in a sea.

Between the Judith and the Big Snowy mountains is a district which has highly accented topography and which constitutes the divide between Judith River drainage basin and the drainage basins of the streams flowing eastward to the Musselshell. The surface of this district is much more diversified than any other part of the Lewistown field outside the mountain tracts.

The range in altitude within the region described is considerable. The lowest point is on Judith River west of South Moccasin Mountains, where the elevation is about 3,600 feet above sea level. Two peaks of the Little Belt Range, termed the Twin Sisters, have an altitude of about 7,500 feet. The Big Snowy Mountains are somewhat higher, the comparatively even crest rising to more than 8,000 feet. Several of the higher points of the Judith Mountains rise to about 6,000 feet, while the Moccasin group is as a whole somewhat lower.

DRAINAGE.

General statement.—The drainage of the Lewistown field belongs to the Missouri River system, though but one minor stream enters that river direct. All others of the area are tributary to Judith River or Musselshell River, which join the Missouri outside the area mapped.

In general the various streams of the field have had and will continue to have considerable influence on coal development. The fact that coal outcrops, or is near the surface in any part of the area, is due entirely to structural movement and subsequent erosion which have laid bare the coal-bearing rocks. Where the strata are inclined streams have cut across the coal horizon, thus allowing ready access to the outcrop, and the stream valleys serve as readily available routes of transportation. No coal washing is undertaken at present in the Lewistown field, but if this additional process should become desirable, water can be obtained in certain of the areas where coal is produced, notably along Big Spring Creek. This stream, as well as Warm Spring Creek, furnishes at present considerable power which is not utilized in the coal-mining industry and which could be more fully developed for mining purposes.

In one respect the streams tend to retard development of the coal resources. This is true where the water flows across the dip and is absorbed by rocks in the direction of the dip, rendering mining conditions far from ideal. An example is furnished by Big Spring Creek above Lewistown, where development has been confined entirely to the southwestern side of the valley because the northern dip of the strata offers a favorable condition for absorption of water in that locality.

Judith River drainage.—Judith River is the largest stream in the Lewistown field and drains nearly three-fourths of the entire area mapped. It rises in the Little Belt Range near Utica and, flowing northeast, passes out of the district a few miles west of South Moccasin Mountains. Throughout the year considerable water is flowing in its upper courses, but below Utica much is diverted for irrigation purposes, and during the growing season the stream bed is often dry in places.

The Judith is joined by various tributaries. Ross Fork, which heads in the vicinity of Judith Gap, is the principal stream entering from the south. Several small tributaries enter Ross Fork from both the east and the west, two of which—West Buffalo and Rock creeks—traverse areas of workable coal. The former is a small intermittent stream, heading on the northern slope of the Little Belt Range; the latter, perennial in its upper course, rises on the north flank of the Big Snowy uplift.

From the east Judith River has two comparatively large affluents—Big Spring and Warm Spring creeks. The former, named from the occurrence of several very large springs 7 miles above Lewistown, flows entirely across the field in a northwesterly direction and joins the Judith northwest of the South Moccasin Mountains. Cottonwood Creek and its main tributary, Beaver Creek, both constantly flowing streams, and Big Casino and Castle Creeks, are the chief tributaries entering Warm Spring Creek from the south. Several small streams, notably Boyd and Pike creeks, also join from the south.

Warm Spring Creek drains the structural basin between the Judith and Moccasin mountains. It heads well within the Judith Mountains tract, flows westward, receiving several minor affluents in its course, and passes off the field to the north of South Moccasin Mountains. In the latter vicinity it is greatly augmented by a large thermal spring, from which the stream is named. Above the spring the stream is intermittent in character, except in its upper course.

The northwestern portion of the field is traversed by Sage Creek, also a tributary of Judith River. It is an intermittent stream and is of importance only because of its relation to the Sage Creek coal district of the Great Falls field to the west.

Musselshell River drainage.—The small area mapped to the south of Judith Gap is included in the drainage of Musselshell River. In this southern area the streams are small and unimportant.

East of the McDonald Creek divide and the Judith Mountains numerous small streams flow eastward, also to join the Musselshell. McDonald Creek with its branches is the most important of these, as it is closely related to the largest coal district of the Lewistown field. These streams have not only exposed the coal zone in many localities, but the valleys also form natural routes of travel.

Other drainage.—But one stream of the entire area is directly tributary to Missouri River. This is Armells Creek, which rises on the northern slopes of the Judith Mountains and flows northward, thus having only a few miles of its course within the field. A small affluent, Deer Creek, also heads in the Judith uplift and passes off the field within a comparatively short distance from its source.

CULTURE.

General statement—As a whole the field is fairly well populated. Within the last few years there has been a considerable influx of settlers, who are cultivating the open bench land and the stream valleys near the mountains. The interests of the area are essentially agricultural, although metal mining is carried on more or less in the Judith and Moccasin mountains, and in various localities towns have sprung up which serve as distributing centers.

Towns.—The chief center of population is Lewistown, located in the central part of the field on Big Spring Creek. It is the county seat of Fergus County, has a population of about 4,000, and is a prosperous growing town. Moore, 17 miles southwest of Lewistown, is the second largest town of the field and has about 400 inhabitants. Still farther southwest are Straw and Garneill, two railroad stations on Ross Fork. In this district also are two new stations, Buffalo and Judith Gap. Utica, the only town in the western part of the area, is located in Judith River Valley on the Lewistown-Great Falls stage road. Below Utica on Judith River is situated the old stage station, Philbrook, and still farther down the valley is Hobson, a new station on the Billings and Northern Railroad. To the northwest and just outside the area mapped the site of a town named Windham has been platted in the valley of Sage Creek. This prospective town is also on the Billings and Northern line and will serve as a shipping point for coal from the Sage Creek district, where a company is planning extensive development.

Three towns are situated in the eastern part of the district. These are Maiden, formerly a prosperous mining town, but now almost deserted, which is located at the head of Warm Spring Creek, well within the Judith Mountains; Giltedge, also a mining town, located at the eastern base of the Judith Mountains near their south end; and Forestgrove, on McDonald Creek.

Railroads.—One railroad is now in operation in the district, and another is nearly constructed. In the spring of 1904 the Montana Railroad was extended through Judith Gap into Lewistown, giving that town connection to the south with the main line of the Northern Pacific at Lombard. Judith Gap is traversed also by the Billings and Northern Railroad, which is now about completed. This line connects Billings with Great Falls and passes through the western part of the Lewistown field.

Roads.—The entire area included in the Lewistown coal field as described is well traversed by roads. Before railroad facilities were available Lewistown was the center of a radiating system of stage lines, most of which are still in operation. Daily stages connect with Great Falls, Maiden, and Giltedge, and a bidaily service is maintained with Kendall, a town on the east flank of the North Moccasin Mountains, and just outside the area mapped. Formerly a stage line was operated between Lewistown and Fort Benton, a town on Missouri River at the head of navigation, but at present the stage goes no farther than Denton, a post-office about 30 miles northwest of Lewistown. There is also a triweekly mail service to Forestgrove and other post-offices to the southwest. Stage service between Lewistown and Billings has been abandoned since the completion of the Montana Railroad. In addition to the main stage roads of the district there are many minor thoroughfares which traverse the area in various directions, largely along section lines in the plains country and along stream valleys, as a rule, in the rougher portions of the field.

STRATIGRAPHY.

SEDIMENTARY ROCKS.

GENERAL STATEMENT.

The rocks studied in the Lewistown coal field range in age from Carboniferous to Pleistocene, inclusive. Still older formations outcrop in the various mountains, notably in the Judith Mountains, where the section is exposed nearly to the base of the Cambrian. Since the coal of the Lewistown field, with which this report is chiefly concerned, is of Lower Cretaceous age, stratigraphic study in the area was confined mainly to formations more or less closely related to the Kootenai, or coal-bearing rocks. In fact, geologic mapping did not include rocks older than Jurassic in certain portions of the field, even where lower formations were exposed.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

MADISON LIMESTONE.

General statement.—The entire section of the Madison limestone was not studied in the field, even in the Little Belt or Judith mountains, where Carboniferous rocks are well exposed. In each of these areas, however, the later Paleozoic sediments have been studied and the stratigraphy is fairly well known.

Character and thickness.—According to Weed,[a] the Madison limestone in the Little Belt Mountains consists of three divisions, with an aggregate thickness of about 1,000 feet. The lower third is grayish, thin-bedded, shaly limestone, named the Paine shale, which is overlain by light-colored limestone, termed the Woodhurst. The top of the formation is a very massive member, designated the Castle limestone. As noted in the field this upper member is usually without bedding and is generally cherty near the top. In areas of Madison limestone the streams cut gorges and usually issue to the plains from narrow box canyons, especially where the strata are considerably inclined. As a rule the topography of the limestone areas is rugged, and usually there is an abrupt change in the character of the topography where the softer rocks of younger formations meet the Madison.

Distribution.—The Madison limestone is exposed in each of the mountain tracts contiguous to or within the field. It makes up the mass of the Little Belt and Big Snowy ranges and a considerable part of the Judith and Moccasin groups. So constant is the association of the Madison with the uplifts of the northern Rocky Mountain region that the name "mountain limestone" is sometimes applied to it.

Stratigraphic relations.—As the entire Madison section was not studied, the relation of that formation to underlying formations was not ascertained, but other workers in the same general region state that it rests with apparent conformity upon rocks of Devonian age. No unconformity has been recognized at the top of the Madison in this region, but the abrupt change in character of the sediments at that horizon may be indicative of a hiatus, which further study may disclose.

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[a] Weed, W. H., Little Belt Mountains folio (No. 56), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

Fossils.—In the upper member of the Madison limestone fossils do not appear to be abundant, at least in that portion of the Little Belt Mountains where search for fossils was made. One collection was obtained near the head of Muddy Creek, 7 miles west of Garneill, at a horizon 400 feet below the top of the formation from which G. H. Girty identifies the following species as of Mississippian types:

Fossils from Madison limestone at head of Muddy Creek.

Syringopora surcularia.	Syringopora sp.
Menophyllum sp.	Schuchertella inflata var.
Productus lævicostus.	Productus parviformis.
Spirifer centronatus.	Eumetria verneuiliana.

As previously stated, no attempt was made in other parts of the field to secure fossil collections from the Madison, as mapping usually did not include formations older than Jurassic. For detailed description of the Mississippian section in the Little Belt Mountains the reader is referred to Weed,[a] or for the section in the Judith Mountains to Weed and Pirsson's report[b] on the geology of that vicinity.

PENNSYLVANIAN (?) SERIES.

QUADRANT FORMATION.

General statement.—Immediately overlying the massive limestone of the Madison is a series of beds of variable character and thickness. In the Little Belt Mountains Weed[c] has correlated these beds with the Quadrant formation, first named from its extensive development near Quadrant Mountain, in Yellowstone Park. In the Lewistown field the Quadrant presents rather interesting stratigraphic and faunal features, which were not worked out in detail, as but little time was devoted to rocks of Carboniferous age.

Character and thickness.—On Judith River west of Utica the Quadrant, according to Weed,[d] has a thickness of 1,400 feet. South of Utica along the Little Belt uplift and in the area adjacent to the west end of the Big Snowy uplift the Quadrant comprises a fairly constant series of beds. Red shale containing many chert fragments constitutes the lowermost member which rests on Madison limestone, and in which no fossils were found. Next above is a white saccharoidal sandstone, likewise apparently nonfossiliferous. Still above is greenish shale containing thin beds of limestone, overlain in turn by limestone in which occur abundant fossils. A section of the Quadrant, measured at the north base of the Little Belt Range, near

[a] Weed, W. H., Little Belt Mountains folio (No. 56), Geol. Atlas U. S., U. S. Geol. Survey, 1899.
[b] Weed, W. H., and Pirsson, L. V., Geology and mineral resources of the Judith Mountains of Montana: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 471–472.
[c] Weed, W. H., Little Belt Mountains folio (No. 56), Geol. Atlas U. S., U. S. Geol. Survey, 1899.
[d] Op. cit.

the head of Muddy Creek, illustrates the above succession and is given below:

Section No. 1 of Quadrant formation at head of Muddy Creek, 7 miles west of Garneill, Mont.

	Feet.
Jurassic? red shale.	
1. Limestone, light gray, weathering almost white, fossiliferous in upper portion	55
2. Shale, green, alternating with limestone members near top; beds partly concealed	105
3. Sandstone, white, soft, saccharoidal, basal members alternating with limestone layers, all weathering like limestone	40
4. Shale, red, containing an abundance of irregular cherts; beds partly concealed	225
Madison limestone.	
	425

The green shale member of the above section is the most striking feature of the formation, as its vivid color contrasts it strongly with other beds either in the Quadrant itself or in other formations represented in the field.

The following section of the Quadrant measured on the south side of the Little Belt Range shows a considerable variation in the beds above the lower shale member:

Section No. 2 of Quadrant formation in SE. ¼ sec. 20, T. 11 N., R. 15 E.

	Feet.
Jurassic sandstone.	
1. Limestone, thin bedded to platy; lower 30 feet soft pinkish color; upper 10 feet massive; no fossils noted	59
2. Shale, red	50
3. Limestone, dark gray, fine grained, finely bedded, with intercalated red shale	40
4. Limestone, in 1-foot layers carrying abundant fossils	38
5. Limestone and shale	5
6. Shale, coppery green	130
7. Beds partly concealed, consisting of red shale at base	425
Madison limestone.	
	747

In the area between the Judith and the Big Snowy mountains the base of the Quadrant was not seen, hence the relation of the formation to the underlying Madison could not be ascertained. That there is a marked change in the lithologic character of the upper members is evident, however, for wherever encountered they were composed of black shale and dark, bituminous limestone, both fossiliferous.

Study of the Quadrant along the base of the Judith and Moccasin mountains was very unsatisfactory, for beds in the stratigraphic position of the Quadrant are, as a rule, much concealed either by talus or by dense vegetation. In fact, no definite evidence, either lithologic or paleontologic, was obtained regarding the presence of that formation along the base of the mountains in question. If present it is certain that it is more attenuated than in the Little Belt Mountains, for the interval between the Madison limestone and beds containing Jurassic fossils is markedly less than as shown in the sections of the Quadrant already given. In only one locality contiguous to the Judith Mountains, namely near the Lewistown-Giltedge stage road as it passes to the north of Flat Mountain, was a member noted which is comparable to the saccharoidal sandstone of section No. 1. No fossils were obtained, however, so that the sandstone in question can not be definitely assigned to the Quadrant. Because of this uncertainty geologic mapping was not attempted below Jurassic beds in the Judith and Moccasin areas, and more detailed work must decide the stratigraphy in the interval between Madison and marine Jurassic. There is no doubt, however, that the Quadrant is represented on the west side of the Judith uplift. In Deer Creek dome a thickness of at least 100 feet of Quadrant is exposed from which fossils were collected, and Quadrant also occurs in the dome south of South Moccasin Mountains, though at the latter locality only the upper shaly members are exposed. In the Deer Creek laccolith the lowest member exposed is a soft reddish sandstone, overlain by dark shale, bituminous limestone, and shale in ascending order. A satisfactory section could not be obtained at this locality.

Near the Judith and Moccasin mountains and to the south as far as mapping was undertaken the Quadrant formation is soft and easily eroded, and consequently forms valleys. Near the west end of the Big Snowy Mountains and along the Little Belt Range the limestone member of the formation is a prominent ridge maker, with the red and green shales forming valleys on either side. The topographic expression of the Quadrant, together with its exposed area in the field, is shown on the accompanying geologic map (Pl. I).

Stratigraphic relations.—As stated under the discussion of the Madison, no unconformity has been recognized at the base of the Quadrant, although there are certain suggestions of a time break in sedimentation. Between the Quadrant and the overlying Ellis, or marine Jurassic, there is no positive evidence of unconformity in the Lewistown field, although to the west an interval of erosion at this horizon has been recognized. It will be mentioned more in detail in the discussion of the Jurassic.

Fossils.—The upper members of the Quadrant formation usually carry an abundant fauna, whereas the lower beds appear to be entirely destitute of fossils. A number of collections were made in the field and the species represented have been identified by G. H. Girty. A list of collections, including locality and identification of forms, is given below.

Fossils from upper members of Quadrant formation.

Antelope Creek, sec. 15, T. 12 N., R. 13 E.

Productus cora.
Schizophoria resupinoides?
Composita subtilita.

From bed 1 of Quadrant section No. 1.

Zaphrentis sp.
Crania sp.
Chonetes sp.
Productus aff. inflatus.
Productus aff. inflatus var.
Productus cestriensis?
Productus aff. cestriensis.
Productus sp. *a*.
Dielasma? sp.
Phillipsia? sp.
Spirifer rockymontanus or increbescens.
Composita subquadrata or subtilita.
Aviculipecten sp. *a* aff. occidentalis.
Aviculipecten sp.
Sulcatipinna ludlowi.
Edmondia n. sp.
Naticopsis? sp.

SE. ¼ sec. 21, T. 11 N., R. 15 E.

Productus cestriensis?
Productus aff. inflatus.
Dielasma? sp.
Spirifer rockymontanus or leidyi.
Composita subtilita or subquadrata.

From bed 4 of Quadrant section No. 2.

Productus aff. inflatus
Productus aff. inflatus var.
Productus cora.
Spirifer n. sp. aff. cameratus.
Composita subtilita.

NW. ¼ sec. 23, T. 14 N., R. 19 E.

Lingula sp.
Productus cf. inflatus.
Aviculipecten sp. *a* aff. occidentalis.
Caneyella wapanuckensis?
Orthoceras sp.
Goniatites? sp.

(This collection was obtained about 75 feet below the top of the formation.)

NW. ¼ sec. 23, T. 14 N., R. 19 E.

Lingulidiscina sp.
Chonetes n. sp.?
Productus cf. inflatus.
Productus cora.
Productus sp. *a*.
Productus sp. *b*.
Ambocœlia aff. planiconvexa.
Aviculipecten sp. *a* aff. occidentalis.
Phillipsia? sp.

Deer Creek laccolith, NE. ¼ sec. 16, T. 17 N., R. 19 E.

Lingula aff. carbonaria.
Derbya? sp.
Chonetes n. sp.?
Productus cf. inflatus.
Dielasma? n. sp.
Harttina n. sp.
Pugnax n. sp.
Rhynchonella (Pugnax?) n. sp.
Composita n. sp.
Cleiothyridina aff. hirsuta.
Ostracoda undet.
Aviculipecten sp. *a* aff. occidentalis.
Myalina aff. monroensis and meliniformis.
Sulcatipinna ludlowi.
Yoldia sp.
Pleurophorus aff. subcostatus.
Macrodon? sp.
Goniatites? sp.
Bellerophon aff. stevensianus.

Previous statements regarding the age of the Quadrant have been somewhat at variance, as it has been assigned to both Mississippian and Pennsylvanian. Of the fossils listed above Girty says:

The fauna represented by these collections is peculiar, differing considerably from any of the known American Carboniferous faunas. A few forms (such as the strongly plicated Terebratuloid cited as *Dielasma?* n. sp.) are suggestive of the Pennsylvanian, or even of the late Pennsylvanian, whereas others suggest late Mississippian. Other faunas, much more closely related to the typical upper Mississippian, have been cited from this area as coming from the Quadrant, and it is possible that under that title have been included rocks of two geologic ages. One of these groups can with high probability be referred to H. S. Williams's Genevieve group of the "Neo-Mississippian." The other, including the beds from which the foregoing fauna was obtained, would probably best be referred to the Pottsville, at least provisionally, with the possibility that it also, in spite of the different facies of its fauna, may prove to be Mississippian.

JURASSIC SYSTEM.

ELLIS FORMATION.

General statement.—Resting on the Quadrant formation is a succession of sandstones, thin limestones, and red or dark shales, which are of Jurassic age and which constitute the Ellis formation. This has been described in more or less detail in the Little Belt Mountains folio [a] and in the report on the geology of the Judith Mountains.[b]

Character and thickness.—The most conspicuous member of the formation is a coarse-grained, conglomeratic sandstone, which in the greater part of the field contains at two horizons an abundance of oyster shells. The sandstone is bluish gray when fresh and weathers to a characteristic soft tan color. In certain localities of the western area this sandstone rests on the Quadrant, and in others the base of the formation consists of red shale or thin-bedded limestone. Throughout the entire field there is a sharp change in lithologic character at the top of the Ellis, which serves as a ready means of separating it from the overlying Morrison formation, or fresh-water Jurassic. Sandstone is invariably the upper member of the former, whereas the base of the Morrison is shale or argillaceous limestone.

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[a] Weed, W. H., Little Belt Mountains folio (No. 56), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

[b] Weed, W. H., and Pirsson, L. V., Geology and mineral resources of the Judith Mountains of Montana: Eighteenth Ann. Rept. U. S. Geol. Survey, 1898, pt. 3, pp. 476-480.

Along the northern base of the Little Belt Range, near its eastern end, the Ellis consists of shale, limestone, and sandstone, as shown by the following section:

Section of Ellis formation at head of Muddy Creek, 7 miles west of Garneill, Mont.

		Feet.
	Morrison formation.	
1.	Sandstone, shaly at bottom, pebbly in middle, grading upward into a massive, greenish gray sandstone, weathering tan, and containing an abundance of shell fragments	40
2.	Limestone, dark gray, weathering dove color, fossiliferous	6
3.	Shale, greenish	4
4.	Limestone, light colored, very thinly bedded	5
5.	Shale, red	10
	Quadrant formation.	
		65

On the south side of the Little Belt Range, only a few miles from the locality where the foregoing section was measured, the Ellis apparently consists of the sandstone member alone. It rests on limestone, which in the locality in question appears to be nonfossiliferous, but which because of lithologic similarity to limestone lower in the section carrying a carboniferous fauna, is assigned to the Quadrant.

In tracing the Ellis eastward from the western part of the field a considerable variation both in thickness and in general character was noted. A section of the Ellis obtained on East Fork of Big Spring Creek is given below.

Section of Ellis formation on bluff of East Fork of Big Spring Creek, sec. 2, T. 14 N., R. 19 E.

		Feet.
	Morrison formation.	
1.	Partly concealed; lowest 30 feet sandy soil, sprinkled thickly with *Gryphæa calceola*, underlain by a ledge of sandstone with abundant oyster shells; lowest 20 feet is sandstone also filled with oyster-shell fragments	100
2.	Sandstone, compact, blocky, gray, weathering tan; upper 15 feet forming bold cliff; fossiliferous at top, but shells mostly fragmentary	48
3.	Concealed, grassy slope with red soil	80
4.	Limestone, shaly at bottom, becoming thinly bedded, dove-colored, fossiliferous	10
5.	Shale, red, sandy	4
6.	Gypsum, white and pure	20
7.	Shale, dark, fissile and gypsiferous	5
8.	Limestone, fossiliferous	3
9.	Partly concealed but containing gypsiferous shale	45
10.	Gypsum and shale	5
11.	Partly concealed slope of dark soil	42
		362

The section given above may include a few feet of the Quadrant, as in this locality the upper beds of that formation and the lower part of the Ellis are dark shales, so that the distinction between the two is not apparent on other than paleontologic evidence. To the east the conglomerate sandstone member, containing abundant shells of *Ostrea strigilecula* White, becomes less conspicuous in its fossil content and bed 1, containing *Gryphæa calceola*, serves as the most valuable fossiliferous datum plane of the Ellis. In certain localities, notably in the vicinity of South Moccasin Mountains, fossils are not abundant, but the formation is still easily recognized by the prevalence of gray or bluish sandstone, weathering to the characteristic soft tan color. The following section of the Ellis, measured on the north slope of South Moccasin Mountains, shows the sequence of beds in that locality:

Section of Ellis formation as exposed on north side of South Moccasin Mountains.

		Feet.
	Morrison formation.	
1.	Sandstone, soft, tan-colored, gray, or yellow when fresh	147
2.	Partly concealed; yellow, sandy soil	150
3.	Sandstone, coarse grained, brownish yellow, weathering grayish brown; contains oyster shells	2
4.	Partly concealed; green and red soil on slope	60
5.	Partly concealed; upper 10 feet is a dark, bituminous limestone	75
6.	Limestone, irregularly bedded, light gray, inclined to be cherty; upper part conglomeratic, pebbles being angular, usually limestone with a few chert; pebbles are all small, one-fourth inch or less	6
		440

As fossils were not obtained from the lower part of the above section the line between the Quadrant and Ellis formations in this locality is largely a matter of conjecture, although the conglomeratic limestone would suggest that it constitutes the basal member of the Ellis.

Distribution.—The Ellis formation is exposed along the base of the various major uplifts in the field and in the domes in the vicinity of the Judith and Moccasin mountains. In these localities the beds are, as a rule, more or less highly inclined and the sandstone members form prominent strike ridges. At other places in the field where the rocks are more nearly horizontal the sandstones where exposed form the surface over considerable areas. This condition prevails in the southern part of the field north of the Big Snowy Mountains, where the Ellis is exposed throughout many square miles.

Stratigraphic relations.—In the Great Falls field to the west the Ellis generally rests unconformably on the Quadrant, but in the vicinity of Stockett it is in contact with the Madison limestone. In the Lewistown field this erosional unconformity, if it exists, is not apparent, and in the eastern half of the area the passage from the dark shale of the Quadrant to similar beds of the Ellis appears to be without a break, though, of course, the absence of the Permian, Triassic, and Lower Jurassic proves that sedimentation was not continuous.

Fossils.—Numerous collections of fossils were made from various horizons of the Ellis, and a list of forms identified by T. W. Stanton is given below. The majority of the collections were obtained from limestone members, as few forms other than *Ostrea* sp. are found in the sandstones. All indicate marine or brackish-water conditions.

Fossils from the Ellis formation.

Pentacrinus asteriscus M. and H.
Rhynchonella gnathopora Meek.
Ostrea strigilecula White.
Gryphæa calceola var. nebrascensis M. and H.
Camptonectes sp.
Eumicrotis curta (Hall).
Gervillia.
Modiola subimbricata Meek.
Trigonia conradi M. and H.
Cyprina cinnabarensis Stanton.
Cyprina sp.
Tancredia inornata Whitfield.
Tancredia bulbosa Whitfield.
Pleuromya subcompressa Meek.
Pleuromya newtoni Whitfield.
Thracia? sublævis M. and H.

MORRISON FORMATION.

General statement.—The Morrison has not previously been definitely recognized in the Lewistown field, although Weed and Pirsson[a] suggested that certain beds in the Judith Mountain district might be the equivalent of the Morrison of Colorado and Wyoming. During the course of a geologic investigation of the Great Falls coal field in 1906, Fisher[b] assigned to the Morrison the beds between the known marine Jurassic and the plant-bearing Lower Cretaceous, chiefly because of their similarity in lithology and stratigraphic position to recognized Morrison in Colorado and Wyoming. Paleontological evidence obtained during that investigation was somewhat meager, but such as was obtained was not unfavorable to their correlation with the Morrison. During the last season (1907) stratigraphic study was continued eastward and additional evidence was obtained, so that the presence of the Morrison in the Lewistown field may now be considered as fairly well established.

Character and thickness.—The Morrison formation consists of shales, sandstones, and argillaceous limestones, all apparently of fresh-water origin. The colors of these beds are extremely variable, greens and pinks predominating, but they are seldom, if ever, brilliant and possess a characteristic soft tint. In lithologic character and in thickness the formation is fairly uniform throughout the field, the various sections approximating 125 feet. Argillaceous members predominate. The shales are very clayey and the limestones also appear to contain a high percentage of silica. The limestone members are

[a] Op. cit., p. 480.
[b] Fisher, C. A., Geology of the Great Falls coal field, Montana: Bull. U. S. Geol. Survey No. 356, 1909.

characteristically bluish gray and break into small blocks. The sandstones are usually brownish and granular in appearance, and in them comminuted bone fragments are of fairly common occurrence.

As the Morrison is usually composed of soft, incoherent beds, it is, as a rule, a valley-producing formation, and it is thus exposed in many places along the sides of the valleys where streams have cut through to the more resistant Ellis sandstone. As a result detailed sections of the formation are not difficult to obtain, and the following, measured at an exposure west of Garneill, may be taken as a type of the Morrison in the Lewistown field:

Section of Morrison formation as exposed at head of Red Bluff Coulee, 5 miles west of Garneill.

	Feet.
Kootenai formation.	
1. Sandstone, fine grained, tan-colored, weathering soft tan, containing bone fragments	12
2. Shale, greenish, becoming sandy upward, with 1-foot layer of limestone, greenish gray, weathering russet 12 feet from top; shale contains many *Unio* shells	34
3. Limestone, reddish brown, weathering russet, containing an abundance of clear calcite crystals	3
4. Shale, greenish	8
5. Limestone and variegated shale; limestone is in thin layers, reddish brown, unchanged by weathering, with calcite crystals as in (3)	11
6. Limestone, fine grained, compact, containing small greenish particles resembling glauconite	2
7. Shale, variegated, red and pink predominating	75
Ellis sandstone.	
	145

Distribution.—The statements regarding the distribution of the Ellis are in a great measure applicable to the Morrison as well, as it is exposed as an irregular band parallel with the Ellis outcrop, but on the outer side from the various centers of uplift in the field. Since it is a much softer formation than the marine Jurassic, the line of contact between the two is very irregular, the details of which are shown on the geologic map (Pl. I).

Stratigraphic relations.—No suggestion of an unconformity was noted at either the base or the top of the Morrison. In fact, the lines of delimitation are somewhat uncertain, especially as regards the upper limit. Marine shells of the Ellis are to be found at the very top of the massive sandstone which is the most prominent member of that formation. Immediately overlying the sandstone are highly argillaceous beds in which fresh-water shells occur a short distance above the known Ellis. The most natural line of demarcation between the marine and fresh-water Jurassic is therefore that indicated by the change in lithology. The top of the Morrison is believed to be marked by a persistent sandstone member 10 to 15 feet thick, in which bone fragments are found. Above this member the beds are distinctly arenaceous, and they are mapped as Kootenai on account both of their lithology and of the occurrence of Lower Cretaceous plants a short distance from their base.

Fossils.—Although fossils are fairly abundant in the Morrison formation, they are unsatisfactory in that, as a rule, they are not determinative. Dinosaur bones have been found at several horizons either in the sandstone members or in the argillaceous limestones, but they are generally very fragmentary. From a collection made on the bluff east of the Big Springs above Lewistown, C. W. Gilmore identified one bone as the proximal end of a tibia of a Jurassic sauropod dinosaur. Unios are abundant in the upper shale members of the formation, but according to Stanton they represent new and undescribed species. The question of the age of the Morrison has been a cause for considerable controversy, and the formation has been assigned to both Jurassic and Cretaceous. Such evidence as has been furnished by vertebrate fauna in the Great Falls and Lewistown fields, however, seems to be in favor of the assignment of the Morrison to the Jurassic, and it is so considered in this report, although the question is one upon which the last word has probably not yet been said.

CRETACEOUS SYSTEM.

LOWER CRETACEOUS.

KOOTENAI FORMATION.

General statement.—The coal of the Lewistown field is of Lower Cretaceous age and occurs in the Kootenai formation. The history of the identification of the formation in the Great Falls field to the west and its correlation with certain sediments in Canada is set forth in a paper by C. A. Fisher,[a] and since the Great Falls and the Lewistown fields comprise practically a single geologic unit so far as the Kootenai is concerned, the following extract from Fisher's discussion has a direct application to the area to which this report relates, and is therefore quoted:

> The name Kootenai, after a tribe of Indians who hunted in the southern Canadian Rockies, was first proposed in 1885 by Dr. George M. Dawson, to apply to beds consisting of sandstones, shales, and shaly sandstones in which there are occasional layers of conglomerate, also a zone of workable coal beds. The area originally described was located along the Rocky Mountain front range in Alberta, between the forty-ninth parallel and Medicine Bow River, including an area about 140 miles long and 40 miles wide. Plants collected from this locality were reported on by Sir William Dawson, who gave 22 forms, including new species in four different genera. In the first publication in which the formation receives its name, and where a list of fossils from the beds is given, the following statements concerning the age of the beds are

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[a] Southern extension of the Kootenai and Montana coal-bearing formations in northern Montana: Econ. Geology, vol. 3, 1908, pp. 78-80.

made by Sir William Dawson: "The Kootenai series should probably be placed at the base of the table as a representative of the Urgonian or Neocomian, or at the very least should be held as not newer than the Shasta group of the United States geologists and the lower sandstones and shales of the Queen Charlotte Islands. It would seem to correspond in the character of its fossil plants with the oldest Cretaceous floras recognized in Europe and Asia, and with that of the Kome formation in Greenland, as described by Heer."

In 1887, two years after the formation was described by Sir William Dawson in the Canadian regions, Dr. J. S. Newberry found fossil plants in the coal-bearing rocks of the Great Falls region, which enabled him to make the definite statement that these rocks are of the same age as those north of the international boundary line, described by Dr. George M. Dawson, and designated the Kootenai series. Following this first discovery by Doctor Newberry, additional fossil-plant collections were made from the coal-bearing rocks of the Great Falls region by Messrs. Peale, Knowlton, Weed, Ward, and others, which materially increased the number of species from this locality. Prior to the investigation of this region by Weed,[a] no attempt had been made to give a stratigraphic limit to the beds of Kootenai age in this locality, the chief interest being centered on the descriptions of the flora and the correlation of the rocks in which it was found with other localities, although fossil plants had been collected from more than one geologic horizon. In Weed's report, about 300 feet of beds, constituting what he called the Cascade formation, were regarded as of Kootenai, or Lower Cretaceous, age. During the field season of 1906 large collections of fossil plants were made by the writer at various horizons, which demonstrated that the Kootenai rocks of the Great Falls region are not only thicker than previously supposed, but that they probably constitute all the sediments between the Morrison formation and Colorado shale in the vicinity of Great Falls, and that the Dakota, or lowest member of the Upper Cretaceous, is probably absent from this district.

In 1907 stratigraphic study was continued to the east by the writer, and the succession was observed to be similar to that in the Great Falls field, as in that field the evidence seemed to warrant the conclusion that the Kootenai comprised beds from 60 to 90 feet below the coal up to the Colorado formation, and that the shale of the latter therefore constitutes the lowest member of the Upper Cretaceous. The geologic mapping in the Lewistown field thus differs from that of Weed and Pirsson in the vicinity of the Judith Mountains in that the Morrison formation is differentiated and the Kootenai includes beds formerly assigned to the Dakota.

Character and thickness.—The Kootenai formation in the Lewistown field consists of red or maroon colored clayey shale and heavy bedded light-colored sandstone members. Limestone, usually in concretionary form, but occasionally in thin beds, also occurs. In general character the formation is fairly constant throughout the field, but locally the beds are extremely variable. Sandstone members of considerable thickness may disappear horizontally within a few feet, so that a section made in one locality may differ markedly from one a short distance away. The most persistent member of the formation is a sandstone which overlies the coal and which is from 60 to 90 feet above what is considered the top of the Jurassic.

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[a] Weed, W. H., Geol. Atlas U. S., Fort Benton folio (No. 55), U. S. Geol. Survey, 1899.

This sandstone where exposed is usually covered by pines, and so constant is the association of timber with this member that it serves as a valuable guide in prospecting for coal. Even where vegetation is lacking elsewhere in the vicinity the sandstone itself is usually tree covered. Plate III, *C*, from a photograph of a strike ridge on the north flank of South Moccasin Mountains, illustrates this feature.

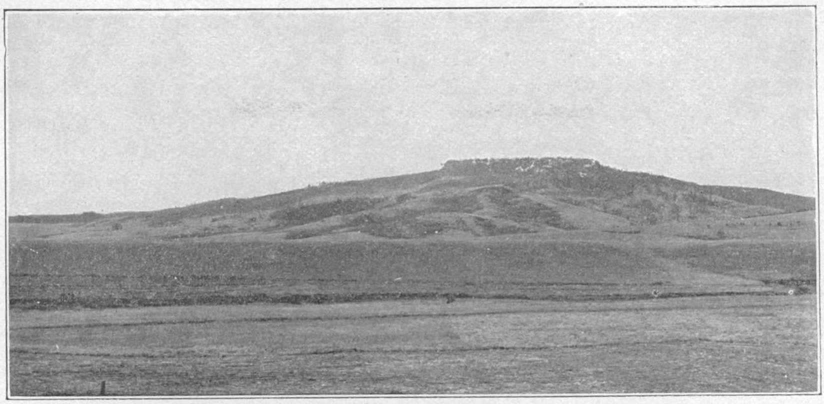
As a whole the physical character of the Kootenai formation changes somewhat in passing from west to east across the field. The sandstones become more calcareous, more or less pure limestones appear, and limey concretions occur more abundantly in the maroon shale. The shale changes from markedly arenaceous to distinctly argillaceous, and in the vicinity of the Judith Mountains might be termed clay shale. Two sections showing the sequence and character of beds in the Kootenai formation are given below:

Section of Kootenai formation at head of Muddy Creek, 7 miles west of Garneill, Mont.

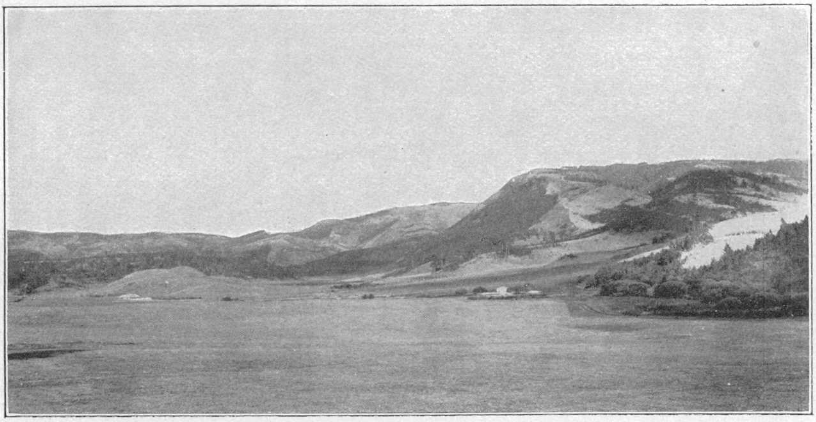
	Feet.
Colorado shale.	
Shale, maroon, sandy, with an occasional thin sandstone layer	200
Sandstone, gray, weathering tan, coarse grained	8
Shale, maroon, sandy	60
Sandstone, gray, coarse grained, weathering irregularly and containing woody fragments	25
Shale, maroon, sandy	72
Sandstone, gray, massive, pebbly	50
Partly concealed; sandstone members in upper part	42
Shale, grayish brown, compact	6
Coal and carbonaceous shale	3
Concealed, probably greenish, sandy shale	87
Morrison formation.	
	553

Section of Kootenai formation on east slope of South Moccasin Mountains, Montana.

	Feet.
Colorado shale.	
Partly concealed; red soil	50
Sandstone, light colored, coarse grained, conglomeratic	10
Shale, maroon, argillaceous	16
Sandstone, white, soft, cross bedded	12
Concealed	10
Sandstone	3
Shale, maroon, argillaceous	6
Sandstone	2
Shale, maroon, argillaceous	30
Sandstone, light colored, medium grained, cross bedded	18
Shale, maroon, argillaceous	20
Sandstone, light colored; lower 3 feet contains small clay balls	15
Shale, maroon, argillaceous	26
Sandstone, thinly bedded	10
Shale, maroon, containing yellowish clay concretions	15
Sandstone, light gray, fine grained, massive, calcareous at top	6
Shale, maroon, with several calcareous members containing clay pebbles	23



A. FLAT MOUNTAIN FROM THE NORTHEAST.



B. KELLY HILL FROM THE WEST.

Showing fault scarp of Madison limestone.

C. SQUARE BUTTE AND STRIKE RIDGE OF KOOTENAI SANDSTONE ON NORTH FLANK OF SOUTH MOCCASIN MOUNTAINS.

	Feet.
Sandstone, white, soft, medium grained	3
Shale, maroon and light colored, sandy	6
Sandstone, coarse grained to pebbly; pebbles chiefly feldspathic with a few dark limestone up to 1 inch	1
Shale, gray, sandy	4
Sandstone, gray, coarse grained to pebbly, cross bedded	60
Shale, dark, carbonaceous, with thin coal beds	10
Concealed	80
Shale, dark gray	1
Sandstone, iron stained, calcareous	1
Limestone, argillaceous to sandy, without bedding, and weathering into concretionary forms	2
Shale, light gray, sandy, upper 2 feet dark bluish	8
Morrison formation.	
	448

The detailed section may be considered as the type of the Kootenai in the Lewistown field. It may be noted from this section that the coal of the formation is in close association with the heavy sandstone member of which mention has been made. This sandstone is coarse grained to pebbly in the western part of the field, but to the east is finer textured. Its characteristic color is light gray when fresh, weathering gray or buff in the western area, and buff or pinkish to the east. Cross bedding is a persistent feature.

With the exception of the above sandstone member the Kootenai is a rather easily eroded formation, and as a result it has a subdued topographic expression. Where inclined at a considerable angle the sandstone member usually forms a prominent strike ridge, along whose steep face the coal of the formation outcrops. Where the angle of dip is slight the sandstone may appear at the surface over a considerable area. A notable example is north of Rock Creek in the north-central portion of T. 13 N., R. 17 E., where the sandstone forms the surface for several square miles, and where in consequence the coal is at only a slight depth. Similar conditions prevail for a mile or so to the north of McDonald Creek in the eastern part of the field. The presence of this sandstone member is fortunate, since it has saved from erosion a considerable area of coal in the above and similar localities.

Distribution.—The Kootenai is one of the most widely distributed formations in the Lewistown field, and the clayey shales with their brilliant coloring are a conspicuous feature over much of the field. In the northwestern part of the field only the top of the Kootenai is shown in a small area in the Sage Creek valley. Farther to the south the outcrop of the formation enters the field as a band several miles in width and trending nearly due south to the base of the Little Belt Range, where it turns sharply to the east. Mapping in T. 12 N., R. 13 E., did not include all of the Kootenai, as the formation extends a short distance west of Antelope Creek. In T. 12 N., R. 14 E., a low anticline causes the Kootenai outcrop to widen considerably, though in the southeastern part of the township overlying beds extend to the very base of the mountains. To the east the outcrop widens again, and northeast of the eastern end of the Little Belt Mountains the red shale covers a considerable area. South of this range the formation is highly inclined and the Kootenai outcrop is a narrow band.

The Kootenai outcrop does not extend across Judith Gap, but the red shale is again prominent around the west end of the Big Snowy Mountains. In this vicinity the outcrop is about a mile wide, but as it swings to the northeast the breadth of the outcrop gradually increases, due to decrease in the angle of dip, until in the vicinity of Lewistown the outcrop is about 5 miles wide. East of Lewistown the shale is at the surface over a large area, although older formations exposed in minor uplifts or local surficial deposits occupy portions of the district. The Kootenai outcrop continues eastward as far as the survey extended on the north side of Middle Fork of McDonald Creek. So far as the writer is aware no Cretaceous formations occur between the Big Snowy uplift and McDonald Creek.

Around the southern half of the Judith Mountains the Kootenai is exposed with narrow and fairly regular outcrop. West of the dome in T. 17 N., R. 19 E., complex structure causes the outcrop to be much more irregular. Around South Moccasin Mountains the red shale is again exposed, and minor domes to the north also bring them up.

The outcrop of the Kootenai is fully shown on the accompanying geologic map. As the coal of the formation is not far above the base, the formation boundary between Kootenai and Morrison in much of the field is nearly coincident with the coal outcrop. The line of contact with the overlying Colorado shale, as shown on the map, corresponds roughly with the 500-foot structural contour of the coal horizon; in other words, the contact occurs where the coal horizon is about 500 feet below the surface.

Stratigraphic relations.—So far as can be ascertained the Kootenai formation rests conformably upon Morrison formation, and the strata apparently represent an unbroken period of sedimentation from Jurassic into Lower Cretaceous time. At the upper limit of the formation relations are not so certain, however, although the Kootenai is overlain with apparent conformity by Colorado shale. As the Dakota is believed not to be present, however, it follows that betwen the Kootenai and the Colorado is a hiatus which elsewhere is represented by several hundred feet of beds.

Fossils.—Plant remains, usually found in close association with the coal, are the most abundant fossils found in the Kootenai, although bones and fresh-water invertebrates also occur. The formation did not prove to be very prolific in fossils in the Lewistown field, thus differing from the Great Falls area, where plants could usually be found wherever the carbonaceous shale members are exposed. Plant collections made in the Kootenai of the Lewistown field were small and included only one species, identified by F. H. Knowlton as *Zamites articus* Göpp. Weed cites several additional forms from the coal horizon near Giltedge. There can be no doubt, however, regarding the correlation of the Kootenai in the Lewistown field with that of the Great Falls field, where fossil evidence was abundant and determinative, as the tracing of the outcrop was continuous from the latter district, except for the short distance across Judith Gap, where the formation passes beneath rock of Upper Cretaceous age.

DAKOTA FORMATION.

In view of the possibility that the Dakota formation might be represented in the Lewistown field careful search was made for evidence which would have a bearing on the question. All evidence was negative, however; hence the Dakota has not been represented on the geologic map (Pl. I).

UPPER CRETACEOUS.

COLORADO SHALE.

General statement.—The Colorado shale includes the rocks from the top of the Kootenai formation, as previously described, to beds of Montana age. In the region to the southeast and considerably removed from the Lewistown field the Colorado group comprises two formations—the Benton, which is essentially shale, and the Niobrara, which is largely limestone. In the central Montana region, however, no limestone is present, but fossils which possess a Niobrara facies have been found[a] near the top of the shale. Since the Niobrara may possibly be represented in the Lewistown field the term "Benton shale" is not appropriate and the term "Colorado shale" is used in referring to the beds in question, as has been done in previous publications.

Character and thickness.—As indicated by the name, the Colorado is principally shale, although in places sandstone occurs. The shale is of somber color, dark gray and black predominating. In the western part of the field, north of Utica, the basal member of the formation is a coarse-grained, brownish-gray sandstone, 50 feet or more thick, but eastward the sandstone is more shaly. Where the latter characteristic prevails the sandstone is uniformly fine grained, finely laminated, and so persistently brownish in color that the term "rusty beds" is very applicable.

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[a] Stanton, T. W., Hatcher, J. B., and Knowlton, F. H., Geology and paleontology of the Judith River beds: Bull. U. S. Geol. Survey No. 257, 1905, p. 11.

Few opportunities were presented for obtaining complete sections of the Colorado shale, for wherever the beds are inclined at a slight angle the dip can usually be only approximated. On the south slope of Big Snowy Mountains, however, east of Garneill, the shale dips steeply, and the thickness, sequence, and character of the beds could be ascertained. A section of the Colorado shale at this locality is given below:

Section of Colorado shale near head of Muddy Creek, 9 miles east of Garneill.

	Feet.
Eagle sandstone.	
1. Shale, drab to black	720
2. Sandstone, greenish, weathering brown, hard, ferruginous, fine grained	3
3. Shale, drab, with a hard bed 420 feet from base	675
4. Sandstone, grayish brown, thinly bedded, containing an abundance of fish scales	47
5. Shale, drab to black, containing occasional thin sandstone members and a thin shaly sandstone at top	890
6. Sandstone, brownish, finely laminated, alternating with thin shaly layers	25
Kootenai formation.	
	2,360

In the northern part of the field between the Judith and Moccasin mountains the entire thickness of the Colorado shale is present, and a section in this district, compiled from measurements made in two localities, is given below:

Section of Colorado shale in northern part of Lewistown field.

	Feet.
Eagle sandstone.	
1. Shale, dark gray to black	625
2. Sandstone, grayish brown, thinly bedded, containing abundant fish scales	22
3. Shale, drab to black	288
4. Sandstone, coarse grained, grayish brown	8
5. Shale, dark gray to black	470
6. Sandstone and intercalated shale; the sandstone is fine grained and laminated; both shale and sandstone weather rusty brown	100
Kootenai formation.	
	1,513

The beds below No. 1 of the above section were measured along the Lewistown-Denton stage road, east of South Moccasin Mountains, and bed 1 was measured in Deer Creek laccolith. At the latter locality a complete section of the Colorado was not obtainable, as the beds below No. 1 are much disturbed by faulting.

A comparison of the foregoing sections shows a considerable thickening of the Colorado southward, although the general character of the formation remains fairly constant. This change in thickness apparently affects only beds above No. 2 of the Deer Creek section and above No. 4 of the section measured east of Garneill.

Since the Colorado shale contains few resistant members it is essentially a formation of the plains, and is apt to be eroded for a considerable distance from the mountains wherever the strata are not steeply inclined. The basal sandstone member and bed 4 of the Meadow Creek section give rise to pronounced strike ridges where the dip is moderate, but as a rule the formation presents monotonous topography. From its stratigraphic position and the characteristic abundance of fish scales bed 4 may be considered as the representative of the Mowry sandstone of the Wyoming section.

The local occurrence of black fissile shale in the Colorado has led to prospecting for coal in localities where it is exposed. There is no likelihood, however, that coal will be found anywhere within the Lewistown field except in association with the gray, cross-bedded sandstone of the Kootenai, and prospecting elsewhere is not likely to lead to favorable results.

Distribution.—The Colorado shale outcrops over a considerable area of the Lewistown field. The gravel, which covers the greater part of the western district, rests upon Colorado shale, so that the extent of the formation is not evident from the first glance at the geologic map, as it is usually only where erosion has removed the surficial material that the dark shale appears. Outside the area covered by gravel, however, there is still a considerable aggregate territory where the Colorado outcrops. In addition to the western area the Colorado shale occupies much of the surface between the Judith and Moccasin mountains, and also to the east of the former. The outcrop of the formation is shown on the geologic map.

Stratigraphic relations.—As stated previously in the discussion of the Kootenai formation, there is only a slight suggestion of an unconformity at the base of the Colorado. At the top of the Colorado the shale is overlain with apparent conformity by the arenaceous shale and sandstone of the Eagle. Both lower and upper limits of the Colorado are based on lithologic grounds, the transition from the Lower Cretaceous being marked by the change from red argillaceous shale to finely laminated sandstone or arenaceous shale. The upper limit is more marked lithologically, as there is a rather abrupt change from dark shaly beds to the massive, light-colored, rather loosely consolidated sandstone or sandy shale of the Eagle.

Fossils.—The stratigraphy of the Colorado shale in the general region of central Montana has been studied in considerable detail by previous workers, as the type locality of the Benton shale is but a comparatively short distance to the northwest of this field. No special search for fossils in the Colorado was made in the Lewistown district. The dark shale just above the "rusty beds" yields *Inoceramus* sp., and numerous *Lingula* sp. were noted in the sandstones near the middle of the formation. Doubtless more careful search would have revealed other forms.

MONTANA GROUP.

GENERAL STATEMENT.

Investigations by Stanton and Hatcher[a] have determined the stratigraphic limits of the formations which comprise the Montana group in northern Montana. The lowermost of these formations is the Eagle, with Claggett, Judith River, and Bearpaw in ascending order. Of these formations only the first two are recognized in the Lewistown field, although there is a possibility that higher beds may be present.

EAGLE SANDSTONE.

Character and thickness.—The Eagle sandstone, named by Weed from the type locality near the mouth of Eagle Creek, immediately overlies the dark Colorado shale. White or yellow sandstones make up the mass of the formation in the Lewistown field, and where shale occurs it is sandy. Within the field the Eagle is not a conspicuous formation, although in its type locality it forms bold cliffs. This lack of topographic expression is due to several factors. In the southern part of the field, where the Eagle occurs, the beds dip steeply and are covered by surficial material. In the extreme northern part of the area, where the Eagle also occurs, like conditions hold; and in certain other localities only the basal member. which is a soft inconspicuous sandstone, is present.

The sandstones of the formation are in some places loosely consolidated, and in other places are more compact, coarsely cross bedded, and frequently contain ironstone concretions and thin lignitic beds, but no workable coals were observed in the area studied, although the formation is coal bearing in certain localities outside of this field. Exposures of the Eagle sandstone are not common in the Lewistown field, and the only complete section obtained was measured on the south flank of the Big Snowy Mountains, east of Garneill, outside of the area mapped. It is introduced here mainly to show the succession of the beds for this general region.

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[a] Stanton, T. W., Hatcher, J. B., and Knowlton, F. H., Geology and paleontology of the Judith River beds: Bull. U. S. Geol. Survey No. 257, 1905.

Section of Eagle sandstone on south flank of Big Snowy Mountains, 9 miles east of Garneill.

	Feet.
1. Shale, dark blue, containing fragments of carbonized wood	5
2. Sandstone, soft, yellowish, cross bedded, containing iron concretions and carbonized wood	53
3. Sandstone, soft, white, containing layers weathering to pisolitic forms	170
4. Shale, yellowish, sandy	70
5. Sandstone, soft, white, with carbonaceous shale layer at top; a few leaf impressions were found	10
Colorado shale.	
	308

A partial section of the Eagle was measured in Deer Creek dome, and is as follows:

Section of Eagle sandstone in Deer Creek dome.

	Feet.
1. Sandstone, white, soft, coarse grained, containing carbonized wood fragments at top	61
2. Partly concealed, but where exposed is a yellow, sandy shale	125
	186

Distribution.—Eagle sandstone outcrops in the southern portion of the area in the vicinity of Judith Gap, and in the district between the Judith and Moccasin mountains. It also occupies a few square miles of surface to the east of the Judith Mountains, and there are two small isolated areas south of Warm Spring Creek, one north of the western extension of the Judith Mountains and the other north of South Moccasin Mountains.

The presence of the Eagle sandstone or other rocks of Montana age was not recognized by Weed and Pirsson in their geologic report on the Judith Mountains and vicinity. That the formation is present in that district, as shown on the accompanying map (Pl. I), is scarcely to be doubted. Direct fossil evidence is lacking, the beds in question having yielded only *Baculites* sp. and *Pecten* sp., which are insufficient to differentiate them paleontologically from the underlying Colorado shale. It is unlikely, however, that the beds given under the Deer Creek section are a part of the Colorado shale, which is elsewhere characteristically dark in color. In addition similar sandstones are overlain in the Judith Gap area by greenish shales and brownish sandstones, from which typical Montana fossils, both plants and invertebrates, were obtained. The same succession of beds occurs in the Judith Mountains district, so that no hesitancy was felt in mapping certain beds in that district as Eagle, even in the absence of direct fossil evidence. In the district no attempt was made to differentiate the Eagle and the overlying Claggett in mapping, and the formations are therefore shown in one color on the geologic map.

CLAGGETT FORMATION.

General character.—Overlying the Eagle sandstone is a succession of sandstones and shales, which are believed to be the equivalent of the Claggett formation as described by Stanton and Hatcher.[a] Where exposed east of Garneill this formation contains near its base about 100 feet of dark drab or greenish shale in which are concretions containing *Baculites ovatus* Say. Above are sandstones which resemble the massive members of the Eagle. Leaves were obtained from the sandstones, but they were too poorly preserved for positive identification. The upper part of the formation consists of yellowish-green shale or chocolate-colored sandstone. A section of this part of the Claggett is as follows:

Section of part of Claggett formation near south line of sec. 13, T. 11 N., R. 16 E.

	Feet.
Gravel.	
1. Shale, greenish, and white sandstone, the shale predominating; a leaf-bearing horizon occurs 10 feet from base	21
2. Shale, dull green and greenish yellow, with occasional chocolate-colored sandstones	66
3. Shale, dull green and yellow, with a thin, soft, platy, leaf-bearing sandstone at top	21
4. Shale, sandy, yellowish green	5
5. Sandstone, soft, light gray	16
6. Partly concealed; dull greenish soil	70
	199

In the vicinity of Judith Gap the thickness of the Claggett is considerable, but could not be ascertained, for the formation is so covered by surface wash or terrace material that the amount of dip is very uncertain. Stanton and Hatcher have assigned to the formation a thickness of 370 to 470 feet in the vicinity of Cow Creek, north of the Lewistown field, but it is probable that it is much thicker in the vicinity of Judith Gap. In the northern part of the field also, where the Claggett occurs, no measurement of its thickness could be obtained.

The Claggett is essentially a soft formation, and in consequence its topography is rather expressionless. In only one locality in the field, namely, in the northeastern part of T. 11 N., R. 16 E., are even the lower sandstones prominent.

Distribution and stratigraphic relations.—The description of the areal distribution of the Eagle sandstone is nearly applicable to the Claggett formation. The Claggett shales and sandstones are exposed in a considerable area in the southern part of the field and in the district between the Judith and North Moccasin mountains. They lie conformably upon the Eagle sandstone and presumably are the latest rocks of Cretaceous age represented in the Lewistown field.

[a] Op. cit.

Fossils.—Although leaves were found at several horizons in the Claggett, all were in a poor state of preservation and could not be identified. Invertebrate forms were found in sandstone exposed in a railroad cut south of Garneill, and include the following, as identified by T. W. Stanton: *Ostrea subtrigonalis* E. and S., *Modiola* sp., *Corbula subtrigonalis* M. and H., *Melania?* sp.

These fossils are known to occur elsewhere in the Claggett as well as in the overlying Judith River formation.

QUATERNARY SYSTEM.

HOT-SPRING DEPOSITS.

General statement.—In certain parts of the Lewistown field there occurs at the surface a flat-lying, white, locally massive limestone, which represents remnants of formerly extensive hot-spring deposits. From a distance this limestone might be mistaken for the upper massive member of the Madison formation, and in fact this resemblance has caused the deposit to be correlated in a previous report [a] with the limestone of the Carboniferous. That it is not Madison, however, is plainly evident, both from the structural relations of the deposit to the underlying beds and from its lithologic character.

Detailed character.—The travertine presents a somewhat variable lithologic character, locally resembling a massively bedded limestone, and in other places having the banded, vesicular, or stalactitic appearance so common to deposits originating from hot springs. Where fully exposed to the weather it tends to break down into bowlders of roughly rounded form with a deeply pitted surface. In certain localities the travertine is highly vesicular, or contains pipes from one-fourth to one-half inch in diameter, which F. H. Knowlton states are probably casts of *Typha,* or common cat-tail. Small cavities which have been partly filled with stalactitic material are of common occurrence. Locally the deposit is finely banded. The accompanying photographs (Pl. IV) show this variable megascopic appearance of the spring deposit.

Microscopically the travertine appears to be almost entirely calcite, much of which is secondary filling in veins or cavities. Where the rock is banded a thin section shows that the veins are subparallel, with oolitic calcite grains between. Several sections show the presence of small quartz grains, but they are not of frequent occurrence.

Distribution.—The travertine occurs chiefly in the vicinity of the Moccasin and Judith mountains and along McDonald Creek divide. Castle Butte, a marked topographic feature about 7 miles south of Lewistown, is also a remnant of the spring deposit. The largest area

[a] Weed, W. H., and Pirsson, L. V., Geology and mineral resources of Judith Mountains of Montana: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, p. 501.

of the travertine, including about 6 square miles, lies between Warm Spring Creek and North Moccasin Mountains. Here, as elsewhere in the field, the travertine is flat lying and rests unconformably on older rocks. The surface is gently undulating, and except near the edges, where it breaks down into cliffs, supports in places a growth of small pines, with open, parklike spaces between. Because of this general appearance the travertine area is locally termed The Park, a name which is also applied to the capping of Flat Mountain. The thickness of the spring deposit is considerable in this locality, reaching a maximum of about 250 feet.

In the vicinity of South Moccasin Mountains there are two small buttes, which are erosion remnants capped by travertine. The northern of the two, termed Square Butte, is located near the southeast corner of T. 17 N., R. 17 E. The accompanying illustration (Pl. III, *C*), a view of Square Butte, shows the manner in which the spring deposit lies horizontally on highly inclined Mesozoic strata.

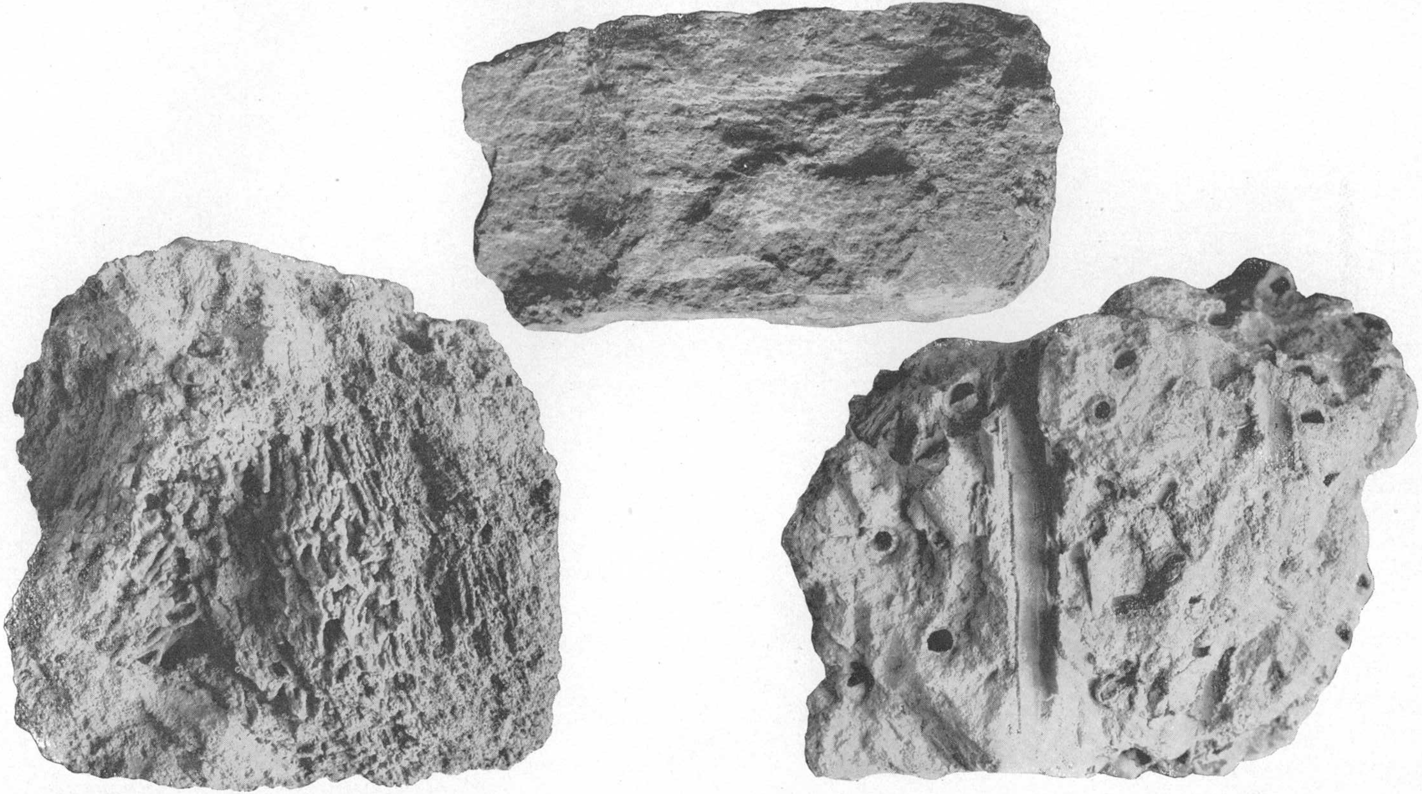
To the south of Judith Mountains are several areas of travertine, whose extent aggregates about the same as The Park. The larger area caps Flat Mountain (see Pl. III, *A*), which might be considered topographically as the southernmost extension of the Judith Mountains. Flat Mountain is largely erosional, however, instead of structural, as has been suggested by Weed and Pirsson,[a] who describe it as follows:

> This is the large flat-topped elevation which is the most southern one shown on the map. From it there runs southward a divide which is much lower and which passes into a group of hills, most inappropriately known as the Little Snowys, foothills of Big Snowy Mountains. Flat Mountain is both topographically and geologically the southern terminus of the Judith Mountains. On top it is somewhat gently undulating with open parklike spaces alternating with groves of small pines and stretches of level limestones. On the outer slopes of the mountains these limestones are very apt to break down into a low cliff, and from the open country to the east, south or to the southeast these long lines of white ledges of the upper Carboniferous are very conspicuous and sharply define the mountains as they rise above the dark pine-covered talus below. * * * Flat Mountain itself is evidently a large single laccolith, or a series of laccoliths, forming one of the combined type whose Paleozoic cover has not yet been broken through.

Field study in the vicinity of Flat Mountain convinced the writer that Weed and Pirsson, probably on account of the hasty nature of their investigation, misinterpreted the structure near the southern end of the Judith Mountains, and consequently did not recognize the true character of the limestone which in the foregoing quotation they assign to the Carboniferous.

From the geologic map it may be noted that Flat Mountain lies between one major and two minor uplifts. On the north side of the mountain the beds dip to the south under the horizontal limestone

[a] Op. cit.



DETAILS OF TRAVERTINE.

cap and normally away from the main uplift of the Judith Mountains. To the east is a small structural dome, from which the Ellis, Morrison, and Kootenai dip westward at a slight angle beneath the travertine cover of Flat Mountain. The mountain is to the north of another dome, and there the beds dip, also at a small angle, northward and under the spring deposit. West of Flat Mountain is Kelly Hill, whose structure is that of a dome broken by a fault, with a sharp synclinal fold between the two uplifts. The structure of Flat Mountain is consequently synclinal, and the travertine is lying horizontally across beds of varying dips. In the center of the travertine area the entire thickness of the Kootenai is probably present, while on the north side of the mountain the spring deposit is in contact with Kootenai, Morrison, and Ellis. The northern slope of Flat Mountain is densely timbered with second-growth pine, but the strike of the massive sandstone overlying the coal may be traced without difficulty, as it curves normally around the southern end of the Judith uplift.

South of Flat Mountain is another area of considerable extent, with smaller outliers, where travertine forms the surface, and concerning this area Weed and Pirsson make the following statement:[a]

> South from here [Flat Mountain] the limestones of the Paleozoic are again seen in a prominent hill, and on the main fork of McDonald Creek, not seen on the map, the Cretaceous is faulted against the Carboniferous, the stream at one point cutting the fault line.

It appears that here again the structure was misconstrued, for, as in Flat Mountain, the travertine, which, as noted in the above quotation, was considered to be Carboniferous limestone, is lying unconformably on beds which, although disturbed by doming, do not appear to be faulted.

The occurrence of the travertine and the misunderstanding of its structural relations with the Kootenai formation have had considerable effect on the development of coal in the vicinity of the spring deposits. Near Flat Mountain it has been believed that the coal bed would be cut off a short distance from the outcrop by what was considered Carboniferous limestone. The relation of the travertine to mining conditions will be discussed more fully later, in the portion of the report relating to economic geology.

Origin.—It seems evident from a field study of the travertine deposits that they are connected genetically with the laccolithic intrusions of the Judith and Moccasin mountains. With the exception of Castle Butte, each travertine area represented in the field is in close proximity either to the main igneous masses of the mountain groups or to the minor structural domes in the vicinity of the McDonald Creek divide. To anticipate certain features which belong properly

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[a] Op. cit., p. 501.

under the general heading of structure rather than stratigraphy, it may be stated that not only are the Judith and Moccasin groups of laccolithic origin, but also the various domes in their vicinity probably owe their structure to similar causes. The most natural inference regarding the source of the heat which caused hot springs to be a feature of the region at one time is that the elevated temperature was due to near-by intrusives, and therefore it may almost be hypothesized that the springs were active during the period of cooling in the Judith and Moccasin igneous masses. Heated waters, probably charged with carbonic acid—a most natural solvent for calcium carbonate—may have passed through the Madison limestone and, finding means of access through fractures developed in the process of doming, deposited the travertine at the surface upon release of pressure and decrease of temperature.

As to the vents by which the mineralized waters escaped, it would appear that here again the domes were a factor. The structural movement which resulted in the formation of these minor uplifts was probably accompanied by more or less fracturing of the strata involved, and along these lines of weakness circulating waters would naturally flow. Near the center of the dome in the southwestern part of T. 15 N., R. 20 E., are two travertine remnants, which may have been the location of vents. They appear as white calcareous masses protruding from the dark shale of the Ellis, but the exact relations of the travertine to the shale could not be ascertained because of talus material thickly scattered about the base. The spring deposit is at approximately the same level as that to the east and west of the structural dome, and because of this it might be inferred that they may not represent vents, but merely parts of the same general deposit. Several factors seem to be inharmonious with this hypothesis, however. The travertine remnants are much more highly siliceous here than elsewhere, as is usually the case with travertine deposit nearest the orifice from which the water flows. In addition there were noted in the mass several small irregular fissures, which have been completely filled by sand and pebbles—a likely occurrence at the time the opening through which the water issued was being closed at the last stage of hot-spring activity. The remnants, too, are in a locality where vents were apt to form—almost at the center of the dome. Taking all things into consideration, therefore, it seems probable that much, if not all, of the travertine which has been deposited in the vicinity of this dome had its source in waters issuing from the locality in question.

There is an alternative hypothesis relative to the source of the waters. The main travertine masses to the south and east of the structural dome are fissured to a considerable extent, and these fissures themselves may possibly have served as vents for the heated waters. The fissures are in places 3 or 4 feet wide, with sides cleanly cut, almost vertical, and in one instance at least seem to penetrate below what was considered to be the thickness of the travertine itself. If such is the case, no other explanation can be offered for the fissure than that it served as a vent for the waters, for had the fissuring occurred subsequent to the deposition of the travertine it is unlikely that it would have extended into the soft underlying rocks, but only the more massive spring deposit itself would have been affected.

The travertine that caps Flat Mountain can scarcely be considered as having the same source as that to the south of the McDonald Creek divide, for the Flat Mountain deposit lies more than 300 feet above the level of the travertine to the south. In the vicinity of Flat Mountain there is no apparent evidence of a vent for the hot waters. This vent was probably in the main Judith mass, and all traces of its location have been removed by erosion.

The travertine deposits in the vicinity of the Moccasin Mountains also present difficulties in regard to the question of the source of the mineralized waters. The large area termed The Park is fissured to a considerable extent, but it is extremely doubtful if these ever served as vents for ascending water. It is likely that in the neighborhood of the Moccasin Mountains, as in Flat Mountain, the vents have been well up on the slopes and all traces of them have been removed by erosion in the long interval which has elapsed since the period of travertine deposition.

Age.—It is believed that the travertine deposits of the Lewistown field are not recent, nor perhaps even as late as Quaternary time. The criteria upon which this conclusion is based are several and will be considered separately. Presuming that the lime-charged waters owed their temperature to igneous intrusions, it might be argued, because of the occurrence of a warm spring between the Moccasin Mountains, that the laccoliths are yet far from cooled and that the spring represents the last phase of general hot-spring activity. If this is true the deposits need not of necessity be placed far back in the geologic time scale. If the spring does represent the last phase of such activity, however, it would seem highly improbable that it should be the only one in the entire district whose temperature is noticeably above the average. Likewise, it would seem strange that not even this spring is depositing lime. In fact, field analysis of its waters shows that they contain no more than the average of carbonates for that region. It might also be argued that the temperature is a result of recent faulting, and the fact that the spring is directly on a fault line gives weight to that assumption. However, numerous other faults, apparently contemporaneous, occur in the region, and since springs near them are not affected as regards temperature, it would seem that some other cause should be sought to account for the exceptional temperature of the water of Warm Spring.

A much more probable theory regarding the elevated temperature of the spring water is that it has come from a considerable depth. The drainage area of Warm Spring Creek is largely a structural basin, the underground waters of which would find an outlet through the syncline between North Moccasin and South Moccasin mountains and find access to the surface on the plane of the fault. The principal water-bearing stratum of this region is the massive sandstone which overlies the coal and which is exposed along the flanks of the Judith and Moccasin mountains on the rim of the structural basin. A mile southeast of the spring this sandstone is buried by practically the entire thickness of the Colorado shale, which, in addition to the 400 feet of Kootenai sediments that comprise the interval between the sandstone in question and the Colorado formation, would fix the depth to the water zone in the above locality at about 1,800 feet. Since the temperature of the spring water is about 70° F., and that of the average spring of the district about 50° F., an increase of 1° for each 90 feet of depth will account for the temperature of the water in question.

That the travertine is not of recent age is shown by the amount of erosion which has taken place since its deposition. The travertine areas are but remnants of their original extent, and they are now from 400 to 700 feet above the main drainages of the field. The view of Square Butte (Pl. III, *C*) gives some idea of the amount of this erosion in the vicinity of the South Moccasin Mountains. What length of time has been necessary to accomplish this erosion can only be conjectured, but it must have been considerable.

For the purpose of age correlation it is unfortunate that the relation between the travertine and the gravel, which occupies much of the surface in the field, could not be ascertained. No gravel was seen on any of the travertine areas, nor on the other hand was the spring deposit noted to lie upon such material. Topographic relations of the two deposits in the vicinity of the South Moccasin Mountains, however, seem to indicate that the travertine is the older, as it occurs at a considerably greater elevation, that of the travertine remnant to the south of the uplift being 4,800 feet above sea level, while the terraces which are adjacent to the mountains on the west and upon which the gravel deposits occur do not rise above 4,500 feet. As these upper terraces are believed to be earlier than late Pleistocene, the travertine must be assigned to an earlier period. All things being taken into consideration, therefore, it appears that, while definite evidence is lacking, the period of hot-spring deposition in the Lewistown field was in early Quaternary time.

TERRACE GRAVEL.

Distribution.—The most conspicuous surficial deposit in the Lewistown field is gravel. It occurs on terraces in much of the area in the western half of the district and is also found in the vicinity of the Moccasin and Judith mountains, extending a considerable distance east of the latter. In the western district the terraces are well preserved, and there are areas of many square miles where streams have not cut through the gravel. Near the base of the mountains only remnants of terraces remain, which occupy the summits of the higher hills.

As a rule the limits of the terraces are not well defined, although the deposits are shown on the geological map with definite boundaries. So gradually does the material covering the terraces thin away from the mountains that the line of delimitation is often exceedingly obscure. There is no doubt that the deposits were formerly much more extensive, and they probably covered much of the entire area, exclusive of the mountain tracts.

Character and source of material.—The material is gravel, sometimes rather loosely consolidated, with sand filling the interstitial spaces, but more often it is united firmly by calcareous cement. The lithology of the pebbles indicates their source. In the western area they are composed almost entirely of limestones and occasionally quartzites, which have no doubt been derived from the Madison and underlying formations, for many of the calcareous pebbles contain Mississippian fossils. Near the Snowy Mountains the gravel is likewise composed chiefly of limestone pebbles, but sandstone pebbles are also present. Farther out on the plains the percentage of sandstone decreases, probably because it is less resistant than limestone. The size of the pebbles also varies inversely with the distance from their source. Near the mountains many of the pebbles are of cobblestone dimensions, but they gradually decrease in size as the distance from the mountains increases. The gravel adjacent to the Judith and Moccasin mountains is composed largely of crystalline pebbles which have been derived from the rocks composing the mountain groups.

In thickness the gravel varies from a mere film to more than 100 feet, the maximum occurring in the vicinity of Moore.

Origin of terraces.—There are various theories current regarding the manner in which the terraces were formed in the Lewistown field and other regions similarly situated with respect to the Rocky Mountain front. The writer is of the opinion that those of the Lewistown area, except possibly certain high remnants in the vicinity of Judith and Moccasin mountains, have been formed by widely meandering streams, and that the various terrace levels represent either differential uplift in the mountain tracts or rather extreme variations in climatic conditions. In fact, both causes may have been in operation simultaneously.

Age.—The question of the age of the terrace in the Lewistown field is one which can not be satisfactorily answered. Such evidence as has a direct bearing on the problem must depend in this instance upon the correlation of similar deposits at a considerable distance from the field. Certain evidence is to be obtained in the field itself, however, and a consideration of the age of the terraces must take into account the following facts:

No apparent evidence of glaciation, either local or continental, is presented in the Lewistown field. The pebbles which occur on the terraces seem to be without striation, so that they are not to be considered as of glacial origin.

The deposits covering the terraces in the western area are composed mainly of limestones derived from the adjacent Little Belt and Big Snowy ranges, and those covering the terraces in the vicinity of the Judith and Moccasin mountains are composed mainly of crystalline rocks and limestones derived from the rocks of the adjacent mountains. The pebbles, therefore, represent strata which were deeply buried at the time of uplift, for a great thickness of Mesozoic and Cretaceous strata was removed before the limestones of the Little Belt and Big Snowy areas and the crystalline rocks of the Judith and Moccasin mountains were exposed to erosion. Previous workers in the Little Belt Mountains state that the last period of uplift took place in Neocene time, and Weed asserts that in the Judith and Moccasin mountains, which are laccolithic in origin, the intrusions probably occurred at some period which was post-Laramie and pre-Miocene. Subsequent to this general uplift a period of peneplanation occurred, and remnants of this peneplain possibly remain in the Lewistown field, preserved by travertine deposits which lie horizontally on tilted beds. How long a period elapsed after the uplift before relative base leveling was accomplished can only be conjectured, so that of the highest terraces it can only be said that they do not antedate Neocene times.

Another factor which should be taken into consideration is the amount of erosion which has taken place between the formation of the highest terrace and that of those now in course of construction in many of the stream valleys. The highest terrace represented in the remnant south of Utica is more than 600 feet above Judith River. Under present climatic conditions and rate of erosion this amount must have required a considerable period, but its extent is too uncertain for age correlation.

More definite information regarding the age of the terraces was obtained in the course of a reconnaissance[a] in 1906, which included the area adjacent to the Lewis Range about 60 miles west of Great Falls. Four terraces are represented in this area, the next to the highest of which is believed, from observations that have extended from the Lewis Range southeastward into the Lewistown field, to be contemporaneous with the upper terrace in the latter area. In the bottom of the valley of Sun River, where it issues from the Lewis Range, and 400 to 500 feet below the oldest terraces, are found terminal moraines of mountain glaciers, which have been shown by Calhoun[b] to be slightly older than moraines of the continental ice sheet; the latter, he asserts, are probably Wisconsin in age. A considerable period must have elapsed, sufficient for the erosion of the Sun River valley, between the formation of the highest terrace and local glaciation, and the extent of this erosion has been so great that Calhoun places the age of the oldest terrace as pre-Pleistocene. If this assumption is correct the older terraces of the Lewistown field antedate the last glacial epoch by a considerable period, and may possibly date back into early Quaternary time.

ALLUVIUM.

No attempt was made in field mapping to include alluvium, although it occurs in many of the stream valleys. Its character varies naturally with that of the rocks from which it is derived. Since the greater number of the streams in the area flow over Colorado shale in much of their courses, the alluvium is usually dark and argillaceous. That originating from the clays and shales of the Kootenai usually possesses the characteristic red color of the Lower Cretaceous in this region.

IGNEOUS AND METAMORPHIC ROCKS.

Within the area mapped geologically, crystalline and altered sedimentary rocks are not of frequent occurrence. In both the Judith and the Moccasin mountains igneous rocks make up much of the mountain mass, but the higher portion of these topographic features were not examined. In the Judith Mountains the igneous rocks have been studied in detail by Weed and Pirsson. As noted by these authors, they are of unusual interest and "comprise granite porphyry, syenite, syenite porphyry, and diorite porphyry in the main masses, with dikes and sheets of phonolite porphyry called tinguaite porphyry."

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[a] Fisher, C. A., Geology and water resources of the Great Falls region: Water-Supply Paper U. S. Geol. Survey No. 221, 1908.

[b] Calhoun, F. C., The Montana lobe of the Keewatin ice sheet: Prof. Paper U. S. Geol. Survey No. 50, 1906.

T. 17 N., R. 19 E., contains several comparatively small bodies of igneous rock. The most prominent of these form two high, nearly conical hills, called Bald Butte and Porphyry Peak. Only a portion of the latter is mapped geologically. They are composed of grayish syenite porphyry, which weathers into sharp angular plates and blocks, very dark in color. The Colorado shale, which extends through the narrow saddle between these hills, appears to be little altered by metamorphism.

South of the buttes and north of Warm Spring Creek a considerable area of igneous rock is exposed. Weed and Pirsson have mapped these as representing sheets and sills, but the writer does not agree in this conclusion, as no sedimentary rocks were noted in this particular locality, and on the accompanying geologic map the entire area is shown as igneous. It is probable that the area in question is a part of the Bald Butte igneous mass. The structural relations of this igneous rock to the sedimentary beds is not clear, but, as suggested by Weed and Pirsson, it is likely that the porphyry has been intruded directly through the strata, without reference to the bedding.

Another occurrence of porphyry was noted in a rudely circular structural dome through which Warm Spring Creek has cut and exposed its structure. The rock is here a considerably altered quartz-bearing, yellowish porphyry, which weathers into small chiplike fragments. As elsewhere in this locality where igneous rocks were noted, there appears to be but little contact metamorphism.

Northeast of the above locality a thin sill of igneous material was noted in Deer Creek dome, which has been intruded into the dark shale of the Ellis formation, and on the east limb of the dome a tongue of syenite porphyry extends to the west for a short distance from the main igneous mass.

Along the southern flank of the Judith Mountains, between Maginnis Peak and Ross Pass, and east of the Pass to the terminus of the mountains, Weed and Pirsson have mapped both Lower Cretaceous and Jurassic, with the latter in contact with igneous rocks. While the investigation made last season (1907) in this particular locality was somewhat hasty and the relation of the sedimentary to the igneous rocks was not studied in detail, the writer is doubtful if rocks older than Upper Cretaceous are exposed south of the intrusives anywhere in the locality in question. An exception to this is in the vicinity of Ross Pass, where local folding has brought up Lower Cretaceous rocks.

In sec. 11, T. 17 N., R. 20 E., there is a small hill, along which the Giltedge-Maginnis road passes, which is composed of acidic porphyry. The intrusion here has been in Colorado shale, which has been but little disturbed.

With the exception of the district contiguous to the northern half of the Judith Mountains, dikes are rarely present. A cut of the Billings and Northern Railroad in sec. 9, T. 15 N., R. 13 E., exposes a dike trending N. 29° E. North of the railroad this dike can be traced only a short distance, but to the southwest it may be followed almost to the west line of the township. A much smaller dike was noted in sec. 7, T. 16 N., R. 13 E., and still another cuts through Colorado shale a few miles east of Utica. None is in a coal area, and consequently all are unimportant in the present consideration.

Of the above occurrences of igneous rocks, that in the Warm Spring Creek dome is the only one which is near an area of workable coal. Even in this locality, however, the character of the coal does not appear to have been affected noticeably by metamorphism, although in openings nearest the igneous mass the coal was noted to be somewhat crushed, probably by structural movement.

STRUCTURE.

GENERAL STATEMENT.

In any coal field the extent, character, accessibility, and consequent conditions for development are more or less related to the structure of the rocks in that particular field. In the Lewistown field this relationship is well illustrated.

It is probable that coal-forming conditions prevailed over the entire field during a certain epoch of Lower Cretaceous time, but it appears that it was only in isolated areas of comparatively limited extent that conditions were sufficiently ideal for the formation of coal of workable thickness, since in much of the field the coal zone is represented by only a few inches of carbonaceous shale. Subsequently the coal was buried by several thousand feet of alternating fresh-water and marine sediments of Lower and Upper Cretaceous age. Then followed a period of mountain building; the Little Belt and Big Snowy anticlines were formed and the intrusions of the Judith and Moccasin groups were forced into sediments of varying age. At possibly the same general period the rocks of the area adjacent to the mountain tracts were folded and faulted locally. Since this period of disturbance there has been a long interval of erosion, and in the mountain areas not only the rocks overlying the coal have been removed but also much of the older rock. This removal has extended in a lesser degree to areas in the plains region along the base of the mountains, especially in the district between the Big Snowy Range and the Judith Mountains. In this latter area, because of the occurrence of minor domes, the structure has favored erosion, and considerable coal has been removed, the extent of which can perhaps be judged better from the geologic map than from description.

MAJOR FEATURES.

As previously suggested, the major structural features of the Lewistown region are the anticlines which form the Little Belt and Big Snowy mountains and the laccoliths of the Judith and Moccasin mountain groups. Detailed study of the geology was not made in any of the mountain tracts, but as their general structure has a bearing on the occurrence and the development of the coal the main features were noted.

Little Belt Mountains.—As indicated on the map, the Little Belt Range extends into the field from the west and ends rather abruptly in T. 11 N., R. 15 E. In this district the range consists of a sharply folded unsymmetrical anticline. Along the northern base the Madison limestone is standing nearly vertical, or even with a dip to the south, while beds stratigraphically above the Madison are likewise sharply upturned and usually exposed as narrow bands whose widths correspond closely with the actual thickness of the formations. The Little Belt anticline, therefore, is slightly overturned to the north, and this structural condition extends almost to the extreme eastern end of the range, where the anticline assumes a normal position. A short distance from the mountains, on the north side at least, the rocks dip to the north only a few degrees. On the south side of the range the strata dip steeply for a little distance from the base of the mountain. As shown on the map, Plate II, the coal outcrop is near the base of the mountain from the eastern end to a point near the western part of T. 12 N., R. 14 E., where a change in amount and direction of dip, together with minor folds, results in the extension of the outcrop along stream valleys a considerable distance into the plain.

Big Snowy Mountains.—Only the extreme west end of the Big Snowy Range is included in the area mapped. The structure of these mountains is similar to that of the Little Belt Range, except that dips are steepest on the south side. To the north the rocks dip at a low angle away from the uplift. In this district erosion has removed Lower Cretaceous rocks from a considerable area, and consequently many of the coal outcrops are miles away from the mountains.

Judith and Moccasin mountains.—The geology of the Judith Mountains has been studied, and that of the Moccasin groups suggested, by Weed and Pirsson, and beyond confirming the broader statements of these geologists regarding the general structure of the mountains, no investigation was undertaken by the writer. Of the Judith Mountains Weed and Pirsson [a] say:

> In general, the mountains may be considered to be laccolithic; that is, they are due to a number of dome-shaped uplifts with laccolithic intrusions of igneous rock. The degradation of the region has exposed numbers of these bodies but has not usually

[a] Weed, W. H., and Pirsson, L. V., Geology and mineral resources of the Judith Mountains of Montana: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, p. 463.

progressed far enough in the large ones to uncover their bases, so that their shapes and thickness can only be inferred. Nor has erosion yet developed the laccoliths that presumably underlie the domed arches which are a common feature of the mountains. It is at once seen that the structure is different from that of most mountain groups or even that of the other island mountains of the plains, but is similar to that of the near-by Moccasins which may be considered a part of this group, and the Sweet Grass Hills near the Canadian border * * *. In the southern half of the mountain group the igneous intrusions appear to be laccolithic in character and the horizon invaded by the larger bodies has been the shale beds of the Cambrian. This is not usually the case in the vicinity of Judith Peak and the mountains east of it. Here the intrusions are much more irregular and break across strata of different ages, though largely intruded in Cretaceous rocks.

Along the base of the Judith and Moccasin mountains dips are usually 30° or more, and Kootenai rocks are exposed in narrow bands. Consequently the coal outcrop in general remains very close to the mountain mass. It is not continuous, however, but is broken here and there by faults or by intrusions. Within the Judith Mountain tract there are, according to Weed and Pirsson, several isolated areas of Kootenai rocks which were forced upward at the time of intrusion. No attempt was made in the present investigation, however, to represent such areas on the geologic map, as they are believed not to be of economic importance.

MINOR FEATURES.

FOLDS.

There is no evidence of structural disturbance in the broad basin west of Lewistown other than the gradual rise of the strata toward the mountains. In the district south of Utica, however (T. 13 N., R. 13 E.), there are gentle folds, and on nearing the Little Belt uplift the rocks are warped to a considerable degree. In sec. 17, T. 12 N., R. 13 E., just outside the area mapped, a sharply folded anticline trends in a general east-west direction, and in secs. 15 and 16 a thrust fault has developed near the crest of the fold. The effect of this stratigraphic break upon the coal outcrop will be noted in the general discussion of faults.

To the east this fault is lost beneath a gravel deposit in sec. 15, and where the underlying rocks are again seen the fault has died out, apparently ending in a sharply folded anticline. This fold broadens eastward, but with steep dips on the north side. Dissection of the anticline by the stream flowing through Saager Canyon has exposed Jurassic rocks, and the coal outcrop is well up on the sides of the valley in the center of the fold. Between the Saager Canyon anticline and the Little Belt Mountains there is a shallow syncline and the coal is covered by several hundred feet of younger rocks. Eastward the anticline pitches gently, and the basal members of the

Colorado shale extend within a short distance of the Little Belt Range.

In the Judith Gap district the major anticlines of the Little Belt and Big Snowy uplifts are connected by a minor fold with curving axis. The line of the Colorado-Montana contact (see geologic map, Pl. I) agrees approximately with the crest of this anticline across Judith Gap. Dips southward on this nearly axial line are steep, varying from 30° to 50°, but on the north side they are much less.

The strata to the north of the Big Snowy Mountains do not appear to be folded to the same degree as those similarly situated with respect to the Little Belt Range, and it is only at a considerable distance from the uplift that folds are developed. A sharply folded anticline trends east-west near the center of T. 13 N., R. 17 E., and is cut just to the north of its axial line by Rock Creek in its westerly course through this township. On the north side of the stream the coal horizon of the Kootenai is near the top of the bluff, while directly across the valley and at the same elevation is the Quadrant formation. Misunderstanding of this structure has led to prospecting for coal on the south side of Rock Creek, and the hope of finding coal has been heightened by the occurrence of a thin bed in the Quadrant not far below the level of the Kootenai coal across the valley. In this connection it may be stated that Lower Cretaceous rocks have been completely removed by erosion in the district between the Big Snowy Mountains and the mines on the north side of Rock Creek, so that prospecting for coal in that area will be unrewarded.

The district between the Rock Spring Creek anticline and the Judith Mountains is one in which there has been more or less folding, and because of such disturbance and the effect of erosion the coal outcrop is very irregular. But little minor folding has taken place adjacent to the Judith and Moccasin mountains except to the south of the former and west of Kelly Hill.

DOMES.

In the vicinity of the Judith and Moccasin mountains, within the territory mapped geologically, there are eleven domes in which rocks older than Lower Cretaceous are exposed, while there are several others which have not as yet been dissected to the same degree. The district of greatest disturbance is to the south of Judith Mountains, and as this is an area of workable coal the structure is of considerable importance to the coal miner. In this district there are six domes, five of which are very similar in size and structure, so that a description of one is applicable to the others. Each dome has been dissected more or less, and two are crossed by streams.

As shown by the geologic map (Pl. I.), four domes in T. 15 N., Rs. 19 and 20 E, have as encircling rims the massive sandstone members of the Kootenai. In one dome, that south of Kelly Hill, the standstones dip at angles varying from 4° or 5° on the eastern side to as high as 50° on the western. Within are the soft shales of the Morrison, in places eroded into a valley, while still nearer the center the more resistant sandstone of the Ellis again forms encircling ridges. The lowest strata present in the uplifts are at the center, where dark shale and limestone of the marine Jurassic are exposed, although still lower beds—black shale and bituminous limestone of the Quadrant—have been exposed by erosion in the dome south of Kelly Hill. The southernmost dome, over which the Lewistown-Forestgrove road passes, is unlike those already described in that it is asymmetrical and is not encircled by Kootenai rocks, and in consequence the coal outcrop swings around the northern and eastern sides of the dome.

T. 17 N., R. 19 E., is also a district where the strata have been much disturbed by doming, three of these minor uplifts occurring in an area of a few square miles. The largest, forming the Warm Spring Creek dome, is cut across by Warm Spring Creek, and its structure is thus exposed. On the north side of the valley there is a high hill with a steep face fronting the stream and extending nearly a mile east and west. At its base are dark shale and limestone of the Ellis, while above is intrusive porphyry. Encircling this porphyry on the north are Jurassic beds dipping northward at a high angle, with overlying formations appearing in succession. It seems, then, that the dome is due to a laccolith, the cover of which is partly striped off.

As a result of the uplift and subsequent erosion coal is exposed in outcrop as a rude ellipse, the major axis of which is followed approximately for a considerable distance by Warm Spring Creek. Coal is mined on the southern limb of the dome, where the attitude of the bed is favorable for working. Elsewhere dips are steep, and in addition the coal is thin and of poor quality.

The cutting across of the dome by Warm Spring Creek is evidence that the stream represents antecedent drainage. Study of the physiographic features in the vicinity reveals the fact that the stream has had a rather complicated history, in which occurred a change in the channel through the dome, due to a landslide on a considerable scale, and a complete change in its course below the dome, due to piracy. It seems evident from field relations that Warm Spring Creek at a former period passed down the valley indicated by the topography west and slightly north of the dome, for the floor of the depression is terraced, and remnants of what appear to be the same terrace occur within the dome.

In Weed and Pirsson's map Carboniferous sediments are shown in the Warm Spring Creek dome. It is believed by the writer, however, that the oldest rocks exposed in this locality are those of the Ellis, as

Jurassic fossils were obtained from what appear to be the lowest beds outcropping in the uplift.

North of the Warm Spring Creek dome, mainly in sec. 20, is a small uplift, about one-half mile across, with encircling rocks of Kootenai and Morrison and with the Ellis exposed at the center. The structure is not evident to the casual observer, and it is only by careful tracing of the beds that their strike is seen to be circular. The coal has been prospected on the northern dip of this dome, where a small drainage has cut across the Kootenai sandstones. Elsewhere the circling outcrop is not easily followed, and the coal has not been opened.

To the northeast of the above-described dome is a considerably larger uplift, to which Weed and Pirsson applied the name Deer Creek laccolith. In the center of this dome a considerable area of Quadrant is exposed. These lowest beds are dark shale, limestone, and brown sandstone, all highly fossiliferous. Outward from the Quadrant are higher beds—Ellis, Morrison, and Kootenai—which dip normally away from the center of the uplift. The regularity of this succession is broken, however, on the east side of the dome, where beds above the Morrison are cut off by a fault and igneous intrusives. Dips are at fairly high angles around this dome, and to the west and north the light-colored sandstones of the Eagle and the greenish shale of the Claggett are soon reached.

In the vicinity of the Moccasin Mountains are several domes, in two of which the coal outcrop is exposed. One is just to the south of the large area of travertine termed The Park, and it is cut by Warm Spring Creek. This uplift is crossed by a fault. The coal outcrops on the north bank of the stream near the fault line, and has been prospected in several places, but without discovering workable coal. The effect of this displacement upon the line of outcrop is shown on Plate II.

Near the center of T. 16 N., R. 17 E., is another dome, regular in outline, with the usual circular strike ridges of Ellis and Kootenai sandstones. A small area of Quadrant shale is exposed near the center of this dome. Big Spring Creek cuts across the southwest limb of the uplift, and at this locality a prospect drift has been driven on the coal outcrop, but, as seems to be the case elsewhere in the area adjacent to the Moccasin Mountains, the coal bed is too thin for working.

Other minor domes occur in the general region described, but with the exception of the Kelly Hill dome, which will be referred to later, they are geologically unimportant and need not be considered in this report. Their location is shown on the geologic map.

As to the origin of these various domes, there is reason to believe that they are connected genetically with the main uplifts of the Judith and Moccasin mountains and represent upheavals due to intrusion of igneous material into sedimentary rock. The Warm Spring Creek dome is clearly so formed, and the others are probably similar except that the horizon of intrusion is lower and the laccoliths have not yet been laid bare by erosion. As in several of the domes Quadrant shale is exposed, it seems probable that the horizon of intrusion has been in almost every case the dark shale and thin limestone of this formation. Below the Quadrant is the massive Madison limestone, which nowhere within the Judith or Moccasin mountains seems to be a horizon at which intrusion has occurred. The most probable conclusion, therefore, is that the intrusions which formed the smaller domes adjacent to the main uplifts were somewhere between the top of the Madison limestone and the base of the Ellis formation.

FAULTS.

General statement.—In the Lewistown field a number of faults were noted which are of considerable linear extent and vertical displacement. Without exception each affects Kootenai rocks, and in consequence the coal outcrop is not continuous across the field. In certain areas, notably in the vicinity of Judith and Moccasin mountains and to the west of the McDonald Creek divide, there are minor faults which affect coal-mining operations. As a rule, these minor breaks can not be detected on the surface, and it is only in underground workings that their nature and extent are revealed. The location of the principal faults in the Lewistown field is shown on both the geologic map (Pl. I), where their effect on geologic lines can be noted, and the coal map (Pl. II), where the relation of the faults to the coal outcrop is brought out. By reference to the latter map it will be noted that no one of the faults is in an area of workable coal, and it can be inferred that the development of the coal has not been materially affected by these stratigraphic displacements. The occurrence of faults in several localities in the field has, however, caused certain mistaken ideas to be accepted regarding the coal, for where repetition of beds resulted from faulting it was believed that a second coal horizon was present stratigraphically below that of the Kootenai. The principal faults noted in the field will therefore be treated briefly, in order that structural relations in the localities where these breaks occur may be better understood.

Antelope Creek fault.—Across secs. 15 and 16 of T. 12 N., R. 13 E., there is a fault which trends N. 83° E., and which, since it cuts across the middle and east forks of Antelope Creek, is termed Antelope Creek fault. Near the north side of sec. 16 the lower sandstones of the Kootenai, dipping north at a moderately high angle, form the valley walls, and upstream lower beds appear in succession until finally, just at the fault line, a considerable thickness of Quadrant is exposed. Here the beds assume a horizontal position, or even have a slight dip to the south, and meet abruptly the shales and sandstones of the Morrison, which here stand almost vertical. The lower members of the Kootenai likewise dip at a high angle to the south. Here, then, as previously stated in the discussion of folds, is a fault which has developed near an anticlinal crest and which is the single representative of the thrust type noted in the Lewistown field. Although Kootenai rocks have been disturbed by faulting, the coal in the vicinity is not workable, and the fault is not of special interest to the coal prospector except to apprise him that the outcrop of the coal zone is offset a considerable distance along the line of break.

Big Spring Creek faults.—Big Spring Creek is flowing for several miles below the springs in a comparatively narrow valley, whose walls are the sandstones of the Ellis; but in crossing sec. 9 above the spring the valley becomes still more narrow, and the stream is cutting through the massive sandstone overlying the coal. This condition continues for about one-half mile to the south, where the stream swings sharply to the southwest. Here the sandstones of the Ellis outcrop on the south side of the valley, while on the north side, and at the same elevation, occur the lower members of the Kootenai. It is evident, then, from this structure that here is a fault block which has been relatively depressed nearly 300 feet. The stream follows for several miles along the line of the southern of the two faults which outline the block, till in sec. 29 the fault line is no longer denoted by the topography, but cuts across the divide and on into T. 14 N., R. 18 E., where, in sec. 25, it unites with the northern fault. At the junction the vertical displacement is slight, and the fault dies out within a short distance.

Unlike the southern fault, the location of the northern can not be determined anywhere within its entire length by topography alone, but careful tracing is necessary. As shown on the map, it practically parallels the southern fault to the west of Big Spring Creek until it nears the range line, where the fault block gradually narrows from its average width of one-half mile, and finally the faults unite. Northeast of Big Spring Creek the fault block ends in a cross fault, which has developed along the crest of an anticline, trending northwest-southeast. This cross fault is about a mile long and has a maximum throw of less than 100 feet, and from it several smaller faults, not shown on the map, branch to the east.

The faults which outline the Big Spring Creek block cause a repetition of the coal outcrop. North of the block the sandstone overlying the coal caps the high hill between Big Spring and Castle creeks, and the coal outcrop can be traced continuously around it.

In the valley to the south the coal outcrops again near the stream bed for several miles. Nowhere in this vicinity is the coal of workable thickness, however. Hence the faults are not, from a mining standpoint, of apparent importance. Indirectly, however, they may have a bearing on coal development in the Lewistown district. The Big Springs, which occur north of the fault block and which constitute the water supply for Lewistown, will furnish an abundance in case washing is undertaken at the present or future coal mines along Big Spring Creek. From a study of the field conditions it appears that the Big Springs owe their origin to the faults above described.

South of the block the strata dip to the northwest, away from the Big Snowy uplift, and underground waters naturally follow this dip. On meeting the fault plane, however, their tendency would be to flow to the northeast along the fault, since the throw is such as to bring the massive Ellis sandstone, the most likely water-bearing stratum in this vicinity, against the more impervious shales in the lower part of the Kootenai. On reaching the cross fault which ends the block the water could readily pass across to the Ellis sandstone again, then follow the dip, which is here westward, and find a vent where the sandstone is cut by the stream valley. The springs probably represent, therefore, the underground water which is stopped by the fault block. Their flow is very constant, amounting to about 140 second-feet, as measured by Robert Follansbee, of the United States Geological Survey.

Northeast of the Big Spring Creek block there is another fault with less extension and throw. It does not appear to extend to the south of Big Spring Creek, and hence it is mapped as a separate and distinct fault. Northeastward it dies out in the dome south of Kelly Hill, and is thus about 3 miles long. The downthrow is on the west side. The coal outcrop is offset more than one-half mile near Big Spring Creek, while around the dome it is offset only a short distance.

Kelly Hill fault.—Kelly Hill is a prominent topographic feature at the south end of the Judith Mountains. In form it suggests what it is structurally—a dome whose northern limb is lacking, thus presenting a bold face in that direction—while the southern slopes, although steep, are not so pronounced. In following the Lewistown-Giltedge road as it passes Boyd Creek valley to the north of the hill it becomes apparent that the stream is flowing for some distance approximately on a line of fault, for to the south and on the right is a cliff of Madison limestone several hundred feet high, against the base of which is the shale and sandstone of the Ellis. (See Pl. III, *B*.) These marine Jurassic beds are horizontal in Boyd Creek valley, but around the south side of Kelly Hill their dip is southward and their strike sweeps in a semicircle. The structure of Kelly Hill, therefore, is that of a dome broken by a fault. Regarding this uplift and break Weed and Pirsson make the following statement:[a]

> From phenomena studied elsewhere in the Judith Mountains it appears most probable that Kelly Hill is due to an intrusion of porphyry in the Cambrian shales, which along the north limb of the dome has lifted the beds with so much force as to rupture them and raise them until the Carboniferous is brought against the Jurassic.

The Kelly Hill fault is unusual in certain respects as compared with the other stratigraphic displacements in the Lewistown field. Although only about 2 miles long, it has a throw sufficient to bring beds well down in the Madison against the upper member of the Ellis. In addition the coal is offset but little by the fault. At the western end of the displacement beds cross Boyd Creek normally a short distance southwest of Kelly Hill. Relations to the east of the uplift are not so apparent because of the dense vegetation between Kelly Hill and Flat Mountain, but that the coal outcrop is broken at this point is doubtful, and it is therefore probably very nearly as represented on the map (Pl. II), bending sharply and swinging normally around and upward across the steep northwest slope of Flat Mountain until it is lost beneath the travertine cap.

Deer Creek fault.—Cutting across the northeast limb of the Deer Creek laccolith is a fault which ends to the southeast in the igneous mass of the Judith uplift and to the northwest is concealed beneath deposits on the terrace west of Deer Creek. The downthrow of this fault is on the east side, and for a considerable distance the dark shale of the Colorado is against red-colored shale of the Kootenai. The maximum throw is about 750 feet. As indicated on the geologic map, a small block has been depressed near the southern end of the main fault.

Warm Spring Creek faults.—Structural relations in the vicinity of the Warm Spring make it evident that the spring issues on a fault line which to the east seems to follow the valley, curving around into Moccasin Creek, and to the west gradually passes to the north of the stream. Just to the southwest of the spring a few feet of sandstone is exposed in the cut bank, which appears to be the sandstone overlying the coal. To the northwest and below the spring the top of the Ellis sandstone is exposed, and in the immediate vicinity of the spring the varicolored shales of the Morrison form the north bank. The downthrow of the fault, therefore, is on the south side and the vertical displacement is the same as the interval between the base of the Morrison and the top of the massive sandstone just above the coal—about 200 feet. One-half mile below the spring a second fault meets that described above. This has a downthrow on the west, extends northeast, and is finally concealed beneath the travertine of

[a] Op. cit., p. 499.

The Park. A short distance before reaching the spring deposit the fault branches, the branch likewise being lost from sight. The throw of the main fault north of Warm Spring Creek is considerably greater than that of the break from which the spring issues.

As a result of the fault and the subsequent erosion of the Warm Spring Creek valley, the coal bed is exposed near the stream in sec. 20 and along the western face of the hill to the north. The coal discovered in several prospects in this locality is thin and of poor quality, so that the faults do not directly concern the coal miner. The spring, whose location is dependent upon the fault and a part of whose very constant flow of about 140 second-feet is utilized by the Barnes-King Gold Mining Company, at Kendall, might later be more fully developed and the resultant power transmitted to the coal-mining district to the southwest.

South Moccasin Mountains faults.—Two faults are connected with the uplift of the South Moccasin Mountains. One cuts across the western limb of an asymmetrical dome near the eastern part of T. 16 N., R. 17 E. The downthrow of this fault is on the west and the maximum amount of displacement is a little greater than that of the Warm Spring Creek fault. A small stream flows along the fault line, and on the west bank coal outcrops a short distance along the face of the bluff, while on the opposite side are the sandstones of the Ellis. The extent of this fault to the north was not determined, but it appears to die out shortly after entering the mountain tract. As indicated on the map, the linear extension of the fault is about 1 mile.

In sec. 3 of the same township and west of the South Moccasin Mountains occurs another fault which offsets the coal outcrop a considerable distance. The downthrow is on the north side of the fault, and the vertical displacement is about 300 feet. Neither of these South Moccasin faults is in an area of workable coal, and hence they are unimportant economically.

ECONOMIC GEOLOGY.

GENERAL STATEMENT.

The mineral resources of the Lewistown field comprise both metallic and nonmetallic. Gold and silver are produced in the Judith and the North Moccasin mountains. Gypsum is mined at present from the Ellis formation in sec. 27, T. 13 N., R. 17 E., and has also been obtained from the marine Jurassic near the head of South Fork of McDonald Creek. A bed 20 feet thick also occurs at the same horizon on East Fork of Big Spring Creek, in the northeastern part of T. 14 N., R. 19 E. The gypsum is white and pure, but has not been developed. Building stone is obtained from the Kootenai sandstone near Lewistown. Clay, which could be utilized for brick, occurs in several localities and in various formations, but none is burned at present. Coal is the principal nonmetallic product of the field, however, and since it is with that product that this report is chiefly concerned, further discussion of other mineral resources will be omitted.

COAL.

GEOLOGIC OCCURRENCE.

All workable coal in the Lewistown field occurs in the Kootenai formation of Lower Cretaceous age. Thin beds are found in two other formations—the Quadrant formation of the Carboniferous system and the Eagle sandstone of the Montana group. These coals, however, are not of economic importance.

As described under "Stratigraphy," the Kootenai comprises a series of sandy shales and thin sandstones up to the coal, above which are heavy sandstone members and red or maroon clay shales. The coal zone of the formation is 60 to 90 feet above the base, and its stratigraphic position is readily determinable, as it occurs beneath and in close association with a coarse-grained, cross-bedded sandstone, which is usually the most prominent sandstone of the entire geologic column.

Study of the coal zone in the Lewistown field emphasizes one important fact which has been noted previously in the Great Falls field. This is that the Kootenai coal is not a continuous workable bed, but occurs in areas of more or less limited extent. Between these productive areas the coal-bearing horizon is represented by a carbonaceous shale zone. Work in the Lewistown field last season (1907), therefore, was conducted with a view to ascertaining as nearly as possible the limits of the more valuable coal in these areas. The more valuable areas of the field are designated Sage Creek, Utica, Buffalo Creek, Rock Creek, Warm Spring Creek, McDonald Creek, and Lewistown districts, because of their respective nearness to those streams or towns.

SAGE CREEK DISTRICT.

As originally described,[a] the Sage Creek district includes the greater part of Tps. 15 and 16 N., R. 12 E., and the western part of Tps. 15 and 16 N., R. 13 E. The latter two townships are within the territory mapped during the present investigation and are consequently considered as a part of the Lewistown field. Coal does not occur at the surface in these townships, and even in the Sage Creek valley, near the town of Windham, the coal bed is nearly 500 feet below the surface, and this depth increases eastward, the dip

[a] Fisher, C. A., The Great Falls coal field, Montana: Bull. U. S. Geol. Survey No. 316, 1907, pp. 161-173.

being in that direction. In sec. 16, T. 16 N., R. 12 E., which has been mapped as a part of the Great Falls field, a shaft has been sunk to the coal, which is at a depth of about 450 feet. It is asserted that the coal bed is about 8 feet thick. Eastward no information is obtainable regarding the coal, so that in that direction the limit of the Sage Creek district is not definitely known.

UTICA DISTRICT.

LOCATION AND EXTENT.

Coal is being mined about 2 miles west of Utica. The outcrop was not followed entirely across T. 14 N., R. 12 E., but from evidence obtained during the investigation of the Great Falls field it would appear that the coal bed of the Sage Creek district is too thin to mine a short distance southeast of the Schultz mine, in sec. 29, T. 15 N., R. 12 E. In consequence, the coal near Utica is regarded as not within the Sage Creek district proper, but as a small isolated district. The more valuable coal is confined to a small area in the immediate vicinity of mine No. 1, shown on the map (Pl. II).

CHARACTER AND THICKNESS.

Exposures in the Utica district show there are three carbonaceous zones in a vertical distance of about 35 feet, but the upper and the lower are not productive. The middle bed occurs in two benches, separated by shale and bony coal. A section measured in the Showan mine gives the following succession:

Section of coal bed in Showan mine.

	Ft.	in.
Shale.		
Coal	1	6
Shale, carbonaceous	1	3
Coal, impure		8
Shale		11
Coal, upper 6 inches bony	2	2
Shale.		
	6	6

A graphic representation of the above section is shown in Plate V. Both benches carry considerable sulphur in the form of lenses and balls of iron pyrites (FeS_2). The coal is soft and slacks quickly on exposure.

DEVELOPMENT.

Showan mine.—Coal was first mined in the Utica district in the eighties, when an entry was driven on the south bank of Heiserman Coulee, in the NE. ¼ sec. 13, T. 14 N., R. 12 E. Coal was mined here desultorily for several years, supplying a small local demand, and later the workings were abandoned. In 1906, H. A. and M. A. Showan reopened the mine, which at the time of investigation was about 100 feet in length. Only a small quantity of coal is produced, the total output amounting to only a few tons yearly, as this coal must compete with near-by mines to the northwest, where the coal is of considerably better quality. It is barely possible that if the entry is extended the coal may become of better grade, owing to increase of cover, but the outlook for future coal development in this vicinity is unfavorable, for it is improbable that coal of good quality or of workable thickness can be obtained.

Prospects.—Several prospects are located on the outcrop southeast of the Showan mine. The three coal zones are here well exposed on the hillside, and each has been prospected, but the coal has proved to be poor and of insufficient thickness. South of Utica, in the Judith River valley, diamond drilling was undertaken by the company now sinking a shaft in the Sage Creek district to the northwest, and although a depth was reached considerably greater than that of the coal zone, it is claimed that no coal was discovered.

BUFFALO CREEK DISTRICT.

LOCATION AND EXTENT.

Southward from Judith River for a considerable distance no workable coal is indicated by the outcrop of the coal zone. A small area near West Buffalo Creek, in T. 12 N., R. 14 E., is the only locality in the southwestern part of the field where workable coal occurs. This area is named the Buffalo Creek district. Its southern limit is defined by the outcrop of the coal zone at the base of the Little Belt Mountains. To the west the more valuable coal does not extend beyond Buffalo Creek, and in fact for a short distance east of the stream the coal is probably thin. It is workable at the Williams mine, in sec. 20, and apparently thins to the north, so that the more valuable part of the workable area probably does not extend beyond West Buffalo Creek in its east-west course. To the east the coal is buried by overlying rocks, and there is no exposure to give a hint of its extent in that direction. The outcrop along the north base of the Little Belt Mountains seems to indicate, however, that the more valuable part of the workable coal does not continue far to the east. The district is believed, therefore, to be rudely circular in form, as indicated on the map (Pl. II).

DEVELOPMENT.

General statement.—Until recently very little coal has been mined in the Buffalo Creek district, a limited amount having been taken from an abandoned mine on West Buffalo Creek. At present two small mines are operating which supply coal to near-by ranchers and villages along the two lines of railroad entering the field. One mine is known as the Williams and the other is spoken of locally as the Gordon mine. It is operated by a company, however, and in this report will be referred to as the Saager Canyon mine.

Williams mine.—This mine was opened in the fall of 1906 on the west side of Saager Canyon in the NE. ¼ NE. ¼ sec. 20, by B. B. Williams. At the time of investigation the entry was in 165 feet. The bed shows 30 inches of coal overlain by hard shale, which is bony at the bottom and which makes a good roof. Sandstone forms the floor. The dip at the mine is slight, but it increases rapidly to the north, and at the mouth of the canyon it is 14°. As a result of this dip the coal zone is buried deeply to the north of West Buffalo Creek.

About 40 feet above the coal bed worked in the Williams mine is another bed of coal 17 inches thick. It has not been worked, but is claimed to be of superior quality.

Saager Canyon mine.—In unsubdivided land, but in what would probably be, if surveyed, the NW. ¼ NW. ¼ sec. 28, a mine was opened a few months prior to the investigation by a company, of which J. F. Lester, J. D. Kipe, E. E. Pearl, and William Gordon are the

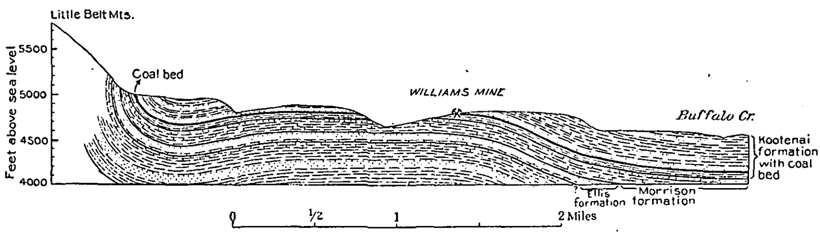


FIGURE 1.—Structure section north from Little Belt Mountains through Williams mine.

members. A drift 85 feet long shows 4 feet of coal without a parting, overlain, as in the Williams mine, by shale and having a floor of sandstone. The entry extends up the rise, as the dip is here about 4° to the south. Mining conditions are favorable, and a considerable amount of coal can be readily removed. Although the analysis of the sample obtained at this mine shows that the coal contains considerable moisture, the mine is dry, and this condition will probably continue as the entry is extended, at least till the crest of the anticline is reached.

There is a strong probability that the coal will be of good quality and thickness in the area between the Saager Canyon mine and the coal outcrop to the south at the base of the Little Belt Range. A syncline parallels the mountain front, but the coal is not at great depth, since apparently not even the entire thickness of the Kootenai is present. The coal is therefore probably less than 400 feet in depth in the locality in question. The cross section, figure 1, is here introduced to illustrate the structure from the Little Belt Range north through Saager Canyon.

ROCK CREEK DISTRICT.

LOCATION AND EXTENT.

Eastward from the Buffalo Creek district the outcrop of the coal zone where exposed indicates that coal is either represented by carbonaceous shale or is below workable thickness. This condition holds around the east end and on the south side of the Little Belt Range, as far as the investigation was carried. Even if coal were present in quantity on the south side of the range, only a small amount would be available, as the rocks are standing practically vertical.

Across Judith Gap the coal-bearing formation is buried beneath Colorado shale, but it is unlikely that workable coal occurs in the vicinity, for where exposed around the west end of the Big Snowy Mountains the Kootenai coal zone comprises little but carbonaceous shale. To the northeast for a considerable distance it appears to be equally barren, but in the vicinity of Rock Creek the coal is thicker and probably of workable proportions. A possible exception occurs on the ranch of William Gordon, in the SW. ¼ SE. ¼ sec. 34, T. 13 N., R. 16 E., where it is claimed that a bed of coal 7 feet or more thick was discovered in a well drilled for artesian water. The bed was encountered at a depth of about 122 feet, and the well record shows the following succession:

Section in well in SW. ¼ SE. ¼ sec. 34, T. 13 N., R. 16 E.

	Feet.
Shale, red	60
Sandstone, soft, yellow	30
Sandstone, hard, gray, ferruginous	30
Clay	2½
Coal	8–9

Small fragments of coal, which burned readily, were obtained from the drill hole. If a bed of coal 7 feet or more thick occurs at this locality it is not evidenced by the outcrop of the coal zone, about one-fourth mile southeast of the well, and while it is the habit of the Kootenai coal to be inconstant in thickness, it would be unusual for the bed to vary to such an extent in the comparatively short distance from the outcrop to the point where the drilling was made. Diamond drilling, which furnishes a more reliable record than the churn drill or shafting, is needed to prove conclusively that there is a bed of workable coal in sec. 34.

In the vicinity of Rock Creek the more valuable workable coal is probably confined to about 4 square miles north of the stream in its east-west course through secs. 15 and 16, T. 13 N., R. 17 E. The southern limit of the area is defined by the coal outcrop on the north bank of the creek. To the west the coal thins, as shown in a prospect near the northwest corner of sec. 16, where it is less than a foot thick. A prospect near the center of sec. 34, T. 14 N., R. 17 E., shows that to the north the coal bed is only 17 inches thick, while no workable coal is found east of the outcrop which extends nearly due north from the Rand mine. (See economic map, Pl. II.) The limits of the most valuable part of the district are therefore fairly well marked.

CHARACTER AND THICKNESS.

The coal bed of the Rock Creek district, as elsewhere in the Lewistown field, occurs just beneath the lower massive, cross-bedded sandstone of the Kootenai formation. Sections in three of the four mines of the district show that the coal is separated from the sandstone by only a few inches of bone. In three of the mines the coal occurs in two benches, which are separated in one locality by shale and in the others by bone.

DEVELOPMENT.

General statement.—Four mines which supply a small local demand from ranchers and the town of Moore are operating in the Rock Creek district. Work during the summer months is confined chiefly to development, and even during the winter the output is small.

Sharp mine.—The mine of Daniel Sharp, opened in 1904, is located in the SE. ¼ NE. ¼ sec. 16, T. 13 N., R. 17 E. An entry has been driven 360 feet N. 7° W., which is nearly on the dip. As in all the mines in the area, the dip is slight, in this particular locality being about 3°. The bed shows 42 inches of coal, a section in the mine being as follows:

Section of coal bed in Sharp mine.

	Ft.	in.
Sandstone.		
Bone		10
Coal		6
Shale		1
Coal	3	
Clay.		
	4	5

The lower 3 inches of the bottom bench is a fair quality of blacksmithing coal and is separated for that purpose in mining. Above it is a very thin clay parting. The 10-inch bone is preferable to the sandstone as a roof, as the latter is creviced. This sandstone member, typically coarse grained and cross bedded, is here about 50 feet thick and is exposed for a considerable distance north of the mine.

Cooper mine.—The B. M. Cooper mine, opened early in 1907, is located in the SW. ¼ NW. ¼ sec. 15, about one-half mile east of Sharp mine. Here the coal is in two distinct benches, the upper 1 foot thick and the lower 2 feet 2 inches thick, separated by 12 inches of bone. The floor is clay, and the roof is bone overlain by sandstone. Much of the coal, especially in the upper bench, is so soft as to be unsalable, due chiefly to weathering, resulting from a lack of sufficient cover. Only 15 to 18 feet of sandstone overlies the coal in this vicinity, and the coal is so soft that no explosives can be used. Surface moisture readily enters the workings, and in consequence the roof is hard to hold.

Rand mine.—Southeast of the Cooper mine are the Rand workings, located in the NW. ¼ SW. ¼ sec. 14. The coal bed outcrops continuously around a flat-topped hill capped by the usual cross-bedded sandstone. The total area of coal in this hill was originally about 15 acres, but the greater part has been mined out. The first opening was made on the north face of the hill, and coal was mined for local use for several years. Later these workings were abandoned, and at the time of investigation an entry was being driven on the south side of the hill. A small fault was encountered a short distance in, which has given some trouble. A section of the bed shows 2 feet 6 inches of soft and dirty coal, with sandstone floor and bone roof.

Knox mine.—A small mine has been opened by Andrew Knox in the SW. ¼ SE. ¼ sec. 3, 2 miles north of the Rand workings. The coal is in two benches, the upper 12 to 18 inches and the lower 10 to 18 inches thick, varying individually, but fairly constant in combined thickness. Between the benches is a bone parting 9 to 15 inches thick. The floor is shale, and the roof is a fine-grained shaly sandstone.

Graphic representations of the coal bed in the mines of the Rock Creek area are shown in Plate V, and the location and approximate extent of workable coal are indicated on the economic map, Plate II.

Prospects south of Rock Creek.—Misunderstanding of geologic conditions in the vicinity of Rock Creek in sections 15 and 16 has lead to considerable prospecting south of the stream, and the occurrence of coal in the Quadrant formation nearly on a level with the Kootenai coal bed on the north side of the creek has been an encouraging factor. While formerly the Kootenai coal probably extended south of the present outcrop along Rock Creek, it has been entirely eroded south of the stream, so that prospecting in the district between the Big Snowy Mountains and the mines will remain unrewarded. The coal which has been discovered in a prospect in section 23 is in the Quadrant formation and about 400 feet stratigraphically below the Kootenai coal, which outcrops to the north of the stream. The coal is only 6 inches thick at the prospect, and in all probability it will not develop into a workable bed.

WARM SPRING CREEK DISTRICT.

LOCATION AND EXTENT.

The only coal of economic importance occuring in the northern part of the Lewistown field is found in the embayment of the Judith Mountains which is drained by Warm Spring Creek. This district is in the southern part of T. 17 N., R. 19 E., and the adjoining portion of the township to the south, the more valuable part of the coal area including in all about 3 square miles. The southern limit of the area is defined by the coal outcrop along the base of the Judith Mountains west of New Year, and the more valuable coal area does not extend north of Warm Spring Creek. To the west the coal-bearing rocks are deeply buried by overlying formations up to and including the basal member of the Eagle sandstone, so that the extent of workable coal in that direction is not definitely known. On the eastern limit of the district the coal along the line of outcrop is thin and of poor quality. A possible extension of the district eastward is suggested by the occurrence of coal along the wagon road near Maiden. The coal here is of poor quality, however, and it was not regarded as a workable bed.

DEVELOPMENT.

General statement.—Only two mines are being worked at present in the Warm Spring Creek district—one, the Mace, on the north side of the coal-producing area, and the other, the Nevin, on the south side, at the base of the Judith Mountains. Several other mines have been opened, but later abandoned.

Nevin mine.—This mine is located in the NW. ¼ SE. ¼ sec. 7, T. 16 N., R. 19 E. It has been opened on the strike, which is here N. 58° E. The entry is 600 feet long, and seven rooms are turned up the rise, which is 48°. A section of the bed shows 2 feet 6 inches of soft, dirty coal, underlain by 3 inches of bone on a gritty clay floor and overlain by bone at least 7 inches thick. Only a small amount of coal has been produced, and this has all been used locally.

Mace mine.—The mine opened by A. Mace in 1902 on the south side of Warm Spring Creek in the SW. ¼ NW. ¼ sec. 32, T. 17 N., R. 19 E., is the chief producer of the district. Three to six men are employed. A greater part of the coal is hauled by wagon to Kendall, a town on the east flank of North Moccasin Mountains. Three slopes have been driven down the dip, which is 3° to 9° to the south. The coal bed is variable, but averages about 4 feet thick. A representative section is given below:

Section of coal bed in Mace mine.

	Ft.	in.
Clay.		
Coal	1	2
Bone		4
Coal	2	5
Coal, impure		5
Sandstone.		
	4	4

The upper bench is a fairly clean coal; the lower 5 inches of the bottom bench contains much sulphur and is not mined. It is claimed that the coal will coke well when the sulphur is removed.

Several pockets of lusterless coal resembling cannel were noted in the mine, the largest being about 200 feet in length. Coal from these lenses ignites readily from a candle.

Abandoned mines.—Prior to the opening of the Mace mine coal was taken from a mine located in the NW. ¼ SE. ¼ sec. 33. An entry was made here about 700 feet, but the coal proved to be of inferior quality and the mine was finally abandoned.

In the late nineties the New Year Mining Company began development of a mineral property about a mile south of New Year. A cyanide plant was erected near the coal outcrop at New Year, and an entry was driven on the strike of the coal bed for 825 feet. The coal was burned under the boilers of the plant, which used about 4 tons per day. The bed is 30 inches thick, underlain by 4 inches of bone, and overlain by shaly clay and sandstone. The coal proved to be of fair quality for steaming purposes, although it burned with a very short flame. It is claimed that the ash of this coal assayed $2 per ton in gold. The mine has been closed for two years, but it is being kept in repair in view of possible resumption of metal mining in the district.

North of the Warm Spring Creek dome a small uplift has brought up coal-bearing rocks, and a mine was opened near the center of the north half of sec. 20. The location is unfavorable, however, as the dip is 24°, and the slope reached water level within 100 feet; in addition, the coal is impure. A section of the bed shows that the coal is in three benches having an aggregate thickness of 2 feet 9 inches, with an upper clay parting 2 inches thick and a lower parting of bone 3 inches thick. Clay forms the roof and the floor.

The various prospects in the northern part of the Warm Spring Creek district, shown on Plate II, indicate that the coal is of inferior quality and below workable thickness north of Warm Spring Creek; hence future development must be confined to the limited area between the Mace mine and the abandoned workings of the New Year Company. This area is structurally synclinal, and midway between the above-mentioned mines the coal is probably 500 to 700 feet below the surface; moreover, the coal will be difficult to obtain because of abundant water.

M'DONALD CREEK DISTRICT.

LOCATION AND EXTENT.

The largest and best-developed coal district in the Lewistown field is to the south of the Judith Mountains, and since much of it is drained by the headwaters of McDonald Creek, near which the greater part of the development has taken place, it is referred to as the McDonald Creek district. This coal-producing part of the field comprises a considerable area in T. 15 N., Rs. 19, 20, and 21 E.; portions of T. 14 N., Rs. 20 and 21 E.; T. 15 N., R. 18 E., and small areas in T. 16 N., Rs. 19 and 20 E.

The limits of the coal-bearing district are indefinite in several directions. On the south, however, the limit is definitely marked by the outcrop of the coal bed along South Fork of McDonald Creek, across the McDonald Creek divide, and along East Fork of Big Spring Creek to the producing area south of Lewistown. Prospects in T. 14 N., Rs. 18 and 19 E., indicate that workable coal does not extend to any considerable distance south of the mines on Big Spring Creek, so that the limit can be closely approximated in that locality. To the west the extent is not known, but judging from the fact that the coal thins to the southwest it is not likely that the bed continues to be especially valuable more than a comparatively short distance west of the Spring Creek mine.

No information regarding the coal could be secured immediately northeast of Lewistown, and the outcrop along the base of the Judith Mountains is the nearest locality in that direction where the thickness and character of the bed could be ascertained. Between these two localities it is possible that workable coal exists. The coal outcrop in this vicinity which continues eastward south of Kelly Hill and north of Flat Mountain is a definite northern limit of the McDonald Creek district.

In regard to the eastern limit no definite information is at hand. East of the group of mines southeast of Giltedge the coal-bearing rocks dip steeply, and the coal is buried within a short distance by a considerable thickness of strata, and even were the bed much thicker than common it is not likely that it could be worked far from the outcrop. A mine located in sec. 35, T. 15 N., R. 20 E., shows a bed 43 inches thick, in two benches, separated by a clay parting 1 inch thick. The upper bench is of very poor quality and is not mined. Regarding the eastern limit of the district north of South Fork of McDonald Creek but little information could be secured, as the coal has not been prospected on the outcrop, and to the north there are no exposures of the bed. The coal bed is 40 inches thick east of Forestgrove, as shown in a prospect in sec. 4, T. 14 N., R. 21 E. It is barely possible that the bed is of workable character in this locality. Hence the area underlain by workable coal may extend to the east beyond the limit of the field as mapped. Near the outcrop the coal has but little cover, and in order to secure a fair quality of coal shafting at a considerable distance back from the outcrop will probably be necessary.

DEVELOPMENT.

General statement.—Seventeen mines are operating in the McDonald Creek district, though the output of most of them is very small during the summer months. With the exception of the Spring Creek mine they supply a very local demand. Most of the mines are near the McDonald Creek divide, where, owing to geologic conditions, there is ready access to the coal bed.

Peiper mine.—The Peiper mine is located in the SW. ¼ NE. ¼ sec, 6, T. 14 N., R. 20 E. A slope has been driven from the outcrop for a distance of 315 feet down the dip, which is about 10°. The bed shows 34 inches of coal, with clay floor and dark shale roof, underlain by about 1 foot of bony coal. A small amount of coal is taken from this mine during the winter.

Black Diamond mine.—The Black Diamond mine is located in the NW. ¼ NW. ¼ sec. 25, T. 15 N., R. 19 E. Several entries have been driven on the coal outcrop in a coulée which is tributary to East Fork of Big Spring Creek. The main entry is in about 450 feet, and five rooms have been turned. The bed shows 52 inches of coal without a parting. The floor is clay and the roof bone, to which much of the coal is "frozen," giving some trouble in mining. A considerable acreage of land is held by the owners, and it is their intent to push development by the extension of the railroad from Lewistown to the mine. At present the coal is hauled by wagon to Lewistown for local consumption.

Cox mine.—In the NE. ¼ SW. ¼ sec. 24, north of the Black Diamond workings, is the mine of Walter Cox. The entry is on the dip on the east side of a structural dome. The section of the bed shows a considerable variation from that in the Black Diamond mine. The lower bench is 30 inches thick and the upper bench 15 inches, with a 2-inch bone parting between. Overlying the upper bench are 4 inches of clay, 2 inches of coal, and 6 inches of bone in succession, overlain by sandstone. Since the surface slopes rather steeply to the east and the dip is moderate, the coal has but little cover.

Hamilton mine.—The mine of R. E. Hamilton is located a short distance north of the Cox mine. The entry is in 585 feet. The bed shows two distinct benches, the lower 46 inches thick and the upper 6 inches, with a 13-inch clay parting. Bone forms the roof, and the floor is clay. Geologic conditions are very similar to those at the Cox mine, and the covering is very light.

Sharp mine.—William and A. Sharp have leased from George Jackson a mine located in the NW. ¼ NW. ¼ sec. 13, a little over a mile north of the Hamilton mine. The mine has been recently opened and the entry is in only a short distance. The dip is 6° to the east. Since the mine is on the west limb of a narrow syncline a slope has been driven from the outcrop on the east limb with the expectation of eventually connecting the two mines, the two openings being about one-fourth mile apart. Between them the coal is under light cover, the maximum being not more than 30 feet. A section of the bed in the western opening indicates that the coal is thinning northward from the Hamilton mine, having a total thickness of 42 inches at this point. The lower bench is 5 inches thick and the upper bench 28 inches, with a 1-inch shale parting. There is 8 inches of bony coal above the upper bench. The roof is shale and the floor clay.

Flaherty mine.—The Flaherty mine is located on the south side of North Fork of McDonald Creek, in the NW. ¼ SW. ¼ sec. 18, T. 15 N., R. 20 E. This mine has been worked on a small scale for about two years. The bed shows two benches, the lower somewhat variable but averaging about 46 inches, and the upper 8 inches, with a 5-inch bone parting. The floor is clay and the roof is clay shale, locally termed "soapstone." The bone is usually left for a roof, as the "soapstone" breaks down on exposure.

It is claimed by the miners that this bed is the middle one of three. The presence of a third bed is doubted, however, for at one place in the mine where the roof had caved the massive sandstone was noted, which occurs everywhere in the field just above the coal. A prospect a short distance north of the Flaherty mine exposes the lower bed, which, because of its alternation of coal and shale, is termed the "dirty vein." The thickest bench of the bed is 14 inches and the coal composing it is extremely hard and of good quality. Above and below are alternating thin layers of clay, coal, and bone. In no other place in the district was this lower bed noted.

"Company" mine.—The Gold Reef Mining and Milling Company, which is operating a gold and silver mine and cyanide plant about a mile northwest of Giltedge, obtains its coal by contract with Shipley & Kemp from a mine located in the NW. ¼ NE. ¼ sec. 9, T. 15 N., R. 20 E. A slope is driven 400 feet down the dip, which is 17°, necessitating haulage of the coal by means of a horsepower winch. A section of the bed shows a lower bench of 8 inches and an upper bench of 27 inches, with a 1-inch clay parting. The roof and floor are clay.

The outcrop of the coal zone passes within a short distance of the mill of the Gold Reef mine, and this company has made several unsuccessful attempts to obtain coal near by. West of Giltedge they sunk a slope on the dip of the bed as it outcrops on the face of a prominent ridge formed by the massive sandstone associated with the coal. The dip is 30°, and water was soon encountered. Moreover, the bed is only 26 inches thick and contains a high percentage of sulphur. On account of these unfavorable conditions operations were abandoned.

Lewis mine.—The Lewis mine is located in the SW. ¼ SW. ¼ sec. 4, about one-half mile southwest of the "Company" workings. This mine has been opened about two years, and about 4,000 tons of coal have been removed. The slope goes in on the dip for 800 feet, where a fault has been encountered. The bed is 31 inches thick, with clay floor and roof.

Cliffe mine.—The Cliffe workings are located in the NE. ¼ NW. ¼ sec. 3, T. 15 N., R. 20 E. An entry was driven in on the strike of the bed for 700 feet, where a fault was encountered. Side entries are now being driven to the right and slightly up the rise. A section of the bed shows the usual two benches, with roof and floor of clay. The lower bench is 6 inches thick, the upper bench 27 inches, with a clay parting. This mine has been operated six years, and, like others in the vicinity, supplies only a local demand, which is small during the summer months.

McDonald Creek Fuel Company's mine.—The earliest development near the head of McDonald Creek was by the McDonald Creek Fuel Company (mine No. 17, Pl. II) to the north of the stream about 1 mile east of the Flaherty mine. A comparatively large amount of coal was taken from this opening for the Lewistown market, but little information could be obtained concerning these workings, as they have been abandoned for a number of years.

Sherman mine.—W. F. Sherman opened a mine late in 1905 on the north side of Flat Mountain from which a small amount of coal has been taken. The entry is driven to the south 300 feet on a dip which is slight at the mouth of the entry but which increases to 14°. A section of the bed is as follows:

Section of bed in Sherman mine.

	Ft.	in.
Bone.		
Coal		6
Bone		5
Coal	2	2
Clay		1
Coal		7
Clay.	3	9

Considerable difficulty has been experienced in holding the roof, and this condition will probably continue till the entry is driven far enough to be on a lower level and where the thickness is greater between the coal and the travertine which caps Flat Mountain. North of the entry the spring deposit is within 40 feet of the coal outcrop, and a short distance to the west it is lying entirely across the dipping Kootenai rocks.

It has been believed that in the vicinity of the Sherman mine the coal would be cut off a short distance from the outcrop by the travertine, since that deposit has been previously considered as Madison limestone. The writer believes, however, that the coal bed is continuous south from the Sherman mine to the outcrop on the south face of Flat Mountain.

Hill mine.—A small mine was opened in 1904 by Benjamin Hill on the north bank of Horsethief Coulee, in the NE. ¼ NW. ¼ sec. 35, T. 15 N., R. 20 E. The entry is 100 feet long. The bed consists of two benches, the lower 28 inches thick and the upper 14 inches, with a ¾-inch clay parting. The lower bench only is mined, as the upper is impure and not of marketable quality. Sandstone forms the roof and the floor is clay.

Hobson mine.—Southeast of the Hill mine W. and H. Hobson operate a small mine on the north side of South Fork of McDonald Creek, near the south line of sec. 1, T. 14 N., R. 20 E. One hundred and forty feet of entry has been driven. The coal bed is made up of two benches, the lower 7 inches and the upper 34 inches thick, with a 2-inch bone parting. The roof is composed of the massive cross-bedded sandstone of the Kootenai, and the floor is a light-colored shale.

Brew & Parsons mine.—The Brew & Parsons mine is located in the NE. ¼ SW. ¼ sec. 32, T. 16 N., R. 19 E., not far from the base of the Judith Mountains. The coal zone is exposed here in a small coulée which has cut back into a dip slope. The mine entry is on the south side of the stream and is driven S. 40° E. for 120 feet, then turns to the left for 180 feet, approximately following the line of strike, which is S. 80° E. A fault was encountered 120 feet in, having a displacement of a few feet. The bed is in two benches, of somewhat variable thickness. A representative section is as follows:

Section of coal bed in Brew & Parsons mine.

	Ft.	in.
Clay shale.		
Bone		4–6
Coal	3	2
Shale, black		2–12
Coal	2	6
Clay.		

It was claimed that the clay which forms the floor is 4 feet thick and that beneath it occurs a second coal bed 2 feet thick, but this statement could not be verified.

The coal of the different benches is quite dissimilar; that of the lower bench possesses no apparent joint planes, but when mined by pick and bar, breaks out in irregular forms with apparently slickensided surfaces. The coal of the upper bench, on the contrary, is distinctly jointed and breaks into the cubical or rectangular form characteristic of the coal of the Lewistown field. Water is present in small quantity in the mine and is removed by a siphon.

LEWISTOWN DISTRICT.

LOCATION AND EXTENT.

The greater part of the coal produced in what is known as the McDonald Creek district comes from the Spring Creek mine, 2 miles southeast of Lewistown. Upon very uncertain evidence it is believed that this producing area is in a measure isolated from the McDonald Creek district proper. Good exposures of the coal zone are lacking along its outcrop on the north bank of Big Spring Creek and East Fork, and the bed has not been prospected in that locality. Such evidence as could be obtained, however, points to the conclusion that the coal is not especially valuable along East Fork of Big Spring Creek. Workable coal may possibly extend from the mines near Lewistown to the Brew & Parsons mine at the base of the Judith Mountains, but as the coal zone is buried by the full thickness of Kootenai, drilling will be necessary to decide the question definitely.

DEVELOPMENT.

Spring Creek mine.—Coal is mined in the NW. ¼ NW. ¼ sec. 26, T. 15 N., R. 18 E., by the Spring Creek Company. Coal was first mined commercially by this company in 1905, although the mine had been operated on a less extensive scale for a number of years previously. At present the workings are the largest in the Lewistown field. They supply about 125 tons per day to the Montana Railroad and a small amount to Lewistown and vicinity. A section of the bed shows 3 feet of coal in two benches, with a bone parting of 6 to 9 inches. The lower bench as measured in the third entry south is 26 inches thick, the upper bench 10 inches. The floor is grayish clay and the roof is gritty shale.

Between the floor and the lower bench is a bony layer 13 to 16 inches thick, which contains thin seams of shiny black bone termed "black jack" by the miners. A sample of this material carried 31.84 per cent of ash. In both upper and lower benches there are thin inconstant clay or shale binders which adhere to the coal and are not separated in mining. The characteristic lenses and nodules of iron pyrites are present in both benches. They are usually small, however, and little attempt is made to discard them. The lower bone and "black jack" are removed in undercutting, after which the coal is shot down.

The mine is worked chiefly on the room and pillar system, though the long wall method is also being used. At the time the investigation was made the main entry was in 1,000 feet S. 70° W., with a dip of about 4°. There are three entries to the south. The first has been extended till it is within a short distance of a coulée tributary to

Spring Creek, where the coal is under but little cover and is consequently softer than it is in the other entries. This entry is also considerably drier than other parts of the mine. Water is removed from sumps in the main entry by two pumps, one operated by steam and the other by compressed air. Air is also used for machine drills in the entries, drilling in the rooms being done by hand. Coal is hauled by mule from the entries to the tipple, where it is loaded direct into cars for the use of the Montana Railroad. Forty men are employed at the mine.

Harmon opening.—A number of prospects are located on the coal outcrop on the south bank of Warm Spring Creek above the Spring Creek mine. One of these, the H. L. Harmon opening, had not been worked recently, but it was the intention to renew development in the winter of 1907–8. The entry is 450 feet long, under slight cover for a considerable distance. The bed is in three benches, the two lower each 12 inches thick with a 6-inch parting of bony coal, and the upper 14 inches thick with a bone parting 7 inches thick below. The roof is bone and the floor is clay.

Graphic representations of the coal bed in the various mines of the McDonald Creek district, including the Lewistown district, are shown in Plate V.

MINING CONDITIONS.

Throughout the Lewistown field mining conditions are fairly uniform. The coal is exposed in outcrop in many localities and is usually in a favorable attitude for working. Dips are not excessive anywhere within areas of workable coal, and minor faults or flexures appear to be uncommon. Timbering is unnecessary in many of the mines, and few of the larger workings are timbered throughout. Mine timbers are obtained chiefly from second-growth pines, which are abundant in the foothills of the Big Snowy Mountains, in the Rock Creek district in the vicinity of Flat Mountain, to the west along the base of the Judith Mountain, and near the Warm Spring Creek district.

In general the coal of the field is not dry, but the problem of drainage in the mines is not difficult. In but two of the mines, the Spring Creek and the Brew & Parsons, is other than natural drainage needed. None of the mines are troubled with gas, and no fans are in operation in the mines, though this is to be expected in view of the small amount of development, which renders natural ventilation entirely adequate. Haulage from the entries in the majority of the mines is by horse or mule, but in a number the cars are pushed by hand.

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

Although the coal is not continuous throughout the Lewistown field, it retains certain marked physical characteristics which differentiate it in a measure from other coals of the State except that of the Great Falls field to the west. That the coals of these two fields should thus be similar is to be expected, for they are of the same geologic age. The coal is persistently banded in appearance, with alternating layers of bright and dull luster, the latter predominating. The dull bands owe their appearance chiefly to the presence of mineral charcoal, and since they form the greater part of the bed, the coal is dull or grayish black in color. Even in the dull bands, however, very thin, shiny lenses are present. The bright bands are thin, their thickness ranging from a mere film to about one-fourth inch.

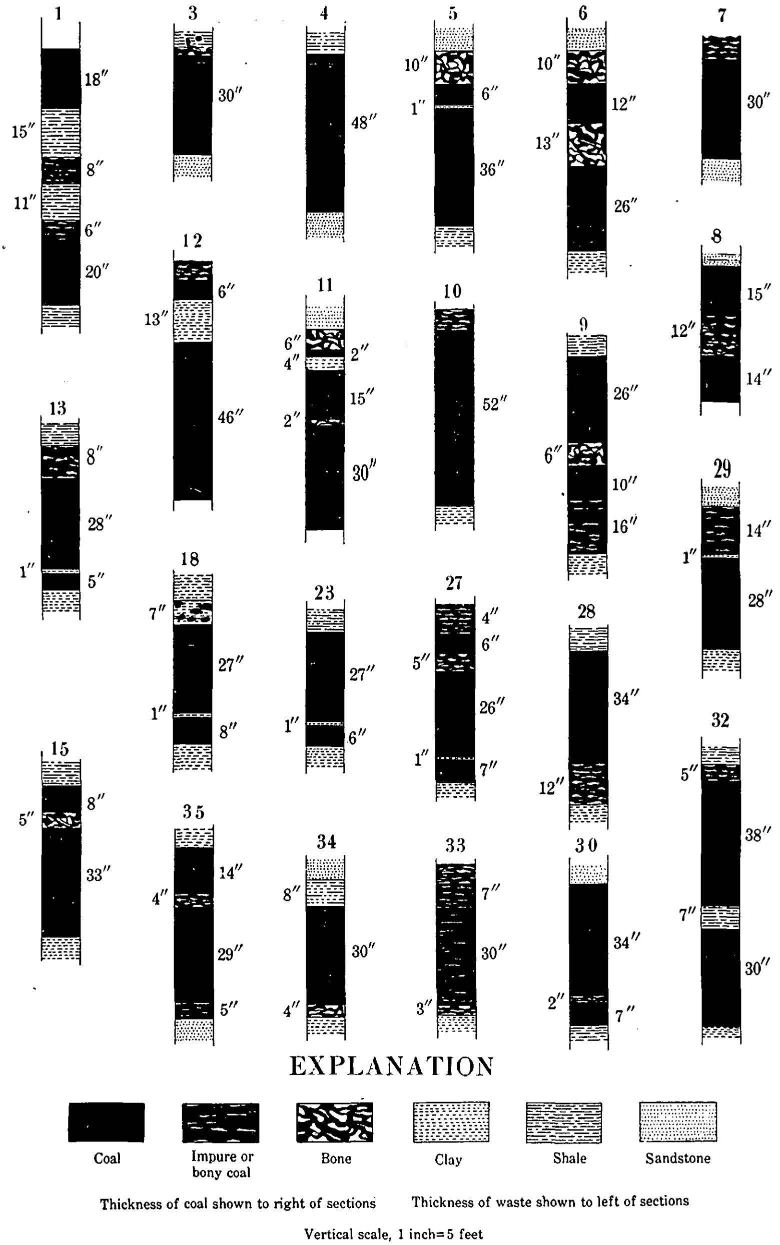
Where unaffected by structural movement the coal breaks into cubical or rectangular form, and even the smaller fragments, when closely examined, show that this prismatic jointing is well developed. As a rule the vertical jointing or "cleat" is indefinite and is not a factor in mining.

Sulphur in the form of iron pyrites (FeS_2) is more or less abundant in the coal, being dissimilar in that respect to other Montana coals of younger geologic age, in which the sulphur content is usually low. Generally the sulphur occurs as small nodules or lenses, though it is present also as a thin incrustation between layers or along joint planes.

Coking qualities.—Practical tests have not been made to determine the coking qualities of the coal of the Lewistown field, but it is generally believed by the local miners that it will not coke. Where commercial tests of the adaptation of coal to coking have not been made, field tests are sometimes employed. The method is to burn a small amount in a pit under conditions as similar as possible to those where coal is coked commercially. Such tests are unsatisfactory in a measure, for even if the coal seems to possess coking qualities commercial treatment may be unsuccessful. In view of this fact, and also because the coals of the Lewistown field contain a considerable percentage of sulphur, which would disqualify them in a measure for use in smelting, field tests were not made.

Recent studies by Max Pishel,[a] of the United States Geological Survey, have shown that the coking qualities of coals can be determined by a simple physical test which apparently is just as reliable, if not more reliable, than the ordinary field method of testing in a pit. It was found that on grinding finely in an agate mortar coal samples representing many fields in the United States certain coals

[a] Practical test for coking coal: Econ. Geology, vol. 3, No. 4, June-July, 1908, pp. 265-275.



LIST OF MINES

1	SHOWAN	8	KNOX	15	FLAHERTY	30	HOBSON
3	WILLIAMS	9	SPRING CREEK	18	"COMPANY"	32	BREW & PARSONS
4	SAAGER CANYON	10	BLACK DIAMOND	23	CLIFFE	33	NEVIN
5	SHARP, SR.	11	COX	27	SHERMAN	34	NEW YEAR
6	COOPER	12	HAMILTON	28	PEIPER	35	MACE
7	RAND	13	SHARP	29	HILL		

SECTIONS OF COAL BED IN LEWISTOWN FIELD.

adhered strongly to the mortar and pestle. Reference to the samples having such behavior revealed the fact that in nearly every instance the coal was of coking quality, as demonstrated commercially. Further tests are of course needed to prove conclusively that adherence of the powder to the mortar or pestle is confined wholly to coking coals, but the experiments seem to point to that conclusion. The above test was applied to samples from several mines of the Lewistown field, and, if it is a safe criterion, the coals are noncoking.

CHEMICAL PROPERTIES.

For the purpose of comparison and classification samples of coal were obtained from practically all working mines of the field, which were subsequently analyzed in the laboratory of the fuel-testing plant of the Geological Survey in Pittsburg under the direction of F. M. Stanton. The samples were collected in a uniform manner in accordance with the instructions for coal sampling which, briefly stated, are as follows:

> Select a clean face of coal and across the bed from top to bottom cut a channel of sufficient depth to obtain 5 pounds of coal for each foot of bed, discard all partings more than one-fourth inch thick and lenses or concretions more than 2 inches in diameter and one-half inch in thickness. The material thus obtained should be caught upon canvas or oilcloth to exclude dirt and excess moisture.
>
> The sample thus obtained should be pulverized in the mine if possible until none of the fragments exceed one-half inch in diameter. The coal should then be mixed thoroughly and divided into four quarters, the two opposite discarded, and the remaining two mixed and quartered again. This process should be continued until the final sample is reduced to about 1 quart, which is to be placed in a can, sealed air-tight, and sent to the laboratory for analysis.

By the above method samples fairly representative of the bed as mined can be obtained. The sealing of the samples insures the coal reaching the laboratory practically unchanged as regards its moisture content.

A detailed description of the methods employed in the chemical analysis of coals may be found in Professional Paper 48, pt. 1.[a]

The analyses of the Lewistown coals are presented in the following table, which is in two parts, one representing samples as received and the other giving the analyses calculated on an air-dried basis. The latter is more nearly representative of the coal as it is used commercially, as a considerable percentage of the moisture evaporates after mining.

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[a] Parker, E. W., Holmes, J. A., and Campbell, M. R., committee in charge, Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904: Prof. Paper U. S. Geol. Survey No. 48, pt. 1, 1906.

Analyses of coal samples from Lewistown field.

	Sage Creek district.	Buffalo Creek district.		Rock Creek district.			
	NE. ¼ sec. 13, T. 14 N., R. 12 E.	NE. ¼ NE. ¼ sec. 20, T. 12 N., R. 14 E.	NW. ¼ sec. 28, T. 12 N., R. 14 E.	SE. ¼ NE. ¼ sec. 16, T. 13 N., R. 17 E.	SW. ¼ NW. ¼ sec. 15, T. 13 N., R. 17 E.	NW. ¼ SW. ¼ sec. 14, T. 13 N., R. 17 E.	SW. ¼ SE. ¼ sec. 3, T. 13 N., R. 17 E.
Laboratory No.	5290.	5265.	5267.	5266.	5264.	5273.	5274.
Sample as received:							
Prox. Moisture	9.95	14.44	17.03	15.72	16.86	13.90	9.18
Prox. Volatile matter	24.87	28.80	27.34	29.64	30.23	26.25	26.69
Prox. Fixed carbon	44.22	45.65	43.83	43.81	45.60	41.84	43.31
Prox. / Ult. Ash	20.96	11.11	11.80	10.83	7.31	18.01	17.82
Ult. Sulphur	5.51	4.08	4.14	2.81	3.03	6.05	9.39
Ult. Hydrogen	....	....	4.98	....	5.62	....	....
Ult. Carbon	....	....	51.73	....	58.27	....	....
Ult. Nitrogen	....	....	.62	....	.67	....	....
Ult. Oxygen	....	....	26.73	....	25.10	....	....
Calories	4,937	....	4,941	....	5,726	5,381	5,371
British thermal units	8,887	....	8,894	....	10,307	9,686	9,668
Loss of moisture on air drying	3.00	7.30	9.00	6.50	8.20	6.10	1.90
Air-dried sample:							
Prox. Moisture	7.16	7.70	8.82	9.86	9.43	8.31	7.42
Prox. Volatile matter	25.64	31.07	30.04	31.70	32.93	27.95	30.27
Prox. Fixed carbon	45.59	49.25	48.17	46.86	49.68	44.56	44.15
Prox. / Ult. Ash	21.61	11.98	12.97	11.58	7.96	19.18	18.16
Ult. Sulphur	5.68	4.40	4.55	3.01	3.30	6.43	9.57
Ult. Hydrogen	....	....	4.37	....	5.13	....	....
Ult. Carbon	....	....	56.85	....	63.48	....	....
Ult. Nitrogen	....	....	.68	....	.73	....	....
Ult. Oxygen	....	....	20.58	....	19.40	....	....
Calories	5,090	....	5,430	....	6,237	5,730	5,475
British thermal units	9,162	....	9,774	....	11,228	10,315	9,855

	Warm Spring Creek district.		McDonald Creek district.				
	SW. ¼ NW. ¼ sec. 32, T. 17 N., R. 19 E.	NW. ¼ SE. ¼ sec. 7, T. 16 N., R. 19 E.	NW. ¼ NW. ¼ sec. 26, T. 15 N., R. 18 E.	SW. ¼ NE. ¼ sec. 6, T. 14 N., R. 20 E.	SE. ¼ sec. 1, T. 14 N., R. 20 E.	NE. ¼ NW. ¼ sec. 35, T. 15 N., R. 20 E.	NW. ¼ NW. ¼ sec. 25, T. 15 N., R. 19 E.
Laboratory No.	5472.	5475.	5272.	5289.	5295.	5294.	5292.
Sample as received:							
Prox. Moisture	2.84	6.89	15.35	18.88	11.35	18.56	14.13
Prox. Volatile matter	27.35	28.61	28.27	25.18	29.74	24.59	27.37
Prox. Fixed carbon	54.29	42.65	48.08	48.34	46.56	48.36	48.43
Prox. / Ult. Ash	15.52	21.85	8.30	7.60	12.35	8.49	10.07
Ult. Sulphur	4.87	5.48	4.53	2.72	4.48	3.72	3.69
Ult. Hydrogen	....	....	5.42	5.19	5.02	....	5.06
Ult. Carbon	....	....	61.15	57.31	58.91	....	59.87
Ult. Nitrogen	....	....	.71	.66	.82	....	.74
Ult. Oxygen	....	....	19.89	26.52	18.42	....	20.57
Calories	6,512	5,229	5,897	5,417	5,841	5,505	5,794
British thermal units	11,722	9,412	10,615	9,751	10,514	9,909	10,429
Loss of moisture on air drying	1.60	2.80	8.20	6.40	3.10	9.60	7.00
Air-dried sample:							
Prox. Moisture	1.26	4.21	7.79	13.33	8.51	9.91	7.67
Prox. Volatile matter	27.80	29.43	30.80	26.90	30.69	27.20	29.43
Prox. Fixed carbon	55.17	43.88	52.37	51.65	48.05	53.50	52.07
Prox. / Ult. Ash	15.77	22.48	9.04	8.12	12.75	9.39	10.83
Ult. Sulphur	4.95	5.64	4.94	2.91	4.62	4.12	3.97
Ult. Hydrogen	....	....	4.91	4.79	4.83	....	4.60
Ult. Carbon	....	....	66.61	61.23	60.79	....	64.38
Ult. Nitrogen	....	....	.77	.70	.85	....	.79
Ult. Oxygen	....	....	13.73	22.25	16.16	....	15.43
Calories	6,618	5,379	6,424	5,787	6,028	6,090	6,230
British thermal units	11,912	9,683	11,563	10,417	10,850	10,961	11,214

Analyses of coal samples from Lewistown field—Continued.

	McDonald Creek district.							
	NE. ¼, sec. 24, T. 15 N., R. 19 E.	NW. ¼ NW. ¼ sec. 13, T. 15 N., R. 19 E.	NE. ¼ SW. ¼ sec. 32, T. 16 N., R. 19 E.	NW. ¼ SW. ¼ sec. 18, T. 15 N., R. 19 E.	NW. ¼ NE. ¼ sec. 9, T. 15 N., R. 20 E.	NW. ¼ sec. 32, T. 16 N., R. 20 E.	SW. ¼ SE. ¼ sec. 33, T. 16 N., R. 20 E.	NE. ¼ NW. ¼ sec. 3, T. 15 N., R. 20 E.
Laboratory No.	5295.	5293.	5291.	5343.	5471.	5473.	5475.	5476.
Sample as received:								
Prox. Moisture	12.66	12.31	12.59	9.84	8.34	15.65	7.39	7.98
Prox. Volatile matter	29.62	28.41	26.71	28.70	29.87	27.05	26.31	26.63
Prox. Fixed carbon	48.81	51.31	43.46	42.14	53.63	49.67	55.46	56.05
Prox. Ash	8.91	7.97	17.24	19.32	8.16	7.63	10.84	9.34
Ult. Sulphur	3.68	3.88	3.51	4.63	4.13	1.82	2.58	4.39
Ult. Hydrogen			4.84		5.10	5.13		4.86
Ult. Carbon			54.83		66.23	56.70		64.85
Ult. Nitrogen			.76		.76	.70		.76
Ult. Oxygen			18.82		15.62	28.02		15.80
Calories	6,061	6,194	5,220	5,283	6,540	5,303	6,035	6,394
British thermal units	10,910	11,149	9,396	9,509	11,772	9,545	10,863	11,509
Loss of moisture on air drying	6.00	6.40	5.30	3.50	3.70	9.70	2.80	3.40
Air-dried sample:								
Prox. Moisture	7.09	6.31	7.70	6.57	4.82	6.59	4.72	4.74
Prox. Volatile matter	31.51	30.35	28.20	29.74	31.02	29.95	27.07	27.57
Prox. Fixed carbon	51.92	54.82	45.89	43.67	55.69	55.01	57.06	58.02
Prox. Ash	9.48	8.52	18.21	20.02	8.47	8.45	11.15	9.67
Ult. Sulphur	3.91	4.15	3.70	4.80	4.29	2.02	2.65	4.54
Ult. Hydrogen			4.49		4.87	4.48		4.64
Ult. Carbon			57.90		68.78	62.79		67.13
Ult. Nitrogen			.80		.79	.78		.79
Ult. Oxygen			14.90		12.80	21.48		12.23
Calories	6,447	6,617	5,512	5,475	6,791	5,873	6,209	6,619
British thermal units	11,606	11,911	9,922	9,854	12,224	10,570	11,176	11,914

Comparison of the foregoing analyses shows that the coals vary considerably, especially as regards moisture and ash content, in the samples as received at the laboratory. The minimum amount of moisture is 2.84 per cent, which is not strictly representative of the coal at the particular locality where the sample was obtained, as it was taken in the practically abandoned Shipley mine, whose entry mouth had been closed for a considerable period. The greatest amount of water was found in the sample from the Peiper mine, which likewise had not been worked for some time prior to the investigation, but in which the coal is in a measure unprotected from air currents. There is thus a range of 16.04 per cent in moisture content, the average amount of water being 12.32 per cent. In ash the coal samples varied from 7.31 to 21.85 per cent, with an average of 12.34 per cent.

The other results expressed in the analyses—volatile matter, fixed carbon, and sulphur—do not show so wide a range, although it is still considerable. The average of the volatile matter is 27.65 per cent, of the fixed carbon 47.52 per cent, and of the sulphur 4.23 per cent.

CLASSIFICATION OF THE COAL.

Six groups of coal are recognized by the United States Geological Survey, namely: (1) anthracite, (2) semianthracite, (3) semibituminous, (4) bituminous, (5) subbituminous, (6) lignite. It has been found [a] that chemical analysis alone will not serve to separate these groups definitely, and that more reliance should be placed on physical characteristics, especially in regard to those below the grade of semibituminous. The chief distinction between bituminous and those of the lower grades is the comparative effect of weathering. Those of the former class possess a well-developed joint system, which is notable even in minute fragments. Those of groups lower than bituminous, on the other hand, when exposed to weather, break irregularly and the fragments do not conform to any rule regarding outline. Upon this basis the coal of the Lewistown field is distinctly bituminous in type.

In one physical characteristic the coal is similar to that from other Montana fields which yield lignite—in that the color of the streak or powder is distinctly brownish, a quality which, it is sometimes asserted, marks a lignite or lignitic coal. As Campbell points out, however, this is not a safe criterion for classification. From the standpoint of heat values, indicated by the calorimeter determination, the coal might be classed as belonging to the lignite, subbituminous, or bituminous group, for the range in calorific value on air-dried samples is, as shown in the table of analyses, from a minimum of 9,162 to a maximum of 12,224 British thermal units.

PRODUCTION.

Since the mines of the Lewistown field, with the exception of that of the Spring Creek Company, supply only a local demand which, unlike that of the Great Falls field, is not augmented by large industrial enterprises, Fergus County has not thus far been a prominent factor in the coal production of the State. The following table shows the production in the county from 1889, the first year for which statistics are available, to 1906, inclusive.

[a] Campbell, M. R., A practical classification for low-grade coals: Econ. Geology, vol. 3 (No. 2, March-April, 1908), pp. 134-142.

Coal production of Fergus County from 1889 to 1907, inclusive.[a]

Year.	Amount.	Year.	Amount.
	Short tons.		*Short tons.*
1889	460	1899	900
1890	1,260	1900	....
1891	250	1901	500
1892	400	1902	5,200
1893	200	1903	9,734
1894	325	1904	19,109
1895	....	1905	15,228
1896	....	1906	29,182
1897	....	1907	45,760
1898	950		

[a]Mineral Resources U. S. for 1889-1907, U. S. Geol. Survey.

In order to show the comparative production of coal by the various counties in Montana in 1907, together with the total value and average price per ton, the following table is appended:

Coal production in Montana in 1907, by counties.[a]

County.	Total quantity.	Total value.	Average price per ton.
	Short tons.		
Carbon	746,110	$1,431,333	$1.92
Cascade	1,026,223	1,724,056	1.68
Chouteau	24,847	71,077	2.86
Fergus	*45,760*	*172,018*	*3.76*
Park	102,555	381,940	3.72
Other counties [b]	69,332	121,080	1.75
Small mines	2,030	5,578	2.75
	2,016,857	3,907,082	1.94

[a] Mineral Resources U. S. for 1907, U. S. Geol. Survey, 1908, p. 150.
[b] Deerlodge and Gallatin.

From the foregoing table it will be noted that Fergus County, though probably ranking fourth in the producing counties of the State, furnished little more than 2 per cent of the total tonnage. It will also be noted that the average price per ton for Fergus County coal is the highest on the list. This higher monetary value can be ascribed to several causes. The demand for coal in the field is not large, but, owing to scarcity of other fuel, is insistent during the winter months at least. The field has not had direct connection with other producing areas of the State, hence competition has not entered as a factor to decrease the price of coal. Mining conditions, especially the relative thinness of the bed in most of the producing districts in the Lewistown field, are not especially favorable to cheap mining, although, in the future, development on a larger scale may tend to decrease the cost. The following abstract from the agreement between Montana Coal Operators and the United Mine Workers of America, District No. 22, for the year commencing October 1, 1907, affords a comparison of mining rates in the adjoining Lewistown and Great Falls fields.

Scale of mining rates and local provisions in the Belt (Great Falls field) and Lewistown fields.

	Belt district.	Lewistown field.
Pick mining per ton of 2,000 pounds run of mine	$0.75	$1.50
Loaders, per ton of 2,000 pounds, run of mine	.43½	.84
Room turning	8.00	10.00
Room crosscuts, per yard	1.50	3.25
Coal delivered to employees, per ton	2.50	4.00

FUTURE DEVELOPMENT.

The Lewistown field has hitherto been, and to a large degree will probably remain, a region more or less commercially isolated so far as coal production is concerned. Transportation facilities were lacking up to the time of the extension of the Montana Railroad into Lewistown in 1904. Had there been an outside demand coal could not have reached other than a local market, and at present transportation rates are too high to allow of competition with other fields. The chief consumers of Montana coal are the railroads and the smelters. The latter are located at Anaconda, Helena, and Great Falls, and each has more ready access to other coals than to those of the Lewistown field.

Other conditions in the surrounding region also point to the improbability that there will be a marked development of the coal resources of the Lewistown field in the near future. To the east is an extensive, sparsely settled area, and this part of Montana will probably remain relatively in its present condition. To the south lies the Bull Mountain field, where a large amount of coal is readily available and where a great impetus in development is being received, due to the construction of the transcontinental line of the Chicago, Milwaukee and St. Paul Railway, which crosses the field and which will furnish an outlet for the coal. Still farther south are the coal fields of Red Lodge, Bear Creek, Bridger, Chestnut, Trail Creek, and Electric, which supply the towns and smelters along the Northern Pacific Railway, as well as the railway itself. To the west is the Great Falls field, which controls the market in that section of the State. This field, especially the Sage Creek district, is the nearest competitor to the Lewistown field. The new line of the Billings and Northern Railroad crosses this district, and extensive developments are under way a few miles west of Windham. This new line of railroad gives an outlet at present for the Sage Creek coal only and spurs will be necessary to make the coal of the other districts available.

In spite of the foregoing considerations, however, there is every probability that there will be a constant and increasing local demand for the coal of the Lewistown field. Judith Basin has developed remarkably within the last few years and now contains a considerable agricultural population. Lewistown is a thriving business center, and other towns within the field are growing rapidly. Another factor which will add to the local demand for coal is the depletion of timber in the field. The Little Belt, Judith, and Moccasin mountains are now almost bare, and the only remaining sources of timber are the Big Snowy Mountains and the district in the vicinity of Rock Creek.

In regard to the possibility of future demands from outside the field for coal, there is a rather important factor which should be taken into consideration. The Great Falls and the Lewistown fields are the only large areas in the central part of the State which contain a bituminous coal. The coal in the eastern part of the State is a lignite, and that of the Bull Mountain and other fields to the south is probably subbituminous. This latter class of coal, while it is a fair grade of fuel for stationary engines, is not so well adapted for locomotives, and in addition it does not stock well. On the contrary, the coal of the Lewistown field both stocks fairly well and is an excellent locomotive fuel. Because of these qualities it seems probable that if in the future an outlet is furnished for the coal it will be used to a greater degree by the railroads of the State in preference to fuel of lower grade.

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