# GEOLOGY AND OIL AND GAS PROSPECTS OF THE LAKE BASIN FIELD, MONTANA.

By E. T. Hancock.

## INTRODUCTION.

### LOCATION AND EXTENT OF THE FIELD.

The Lake Basin field is situated in south-central Montana and includes portions of Sweet Grass, Stillwater, Musselshell, and Yellowstone counties. It embraces an area of about 1,000 square miles between the Chicago, Milwaukee & St. Paul Railway and the main line of the Northern Pacific Railway. A branch of the Great Northern Railway running southeast from Great Falls crosses the eastern part of this field and furnishes shipping facilities at Broadview, Comanche, and Acton. The Billings & Central Montana Railway with its beet elevators furnishes a ready means of transporting the large quantity of sugar beets raised on the irrigated lands along Yellowstone River.

### ACKNOWLEDGMENTS.

In presenting this report the writer desires to express his thanks to David White and M. R. Campbell for valuable suggestions and criticisms, and to W. T. Thom, jr., and J. D. Sears for assistance in the detailed mapping. He also wishes to call attention to the public service rendered by the oil and gas operators who have furnished records of deep borings and by individuals who have contributed in no small way to the success of the investigation.

### EARLIER INVESTIGATIONS.

The history of geologic investigation of the region including the Lake Basin field begins with the Northern Transcontinental Survey of 1882. Prior to that time geologists had described certain structural features and the stratigraphic succession at points closely adjacent, such as Judith Gap, the canyon of the north fork of the Musselshell, and the Bridger Range, but almost nothing had been written concerning the geology of the area herein described. One of the topographic maps made by the Northern Transcontinental Survey in 1882–1884 (the Crazy Mountain sheet) includes a small area in the northwest corner of the Lake Basin field. These maps were printed on a scale of 1 inch to 4 miles, with 200-foot contours. In 1883 George H. Eldridge was engaged in an examination of the coal fields of Montana for the Transcontinental Survey. At that time J. E. Wolff, of the same Survey, studied the Crazy Mountains and surrounding country.

In later years the Crazy Mountains have been restudied by Prof. Wolff, and the stratigraphy and paleontology at certain points in the Musselshell Valley, particularly on Fish Creek, have been investigated by T. W. Stanton, J. B. Hatcher, W. B. Scott, and Earl Douglas, to whose reports reference is made in the subsequent text.

After the withdrawal from entry of certain coal lands in Montana R. W. Stone began in 1907 the examination of a belt of reported workable coal seams extending around the north and west sides of the Crazy Mountains, and in the same year L. H. Woolsey undertook the examination of an area extending east from Shawmut toward the Bull Mountains. The few occurrences of coal found around the Crazy Mountains have been described by Stone in Bulletin 341 of the United States Geological Survey, and the Bull Mountain field is discussed by Woolsey in the same bulletin and by Woolsey and others in Bulletin 647. A detailed report by Stone and Woolsey on the geology of the Musselshell Valley has been submitted but not yet published. The area embraced in that report joins the Lake Basin field on the north.

In the summer of 1910 W. R. Calvert made a reconnaissance from the east end of Stone's area southeastward to Columbus, mapping in a general way the outcrop of the Lennep sandstone.

In the fall of 1915 C. J. Hares made a rapid reconnaissance investigation of the Lake Basin field in order to procure the necessary data upon which to base certain withdrawals from entry of lands supposed to contain oil and gas.

## PURPOSE OF THE PRESENT INVESTIGATION.

The purpose of the present investigation was primarily to make a detailed study of the stratigraphy and to discover and locate such structural features as have elsewhere been found to bear a definite relation to accumulations of oil and gas.

## FIELD WORK.

The field investigation that furnished the basis for the present report was made during June, July, August, and September, 1916. The field observations were made and the maps prepared under the immediate supervision of the writer, who was ably assisted by W. T. Thom, jr., and J. D. Sears.

In the process of mapping nearly all locations were made by the triangulation method and elevations determined by means of vertical angles. The work was begun in the vicinity of Locomotive Butte, near the north line of T. 4 N., R. 19 E. A base line 13,500 feet in length was carefully measured along the east-west wagon road 1 mile north of the township line, and the extremities were designated by means of white flags. After the plane table was carefully oriented at the points designated the monument on Locomotive Butte was located by intersection and a system of triangulation points was extended west and south to the limits of the field.

A new base line 12,750 feet in length was later measured along the north-south section line 1 mile west of the east line of T. 3 N., R. 19 E. The north end of this line was on the Lennep sandstone ridge immediately south of Shorey Basin, and the south end was on the ridge about three-fourths of a mile south of Six Shooter Creek. From this base line a new system of triangulation points was extended east and southeast on a scale of 1 inch to 1 mile, controlling all locations throughout Hailstone Basin and the principal Lake Basin country to the south. Later in the season another base line 15,000 feet in length was measured along the railroad track southeast from the red grain elevator at Comanche. From this base line a new system of triangulation points was extended to the eastern limits of the field. In the absence of a permanent bench mark in the vicinity of Locomotive Butte it became necessary to assume a certain elevation for the top of the monument at that point. All subsequent elevations were based upon the assumed elevation, and the necessary correction was made when the work had progressed far enough eastward to allow the reading of an angle on the railroad track at Broadview.

In view of the purpose of the investigation, it was necessary to map the boundaries between the different formations and to record the strike and dip of the beds at many points. Where it was possible to trace a definite horizon, and especially where the beds are inclined at a very low angle, the structure was determined by means of elevations taken at short intervals. Where the strata are broken by faults it became necessary to trace out and map the fault planes and, if possible, to determine their inclination and the amount of vertical and horizontal displacement along them. Ordinarily the locations were made by intersection from points of primary control, but here and there, as in the intensely faulted belt, the details were mapped by the use of the stadia rod after the plane table had been located by intersection.

In mapping the geology it was found necessary to locate numerous points for control, and accordingly practically all the houses were "cut in" by triangulation, and the principal roads are also shown on the map. Throughout most of the field, except those portions which are deeply dissected by streams, the roads follow the section lines.

## LAND SURVEYS.

Seven of the townships in this field were subdivided in 1877 and 1878, eighteen in 1883, 1884, and 1887, and seven in 1891 and 1892. Only a few of the section and quarter corners were found in the course of the mapping, and it is quite evident that most of them have been destroyed. Many of the old pits have probably been located, as most of the roads recently laid out run along the section lines. Throughout much of the field the section lines do not maintain the same course more than a mile, and at many of the section corners the change in course is very conspicuous, although the township plats show the lines perfectly straight.

In certain particulars the township plats do not seem to conform to the conditions in the field. For example, some of the discrepancies in land lines may be noted by comparing the course of the west boundary of T. 3 N., R. 18 E., as shown on the plat of 1884 (N. 0° 44′ E.), with the course of the east boundary of T. 3 N., R. 17 E., reestablished in 1898 (N. 3° 32′ E.). Other discrepancies in land lines are shown near the south boundary of T. 4 N., R. 21 E., as compared with the north boundary of T. 3 N., R. 21 E. For example, the north line of sec. 6, T. 3 N., R. 21 E., is shown as having practically an east-west course and a length of 79.10 chains, but the retracement of the south line of sec. 31, T. 4 N., R. 21 E., under date of July 18, 1892, shows the course of the line to be S. 69° 10′ W. and the length to be only 42.88 chains, which conforms with the positions of the southeast and southwest corners of sec. 31 as they were located by triangulation.

## TOPOGRAPHY.

### RELIEF.

The name of this field is very suggestive of its relation to the surrounding region. Although the field is somewhat elevated above the valleys of Yellowstone and Musselshell rivers, it is nevertheless in the nature of a basin. The Crazy Mountains on the west, the Big Snowy Mountains on the north, and the Bull Mountains and Pryor Range on the east and south present a striking contrast to the relatively low, undrained depression commonly known as Lake Basin. Intimately related to the basin itself are minor features which collectively are the topographic expression of the attitude of the different formations and the marked differences in the degree of resistance they have offered. There are in this field great bodies of shale which alternate with belts of resistant sandstone. Where the overlying sandstones have been eroded the shale is soon worn down to a much lower level, and a basin or broad valley is formed. Such a basin or valley is almost invariably surrounded by a bold escarpment formed by the relatively resistant sandstones. In places streams cut back into the escarpment and masses of sandstone are isolated, which in the course of time give rise to buttes out in the shale area. Battle Butte, a landmark well known throughout this region, is an excellent example.

Lake Basin is a broad depression eroded out of the Bearpaw shale, and the Lennep sandstone, which overlies the shale, forms a rather pronounced escarpment all along the west side of the basin.

Hailstone Basin is structurally a dome in which the Eagle sandstone and the overlying beds have been eroded, and the present surface is well down into the underlying Colorado shale. The basin is limited on the north and east sides by the bold escarpment of Eagle sandstone, and the same condition exists along the south margin of Big Coulee, along the stream leading down toward Painted Robe, and along the north edge of the Yellowstone flats. The south rim of Hailstone Basin, on the contrary, is made up of a great series of fault blocks which erosion has carved into a long chain of low hills without any apparent topographic relationship.

In the small uplift southwest of Broadview the conditions are very different from those of Hailstone Basin. The Eagle sandstone has been removed only in part, and instead of a basin in the underlying shale the sandstone forms the top of a roughly circular hill. This hill, together with the elevated area to the south, separates Lake Basin proper from the broad, depressed area around Comanche.

## DRAINAGE.

The name of this field is not only indicative of its topographic relations, but it expresses to a certain degree the nature of the drainage. Lake Basin proper is occupied by a number of small lakes, and the lower portions of Comanche Basin bear unmistakable evidence of having been covered with water very recently. In fact, the alluvium which is mapped in this field very probably consists of lake deposits and marks the location of lakes many times larger than those which now exist.

The streams in this field are for the most part intermittent. Many of them are fed by springs and flow continuously in their upper courses but dry up on reaching the flat country. This is particularly true of those which originate along the Lennep sandstone ridge, which bounds the field on the west. With the melting of the snow in the spring the streams receive great volumes of water and continue to flow for some time, discharging their contents into the lakes. Later on, as this supply is cut off and the hot sun and wind increase the amount of evaporation, the streams and some of the small lakes gradually dry up.

# GEOLOGY.

## *STRATIGRAPHY.*

### GENERAL SECTION.

The lowest beds in the sedimentary series exposed in this field are those which occur a few hundred feet below the top of the Colorado shale, but in a comprehensive discussion of the possibilities of oil and gas concentration it is necessary to consider some of the deeper beds down to the top of the marine Jurassic. Fortunately there are exposures of these beds not far distant which strongly indicate their nature in this field.

The sedimentary rocks to be discussed in this report have been divided into formations on the basis of lithologic and paleontologic character. The nature, thickness, and relations of these formations to the large divisions of geologic time are clearly brought out in the following table. (See also Pl. XVI, in pocket.)

*Rock formations exposed in Lake Basin oil field, Mont.*

| Era. | System. | Series. | Group and formation. | | Character. | Topographic expression. | Thickness in feet. |
|---|---|---|---|---|---|---|---|
| Cenozoic. | Tertiary (?). | Eocene (?). | Lance formation. | | Light-yellow to light-gray sandstones and bluish to gray shales interbedded. Also occasional thin beds of dark carbonaceous shale. The formation, as a whole, presents a decidedly light-gray aspect. | Commonly weathers down to rather even elevated ridges. Where the sandstones overlie the Bearpaw directly they form rather prominent escarpments. | Several hundred feet. |
| Mesozoic. | Cretaceous. | Upper Cretaceous. | Montana group. | Lennep sandstone. | Generally consists of a lower member of massive light-colored, in places false-bedded sandstone, a middle member consisting of brown andesitic beds, and an upper member containing abundant tufaceous material. | Commonly forms a prominent escarpment bordering broad valleys underlain by Bearpaw shale. | 300-350 |
| | | | | Bearpaw shale. | Bluish and light to dark grayish marine shale, including lenses and fingers of sandstone containing numerous plant remains. | Erodes rapidly, forming low, broad valleys and basins. | 500-600 |
| | | | | Judith River formation. | Beds of soft, massive light-yellow sandstone interbedded with layers of light bluish-gray to black carbonaceous shale, including an occasional thin seam of coal. Many of the beds yield numerous plant remains. | In areas of low relief commonly forms even ridges. Where highly dissected by streams it forms badlands. | 300-400 |
| | | | | Claggett formation. | Belts of thin-bedded sandstone alternating with those consisting mainly of soft sandy shale. | Commonly forms long dip slopes from the top of the Eagle sandstone back to the ridges formed by the basal sandstone of the Judith River formation. | 300-400 |
| | | | | Eagle sandstone. | This formation includes a belt of thin-bedded to massive sandstone at the top and a massive ledge-making sandstone from 50 to 100 feet thick at the base. The upper and lower sandstones are separated by a belt of softer beds including sandy and carbonaceous shales and locally thin seams of coal. The upper sandstone is commonly capped by a thin layer of black chert pebbles. | Usually characterized by an abrupt escarpment surrounding the low depression eroded out of the underlying shale. | 150-250 |
| | | | Colorado shale. | | Composed mainly of light to dark gray shale, including thin layers and lenticular beds of sandstone. About 90 feet below the base of the Eagle sandstone is a soft sandstone entirely without bedding planes but including innumerable small joint planes. This sandstone is capped by a thin layer of hard brown sandstone separated into rectangular blocks by two sets of parallel joints. | Commonly forms broad valleys and basins. | Several hundred feet exposed. |

It is apparent from this table that most of the sediments to be considered were laid down during the closing stages of the Mesozoic era, and it is the purpose of the writer to point out briefly the nature of these sedimentary formations and the conditions of land and water in the Lake Basin field while they were being laid down.

## CRETACEOUS (?) SYSTEM.

### MORRISON (?) FORMATION.

The deposits which are believed to represent the Morrison formation are not exposed anywhere in the Lake Basin field. Calvert,[1] in his discussion of the Lewistown coal field, describes these deposits as follows:

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 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.

The following stratigraphic section, given by Calvert, is said to be typical of these beds 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 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 |

There are two small uplifts much nearer this field where some of the rocks older than the Colorado shale are exposed. Both of these localities are about 10 miles southeast of Harlowton, between

[1] Calvert, W. R., U. S. Geol. Survey Bull. 390, p. 23, 1909.

American Fork and Fish Creek. One of these uplifts is about 4 miles north of Widdicombe Brothers' ranch, near the northeast corner of T. 6 N., R. 15 E., and the other (of which a section is given on p. 110) is north of Joe Widdicombe's, in the southern part of T. 7 N., R. 16 E. Although the Kootenai formation (of Lower Cretaceous age directly underlying the Colorado shale) is well exposed in each of these small uplifts, there appears to be some doubt as to whether erosion has cut deep enough to expose the uppermost beds of the underlying Morrison (?) formation.

## CRETACEOUS SYSTEM.

### LOWER CRETACEOUS SERIES.

#### KOOTENAI FORMATION.

The Kootenai formation was named after a tribe of Indians who hunted in the southern Canadian Rockies. The name was first proposed by Sir William Dawson to apply to a succession of sandstones, shales, conglomerates, and coal beds and was used in the description of an area located along the Rocky Mountain front range in Alberta between the fortieth parallel and Medicine Bow River.

In a report by Weed [1] about 300 feet of beds, chiefly sandstones and constituting what he called the "Cascade formation," in the Great Falls region of Montana were regarded as of Kootenai or Lower Cretaceous age. Fisher [2] demonstrated not only that the Kootenai rocks in Montana are much thicker than had been previously supposed but that they probably constitute all the sediments between the Morrison (?) formation and the Colorado shale and that the Dakota sandstone is absent in the vicinity of Great Falls. In the Big Horn Mountain region of northern Wyoming, about 100 miles south of this field, rocks which have the same stratigraphic position and which are similar lithologically have been designated the Cloverly formation by Darton,[3] and that name was later used in the same sense by Fisher.[4] In his report on the coal-bearing Kootenai formation Fisher [5] shows the character of the formation by means of several stratigraphic sections measured near Great Falls, in the Judith Basin and Musselshell regions, and in the Big Horn Basin. His published sections show that the formation ranges in thickness from about 300 to 550 feet.

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

[2] Fisher, C. A., Southern extension of the Kootenai and Montana coal-bearing formations in northern Montana: Econ. Geology, vol. 3, pp. 77-99, 1908.

[3] Darton, N. H., Geology of the Bighorn Mountains: U. S. Geol. Survey Prof. Paper 51, 1906.

[4] Fisher, C. A., Geology and water resources of the Bighorn Basin, Wyo.: U. S. Geol. Survey Prof. Paper 53, 1906.

[5] Fisher, C. A., Southern extension of the Kootenai and Montana coal-bearing formations in northern Montana: Econ. Geology, vol. 3, pp. 77-99, 1908.

Erosion has not progressed sufficiently to expose the Kootenai formation in the Lake Basin field, but at least a part of the formation is exposed in a small eroded dome about 15 miles to the northwest, between the American Fork and Fish Creek, where, according to Bowen,[1] the following section was measured:

*Section in the small eroded dome in the NW. ¼ sec. 35, T. 7 N., R. 16 E.*

| | Feet. |
|---|---|
| Sandstone, irregularly jointed at base, quartzitic at base; forms the outer hogback of the Kootenai formation | 45 |
| Shale, drab to greenish gray | 45 |
| Shale, maroon and white, with sandy layers | 31 |
| Sandstone, white, concretionary; thickness variable | 2 |
| Shale, maroon to grayish white | 16 |
| Sandstone, ledge maker, concretionary, brown | 5 |
| Shale, maroon and white alternating, containing brown sandstone nodules and calcareous concretions | 75 |
| Sandstone, reddish brown; thickness variable | 3 |
| Shale, light gray, slightly maroon at top | 13 |
| Shale, maroon | 15 |
| Shale, clay, dark colored; bakes and cracks when dry. Small irregular limestone nodules near top | 45 |
| Sandstone, only partly exposed. | |
| | 295 |

During the summer of 1916 C. J. Hares measured the Cloverly formation (in part at least of Kootenai age) along Bridger Canyon in T. 7 S., R. 24 E. The nature and relation of the beds are shown in the following stratigraphic section:

*Section of Cloverly formation in T. 7 S., R. 24 E.*

| | Feet. |
|---|---|
| Sandstone and shale interbedded; sandstone micaceous, in paper-thin beds, in places cross-bedded, light buff to greenish yellow, marked by great number of worm burrows or tracks; shale light colored and sandy; at the top are great numbers of small rounded balls which contain phosphatic material and are pseudomorphs after marcasite. This member is ridge-forming and contains at the bottom the Greybull sandstone member | 127 |
| Shale, brilliantly colored, containing great numbers of gastroliths and a few bones. The different colors give the shale a banded effect and are well exposed in Rainbow Butte, just north of Bridger Canyon | 95 |
| Conglomerate, composed mostly of black chert pebbles 2 inches or less in diameter containing Paleozoic fossils. Toward the top the conglomerate becomes sandy and contains fewer pebbles. The conglomerate forms cliffs on each side of Bridger Canyon | 35 |

[1] Bowen, C. F., unpublished manuscript.

## UPPER CRETACEOUS SERIES.

### COLORADO SHALE.

In the Lake Basin field only a few hundred feet of the Colorado is exposed, but from a small number of well logs in this field and from well logs and exposed sections of the Colorado in neighboring fields it is evidently made up for the most part of shale.

In the preparation of a report outlining the possibilities of oil and gas in the Lake Basin field it is of the utmost importance to determine to what extent sands are present in the Colorado shale, for these sands afford the principal sources of oil and gas in north-central Wyoming. Unfortunately only four records of deep wells which furnish information regarding the lower portion of the Colorado shale in this region are available, and one of these wells is outside of the Lake Basin field. For this reason it seems almost impossible to convey an adequate notion of the probable lithology of the lower half of the Colorado shale in the Lake Basin field without showing the conditions in adjacent fields. The character of the Colorado shale is indicated by a number of stratigraphic sections, included in Plate XVII (in pocket). Some of these are detailed stratigraphic sections measured where the Colorado shale is well exposed; others are somewhat generalized to show the composition of the Colorado shale and some of the underlying and overlying beds for certain fields. These sections not only show the stratigraphic position of sands in the shale, but they also indicate those sands which yield the main production of oil and gas as distinguished from others which yield only a small amount, or from which oil and gas are known to issue in the form of springs and seeps. In the preparation of the plate it was necessary to assume horizontality for some horizon—a condition which is, of course, not strictly true. The horizon chosen is the base of the Upper Cretaceous series.

Although it is entirely beyond the scope of an economic report to present a detailed discussion of the stratigraphy of the region represented by these sections, nevertheless there are certain features which ought to be mentioned briefly because of their relation to certain stratigraphic problems presented by the Lake Basin field and because of the possibility of their furnishing a basis for further stratigraphic study.

In examining the sections it is immediately apparent that the principal sands are confined almost entirely to the lower half of the Colorado shale. As shown by the Musselshell Valley section and the well records from the Lake Basin fields there is a progressive lowering of the top of the sandy portion of the Colorado shale in passing from Musselshell River southeastward to Billings. There is a striking similarity between the Musselshell River section and the section measured in the Electric coal field in Park County. Southward from Billings to Bridger and Elk Basin and thence to Cody, on the west side of the Big Horn Basin, the sandy portion of the Colorado becomes much thicker, and the upper shale portion rises very rapidly in the stratigraphic column. From Cody eastward and southward to the central Wyoming area the thickness of the lower sandy portion of the Colorado remains very constant, as indicated by the sections, although there is a great variation in the number and character of the sands from place to place. The Musselshell River section shows two prominent sandstones in the lower portion of the Colorado shale, the upper one of which has a thickness of approximately 200 feet. The few deep well records in the Lake Basin field, however, indicate no such prominent sandstone but rather a series of thin beds considerably lower in the section. It is quite possible that these well records do not represent the true condition in the Lake Basin field, for the sands in the lower part of the Colorado shale throughout north-central Wyoming and central Montana are inclined to be rather lenticular. For example, at Greybull, Wyo., according to Hewett and Lupton,[1] the Frontier formation of the Colorado group contains only two beds of sandstone, but in the southern and western parts of the Big Horn Basin five or six sandstones are present. This fact is clearly brought out in the stratigraphic section measured along Shoshone River near Cody. According to Wegemann,[2] in the interval between the Mowry shale and the Wall Creek sandstone at Salt Creek there are several thin sandstones, which change considerably from place to place. At certain places one is conspicuous and at others another, indicating that the sands are very lenticular. According to Wegemann's report on the Powder River field[3] the shale in that locality, which overlies the Mowry, contains several sandstone beds in its upper part. Wegemann says that these sandstone beds are most variable and that although in the southern part of the Powder River dome four distinct sandstone strata occur below the outcrop of the Wall Creek sandstone, in the northern part only two of these sandstone beds are present, the others apparently having been replaced by shale.

In a recent report on central Wyoming Hares[4] says:

> The Mowry shale is overlain by shale and sandstone that are referred to the Frontier formation, of Upper Cretaceous age. The sandstones, of which there are three distinct divisions corresponding in ascending order to the Peay, an intermediate sand, and the Wall Creek are of medium to fine grain, gray, somewhat massively bedded, and from 20 to 200 feet thick.

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[1] Hewett, D. F., and Lupton, C. T., Anticlines in the southern part of the Big Horn Basin, Wyo.: U. S. Geol. Survey Bull. 656, 1917.

[2] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, 1911.

[3] Wegemann, C. H., The Powder River oil field, Wyo.: U. S. Geol. Survey Bull. 471, p. 63, 1912.

[4] Hares, C. J., Anticlines in central Wyoming: U. S. Geol. Survey Bull. 641, p. 246, 1916.

According to Hares [2] these sandstones can generally be recognized, although they vary a great deal from one place to another.

As stated in a preceding paragraph, only a few hundred feet of the Colorado shale is exposed anywhere in the Lake Basin field. Underlying the lower massive sandstone of the Eagle formation is a belt consisting of sandstones and sandy shales, which merge downward into pure shale. Approximately 90 feet below the base of the Eagle there ordinarily occurs a light-gray sandstone from 15 to 25 feet thick. This sandstone is massive, free from bedding planes, and separated by minor joints into an infinite number of small irregular-shaped masses. This sandstone is in many places capped by a thin slab of reddish-brown sandstone, commonly separated into a series of rectangular blocks by two systems of parallel joints. This resistant cap protects the underlying soft sandstone and gives rise to a well-defined terrace. Here and there a very pronounced checkered appearance is presented for some distance back from the escarpment, owing to the luxuriant growth of vegetation along the joint planes. In the course of the field work the writer collected from this sandstone an undetermined species of *Baculites*, together with fish scales, bones, and teeth, which, according to T. W. Stanton, are probably of Colorado age.

The following stratigraphic sections measured on opposite sides of the Lake Basin field show the nature of the upper 300 or 400 feet of the Colorado shale:

*Section measured down the steep north slope of Locomotive Butte, in sec. 2, T. 4 N., R. 19 E.*

| | Feet. |
|---|---|
| Sandstone, yellowish brown, massive (base of Eagle formation) | 80 |
| Shale, sandy and carbonaceous, and sandstone in distinct belts | 6 |
| Shale, dark gray to black, sandy | 65 |
| Sandstone, yellow, soft | 12 |
| Shale, gray to brownish | 8 |
| Sandstone, shaly, containing large concretions of yellowish-brown sandstone | 17 |
| Shale, dark gray, almost entirely free from sandstone layers | 225 |
| | 413 |

*Section of the upper beds of the Colorado shale along Canyon Creek, in T. 1 N., R. 23 E.*

| | Feet. |
|---|---|
| Shale, gray, with faint bluish tint, soft and flaky; contains much gypsum | 81 |
| Sandstone, gray, coarse grained, soft and somewhat shaly | 22 |
| Shale, grayish, sandy; contains some concretions | 66 |
| Sandstone, gray, thin bedded; ripple marked at top and forms a prominent shelf; contains much gypsum along seams | 11 |
| Shale, light gray with slight bluish tints, very sandy; contains considerable gypsum | 40 |
| | 220 |

[1] Personal communication.

## MONTANA GROUP.

### SUBDIVISIONS.

The rocks of the Montana group, of the late Upper Cretaceous, occupy about nine-tenths of the total area included in the Lake Basin field. The five formational subdivisions of the Montana which are present are, in ascending order, the Eagle sandstone, Claggett formation, Judith River formation, Bearpaw shale, and Lennep sandstone.

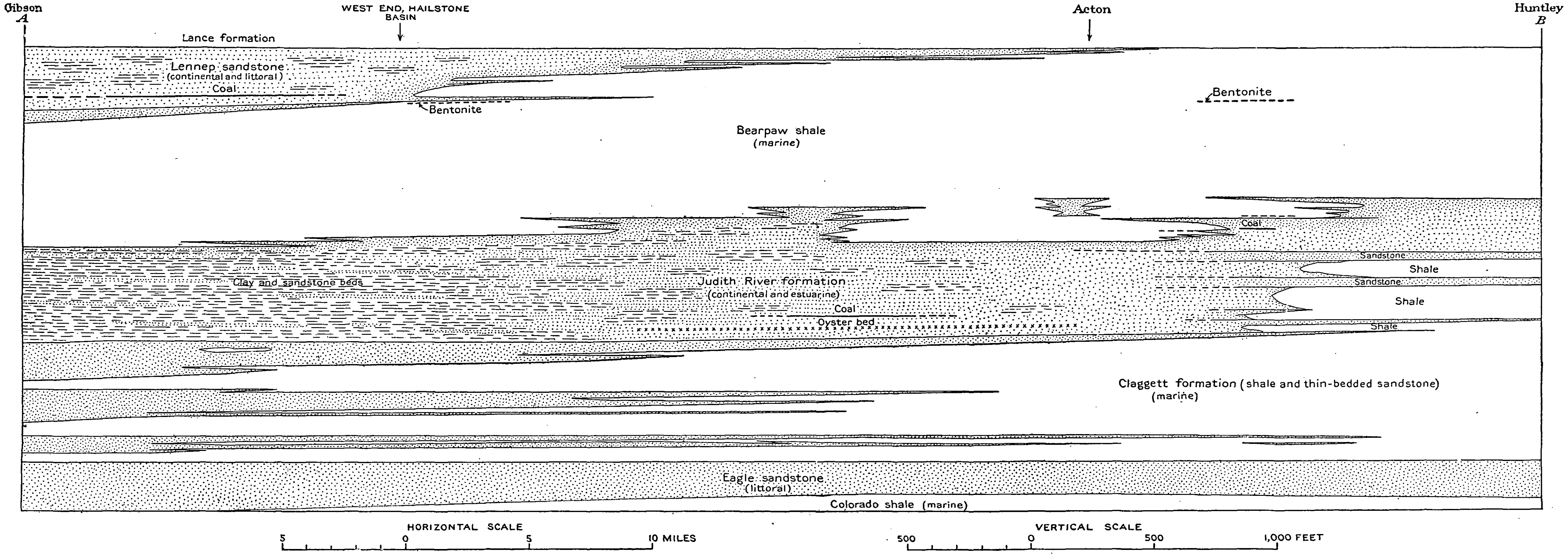
Before entering upon the detailed descriptions the writer desires to call attention briefly to the nonpersistence of the lithologic units. The relationship of these units is more easily understood by referring to the diagrammatic representation on Plate XVIII. Conditions here and elsewhere indicate that the Eagle sandstone represents a wedge of littoral and continental sediments built seaward after the end of Colorado time. The Judith River formation resembles the Eagle in mode of origin, but it is much thicker and exhibits fresh-water and estuarine phases much farther east than the Eagle. The Lennep sandstone represents a third littoral and continental wedge characterized by an abundance of volcanic material among the component sediments. Separating these coastal-plain deposits are the marine shales of the Claggett and Bearpaw formations, indicating oscillatory movements of the shore and a corresponding advance of marine waters. The nonpersistence of some of these formations is brought out in the following detailed descriptions.

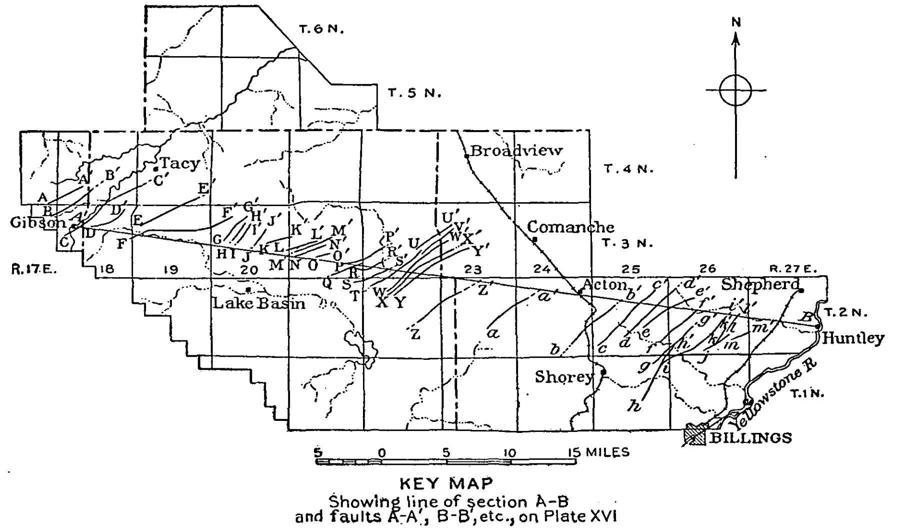
### EAGLE SANDSTONE.

The term Eagle sandstone was used by Weed [1] to apply to the formation overlying the Colorado shale in north-central Montana and typically exposed on Missouri River at the mouth of Eagle Creek, 40 miles below Fort Benton. In the type locality the formation consists of three more or less distinct units—an upper member of thin-bedded sandstone, a middle member of shale, and a lower member of massive ledge-making sandstone. The lower member has been found to be very persistent over a large area in north-central Montana, even where the other members of the formation can not be recognized, and for that reason a name has been adopted by the United States Geological Survey to apply to this member—the Virgelle sandstone member of the Eagle sandstone.

The Eagle sandstone as exhibited in the Lake Basin field resembles that at the type locality in that all three members are generally recognizable. The middle member, however, does not, as a rule, contain very much shale. It is ordinarily composed of belts of thin-bedded shaly sandstone and very sandy and carbonaceous shale, but locally it is made up almost entirely of sandstone. The lower massive sandstone member varies considerably in thickness

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




DIAGRAMMATIC REPRESENTATION OF THE NONPERSISTENCE OF LITHOLOGIC UNITS IN THE LAKE BASIN FIELD, MONT.

but everywhere forms a rim rock surrounding the basins and valleys that have been eroded out of the underlying Colorado shale. The belts of carbonaceous shale in the middle member locally contain thin seams of coal.

At numerous localities throughout this field there occurs near the top of the Eagle sandstone a thin layer of small black chert pebbles. On many of the long dip slopes at the top of the Eagle sandstone there are large numbers of these pebbles. They were observed over the long dip slope in the eastern part of T. 4 N., R. 21 E., and along the main road leading up out of Hailstone Basin toward the east. These pebbles as a rule do not exceed an inch in diameter and are generally flattened in one direction and embedded in a coarse sandy matrix. Their smoothness and uniformly small size indicate perfect separation and transportation for a considerable distance. Similar pebbles were observed in the Claggett formation about 125 feet above the base in T. 4 N., R. 22 E., but the pebbles are not so well rounded as those at the top of the Eagle.

The following sections of the Eagle formation measured at two widely separated localities indicate the composition of the formation in this field:

*Section of the Eagle sandstone along Canyon Creek, in the southern part of T. 1 N., R. 23 E.*

| | Feet. |
|---|---|
| Sandstone, gray, commonly massive but locally very thin bedded.... | 51 |
| Sandstone, for the most part thin bedded but with some massive layers. Belts of sandstone alternate with belts of sandy shale, forming a succession of ledges with grassy slopes between. Locally almost the entire interval is a massive sandstone continuous with that below, forming a sheer cliff. Some brown to black carbonaceous shale was noted 52 feet above the base.................... | 101 |
| Sandstone, gray, weathering yellowish, massive, medium to coarse grained, hard, resistant; forms prominent cliff, especially where it is the rim rock of all the prominent coulees.................. | 91 |
| | 243 |

*Section of the Eagle sandstone a quarter of a mile west of main wagon road, in sec. 4, T. 4 N., R. 19 E.*

| | Feet. |
|---|---|
| Interval, not well exposed, probably shaly sandstone or sandy shale; forms a broad, gentle slope extending down from crest of hill.................................................... | 20 |
| Sandstone, thin bedded............................................ | 10 |
| Sandstone, massive; forms a vertical cliff.......................... | 35 |
| Shale, carbonaceous................................................ | 2½ |
| Sandstone, in thin shaly layers; exhibits much cross-bedding; contains some carbonaceous materials............................... | 40 |
| Shale, sandy, and shaly sandstone; forms a terrace................. | 22 |
| Sandstone, yellowish brown......................................... | 15 |
| Shale, sandy, carbonaceous......................................... | 10 |
| Sandstone, yellowish brown, massive................................ | 63 |
| | 217½ |

## CLAGGETT FORMATION.

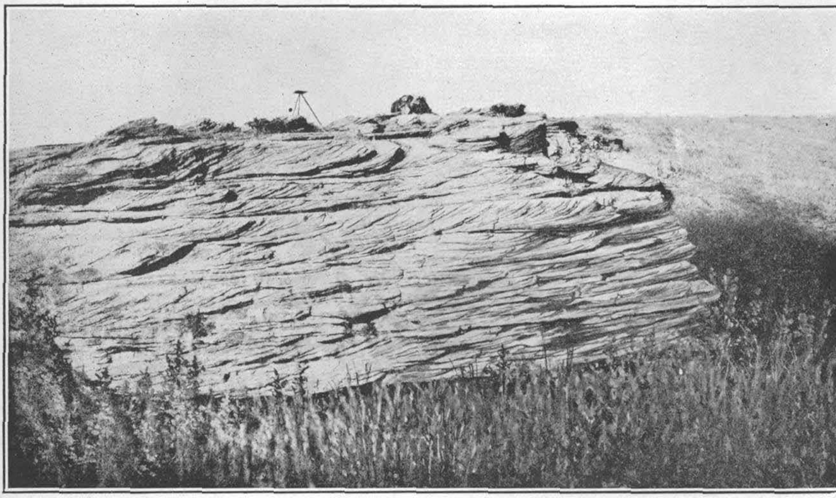
The name Claggett was given by Stanton and Hatcher [1] to the formation overlying the Eagle sandstone. The name was adopted because the formation is well exposed in the neighborhood of Judith (old Fort Claggett), on Missouri River, the type locality. The relation of the Claggett formation to the underlying Eagle sandstone in the Lake Basin field indicates a sudden change from conditions resulting in the deposition of coarse sand to those under which fine sands and silts were the predominant sediments. That all these sediments were laid down in comparatively shallow water seems reasonably certain. The strand origin of the upper portion of the Eagle sandstone is indicated by the coarse grain of the sandstone, the numerous impressions of the fossil seaweed *Halymenites major*, the presence of false bedding, as shown in Plate XIX, *A*, and the almost universal distribution of small flattened chert pebbles near the top of the formation; whereas the shallow-water origin of the sandy shales and thin-bedded sandstones of the Claggett formation is indicated by the presence of ripple marks at several horizons in the formation. The Claggett formation in the Lake Basin field consists of belts of sandy shale alternating with those of thin-bedded sandstone, but the proportion of sand appears to decrease rapidly from southwest to northeast across the field. The following stratigraphic section measured along the valley of Canyon Creek shows an abnormal development of the sandstone belts, but farther east along the Yellowstone these belts are scarcely recognizable.

*Section of the Claggett formation along the valley of Canyon Creek, in T. 1 N., R. 23 E.*

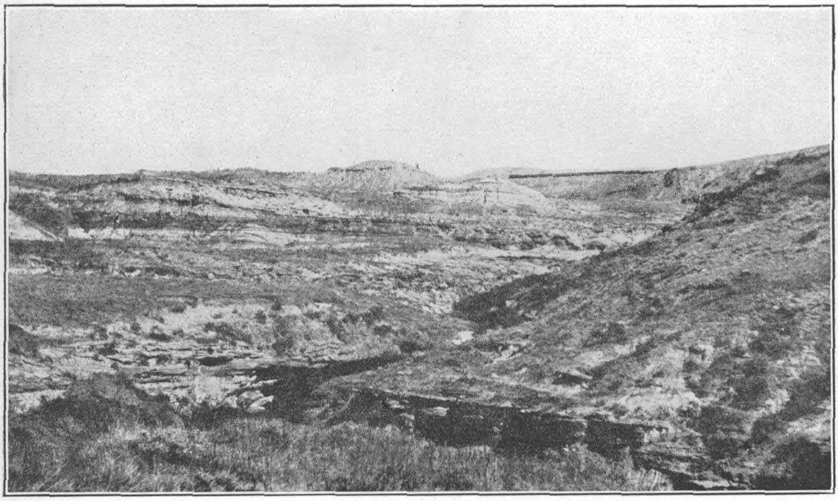
| | Feet. |
|---|---|
| Shale, soft, flaky, including a few concretions. Thin layers of sandstone near the top show ripple marks | 152 |
| Sandstone, gray, thin bedded; includes a few thin bands of interbedded shale | 79 |
| Shale, gray, soft, flaky | 38 |
| Sandstone, gray, thin bedded; forms a bench | 6 |
| Shale, soft, flaky; contains some gypsum; includes a few concretions and also some very thin sandstones | 93 |
| Sandstone, gray, mostly thin bedded but with some massive layers, coarse grained; forms a prominent bench | 50 |
| Shale, the upper part sandy | 50 |
| Sandstone, thin bedded; contains some interbedded shale | 21 |
| Shale, gray, sandy; contains a few thin sandstones | 78 |
| | 567 |

The Claggett formation is exposed chiefly in the northern and southeastern parts of the field, where it borders the uplifts of Eagle

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



*A*. FALSE-BEDDED EAGLE SANDSTONE CUT OFF BY A FAULT IN THE SE. ¼ SEC. 23, T. 3 N., R. 22 E., MONT.



*B*. THE JUDITH RIVER FORMATION AS IT IS EXPOSED IN THE VERY MUCH DISSECTED AREA 1½ MILES SOUTH OF ACTON, MONT.

sandstone. The formation, being composed largely of shale and thin-bedded sandstone, is much less resistant than the underlying massive Eagle sandstone and somewhat less so than the overlying Judith River beds. Where the dip is very low the Claggett commonly underlies a comparatively low, more or less even surface extending from the Eagle sandstone escarpment back to the line of low hills formed by the lower prominent sandstones of the Judith River formation. The base of the Judith River formation was drawn at the base of these sandstones because they mark a change in lithology and because a collection of fossils from the sandstones in sec. 1, T. 6 N., R. 16 E., examined by T. W. Stanton, were said by him to suggest Judith River beds rather than anything older. Where the Claggett formation dips rather steeply the alternating belts of shale and sandstone are expressed topographically by a succession of narrow strike valleys separated by narrow, jagged ridges.

### JUDITH RIVER FORMATION.

The Judith River formation overlies the Claggett formation and underlies the Bearpaw shale. The name Judith River was first given by Hayden[1] in 1871 to a group of sediments occurring in "Judith Basin," on Missouri River, which contain beds of lignite, fresh-water Mollusca, leaves of deciduous trees, and particularly a great number and variety of curious reptilian remains. For convenience of mapping and because of lithologic similarity, there is included at the base of the Judith River formation in the Lake Basin field, a sandstone which seems to be the approximate equivalent of the sandstone included in the top of the Claggett formation in its type area and in the eastern part of the Big Horn Basin. The Judith River differs very materially in character in the extreme western and extreme eastern part of the Lake Basin field. Near Gibson the formation is of fresh-water origin and consists of sandy shale and numerous beds of quartzitic sandstone containing abundant plant remains. The sandy shales and sandstones all contain tuffaceous material, which was poured out abundantly by the volcanoes of the Crazy Mountains. The presence of this constituent imparts to some of the softer units a rather striking yellowish-brown color. Toward the east the proportion of volcanic material decreases and the section gradually approaches that exhibited along Missouri River, in which there is an alternating series of light-colored sandstones, light-gray to white clay shales, and black carbonaceous shale, giving the exposures a very striking banded appearance, as shown in Plate XIX, *B*. The following stratigraphic section measured 1½ miles south of Acton includes the beds shown in the view.

[1] Hayden, F. V., Geology of the Missouri Valley: U. S. Geol. Survey Terr. Fourth Ann. Rept., p. 97, 1871.

*Section of the Judith River formation about 1½ miles south of Acton, Mont.*

| | Ft. | in. |
|---|---|---|
| Sandstone, white, soft | 3 | |
| Shale, brown, carbonaceous | 1 | |
| Sandstone, white, loosely consolidated, weathers into fantastic forms | 12 | |
| Shale, gray, sandy, contains two 3-inch seams of coal | 27 | |
| Sandstone, white, loosely consolidated; contains iron concretions | 10 | |
| Sandstone, light yellowish brown, cross-bedded | 12 | |
| Shale, light yellow, very sandy; contains some iron concretions | 10 | |
| Shale, sandy, contains carbonaceous material | 12 | |
| Shale, brown to black, carbonaceous | 3 | |
| Shale, bluish gray | 2 | 6 |
| Shale, reddish brown, carbonaceous | 5 | |
| Shale, black, carbonaceous | 2 | 1 |
| Sandstone, white, soft, loosely consolidated | 6 | |
| Shale, black, carbonaceous | | 6 |
| Shale, gray, with some streaks of brown sand | 22 | |
| Shale, very black, contains some thin streaks of coal | 2 | 2 |
| Sandstone, light yellow, soft, in places shaly | 15 | |
| Shale, brown to black, carbonaceous | 18 | 3 |
| Shale, light gray, very sandy, in places soft sand; contains some large iron concretions | 27 | |
| Sandstone, very white, soft; contains several layers of iron concretions | 12 | |
| Shale, black, carbonaceous | 3 | |
| Sandstone, thin bedded | 1 | 4 |
| Shale, gray, sandy | 1 | 1 |
| Shale, brown to black, carbonaceous | 1 | |
| Sandstone, light yellow, massive | 9 | 6 |
| Shale, black, carbonaceous | 1 | |
| Shale, gray | 7 | |
| Layer of iron concretions | | 6 |
| Sandstone, soft, thin bedded; exhibits much cross-bedding | 15 | |
| Sandstone, light yellow, massive | 45 | |
| Shale, gray | 19 | |
| Oyster bed | 1 | 1 |
| Sandstone, light yellow, soft | 10 | |
| Shale, bluish gray | 3 | |
| Basal portion of Judith River not exposed, estimated | 75 | |
| | 395 | |

With the advent of the carbonaceous belts in the section the brackish-water shell *Ostrea subtrigonalis* also makes its appearance at several different horizons in the area immediately north of Broadview, and it is present in one very thick shell bed of extraordinary uniformity and persistence of development about 50 feet above the basal sandstone of the formation.

As the above section clearly shows, the formation at Acton presents its usual appearance and lithology, but east of Acton there is a very rapid change in the character of the sediments, for within a distance of 5 or 6 miles the individual sandstone members increase in thickness from 10 or 15 feet to 50 feet, and in consequence the formation as exposed about 6 miles east of Acton consists of four massive sandstones separated by intervals of shaly sandstone or sandy shale. (See Pl. XVIII, p. 114.) These sandstones contain abundant impressions of the fossil seaweed *Halymenites*, indicating strand conditions. The more typical section farther west, however, including numerous beds of carbonaceous shale, layers of brackish-water Mollusca, leaves, fossilized wood, and bones of land animals, suggests coastal-plain deposition. Aside from the beds of *Ostrea subtrigonalis* mentioned above the following species of leaves and bones were collected from the Judith River formation during the field work:

Sequoia reichenbachi (Geinitz) Heer.
Castalia stantoni Knowlton.
Populus cretacea Knowlton.
Diospyros judithae Knowlton.
Populites amplus Knowlton.
Carpites sp.
Trapa? microphylla Lesquereux.
Cunninghamites elegans (Corda) Endlicher.
Asplenium? sp.
Woodwardia sp.
Dryopteris? sp.
Dammara sp.
Woodwardia crenata Knowlton?
Ferns, two species.
Ficus wardii Knowlton?

The following is a list of the vertebrate fossils obtained from the Judith River formation during the field work:

Fragment of limb bone of a dinosaur; not determinable.
Various fragments of dinosaur bones; none determinable.
Scapula and coracoid of a ceratopsian dinosaur.

The Judith River formation occupies for the most part a comparatively narrow belt extending from northwest to southeast across the central part of the field. It rests conformably upon the Claggett formation and completely surrounds the area of older rocks in the north-central part of the field, at the same time dipping beneath the soft shales of the Bearpaw formation. In the western part of Lake Basin denudation has progressed sufficiently to expose the upper sandstones of the formation along the principal streams.

The area underlain by the Judith River beds is generally somewhat elevated in comparison with that underlain by the overlying and underlying shales. Where the formation presents a typical Judith River aspect the sandstones are not hard and resistant enough to result in any very pronounced topographic features, but in the eastern part of the field, where the sandy layers attain an abnormal development, and toward the west, where the volcanic constituent is abundant, high ridges and escarpments are more noticeable.

### BEARPAW SHALE.

Overlying the fresh-water and brackish-water beds of the Judith River formation is approximately 500 feet of marine shale. This, the Bearpaw shale, was named from the Bearpaw Mountains by Stanton and Hatcher,[1] who determined its stratigraphic relations. It is difficult in this field to determine the thickness of the Bearpaw shale very accurately, but measurements outside of the field appear to indicate a gradual thinning of the marine shale from about 1,000 feet on Big Elk Creek to 100 feet near Bridger, so that in all probability the Bearpaw decreases gradually in thickness from the northwestern part of the Lake Basin field toward Billings. The rapid lateral variation in the Bearpaw shale will be better appreciated when its relations to the overlying and underlying beds are clearly understood, and for that reason those relations are described in considerable detail.

In tracing the Bearpaw-Lennep contact from the Lake Basin field northwest to Fish Creek it was found that in the upper part of the Bearpaw in sec. 21, T. 5 N., R. 17 E., a sandstone appears abruptly from 30 to 50 feet below the lower basal white sandstone of the Lennep farther south. In going northwest toward Fish Creek the rocks in the 30 to 50 foot interval between the two sandstones gradually change from marine shale to shale containing numerous sandy concretions and fragments of plants and finally to sandstone not unlike those above and below.

In the SE. ¼ sec. 31, T. 2 N., R. 20 E., a rather prominent shelf indicates the appearance of another sandstone in the Bearpaw shale about 160 feet below the top of the formation. This sandstone was traced southeastward around Battle Butte to the southwestern part of T. 1 N., R. 21 E., where it is represented by about 30 feet of hard sandstone that caps a long slope for approximately 2 miles down the dip.

The relations of the marine shale to the underlying fresh-water and brackish-water beds of the Judith River formation are by all means the most striking. In the NW. ¼ sec. 33, T. 3 N., R. 19 E., the lower 50 feet of the Bearpaw consists of very sandy shale, above which occurs a similar thickness of pure shale from which a dinosaur was obtained, together with numerous baculites. The white sandstone mapped as the top of the Judith River formation was traced almost continuously from sec. 3, T. 2 N., R. 19 E., to sec. 5, T. 2 N.,

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

R. 20 E. In sec. 3 it is overlain by shale, but in sec. 5 it is overlain by an almost continuous succession of sandstone beds up to the top of Twin Buttes, an interval estimated to be about 150 feet. The upper 113 feet 10 inches of these sandstones is shown in the following stratigraphic section:

*Section showing the sandy phase of the Bearpaw shale at Twin Buttes, in sec. 16, T. 2 N., R. 20 E.*

| | Ft. | in. |
|---|---|---|
| Sandstone, yellowish, lithologically much like the Lennep sandstone, commonly cross-bedded, massive; contains an abundance of concretions near the top; forms top of Twin Buttes | 20 | |
| Shale, bluish, hard, sandy | 1 | |
| Sandstone, yellowish, coarse, in thin beds; weathers yellowish brown | 9 | |
| Sandstone, yellowish, massive, coarse; contains *Halymenites* and worm borings | 9 | |
| Sandstone, rather thin bedded; includes belts of bluish fissile fine-grained sandstone | 10 | 6 |
| Sandstone, fairly hard, light yellowish, massive; contains abundant *Halymenites* | 5 | |
| Sandstone, argillaceous, thin bedded; yields fragments of petrified wood and broken dicotyledons | 1 | 4 |
| Sandstone, fairly soft, white, locally in massive beds but grading laterally into thin-bedded sandstone, commonly cross-bedded | 22 | |
| Sandstone, light colored, soft, false bedded in places; weathers dark; constituent grains locally coarse; on weathering leaves harder rusty concretions that form a well-defined terrace south of Twin Buttes; dark stems and leaves of grasses or sages abundant near the base | 26 | |
| Slope, mainly concealed, probably light-colored soft sandstone | 10 | |
| | 113 | 10 |

Near the base of the sandstone phase of the Bearpaw is a belt of carbonaceous shale which locally contains some thin lignite beds. At one locality in the S. ½ sec. 29, T. 2 N., R. 20 E., the cover has been removed and the lignite mined out from an area approximately 100 by 200 feet in extent. At the open pit the following section was measured:

*Section of Bearpaw shale in the S. ½ sec. 29, T. 2 N., R. 20 E.*

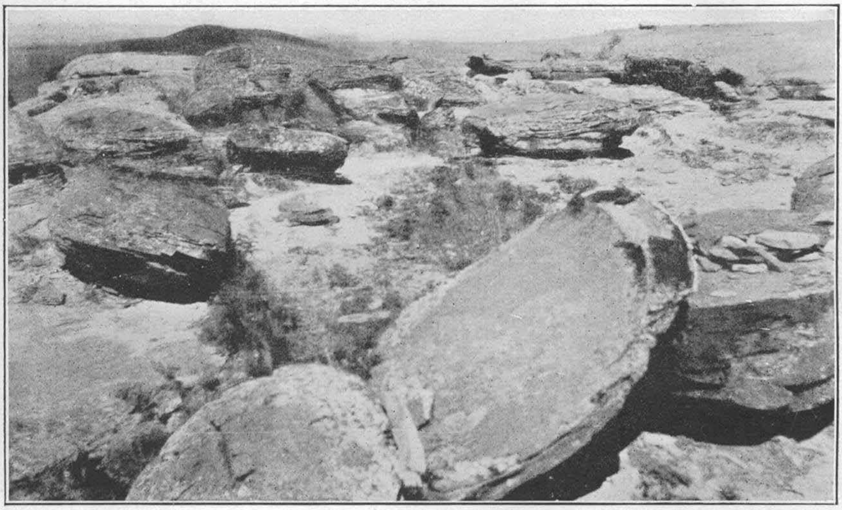
| | Ft. | in. |
|---|---|---|
| Shale, dark | 3 | 6 |
| Shale, hard, stained dark red | 1 | 5 |
| Shale, carbonaceous | | 5 |
| Ash | | 6 |
| Shale; contains some bone | | 7 |
| Lignite, fair | | 10 |
| Bone | | 6 |
| Lignite, dirty | | 4 |
| Lignite | | 11 |
| | 9 | 0 |

A 14-inch bed of lignite was reported 14 feet below the surface.

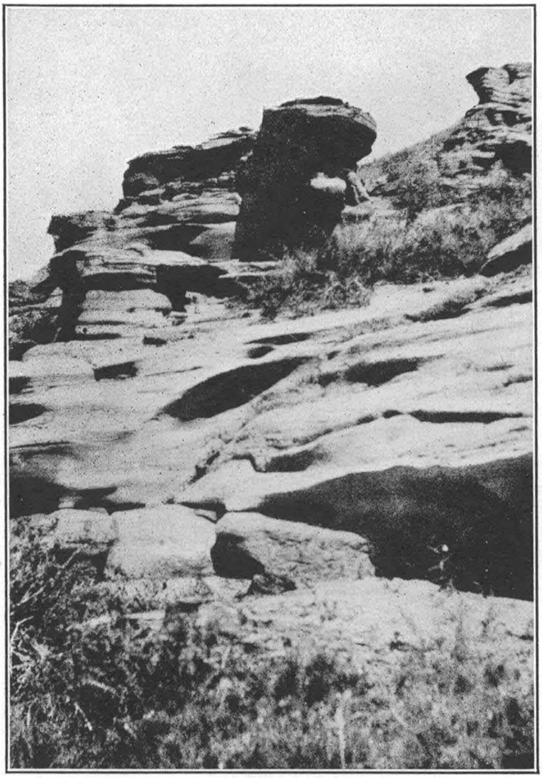
Certain other remarkable features of the Bearpaw shale occur in the vicinity of Big Lake and in the south half of T. 1 N., R. 21 E. Long, narrow ridges capped by hard andesitic sandstone extend for considerable distances, mostly in an east-west direction. These ridges may owe their existence to the remnants of a once continuous sandstone, for most of them appear to be at about the same level, but presumably the sandstone was never laid down over the intervening areas. The ridges are, however, made up of rocks so similar lithologically that they are in all probability the products of the same agency. The section below these sandstones differs materially from one locality to another. At certain places sandy beds containing carbonaceous shale and lignite occupy the entire interval down to the more typical Judith River beds, while elsewhere, even in the same ridge, the sandstone overlies typical Bearpaw shale. The following stratigraphic section measured north of Antelope Point, in secs. 22 and 27, T. 1 N., R. 21 E., shows the nature of the Bearpaw from the upper prominent ledge-making sandstone down to and including the prominent sandstone which forms the cap for the long ridges.

*Section of a part of the Bearpaw shale in secs. 22 and 27, T. 1 N., R. 21 E.*

| | Ft. | in. |
|---|---|---|
| Sandstone, hard; thickness indeterminate but abundant fragments cover the hilltop. | | |
| Shale, clayey, white, more or less sandy, apparently very siliceous | 28 | |
| Sandstone, quartzitic, hard, separated into rectangular slabs by jointing | 5 | |
| Sandstone, thin bedded, with shale partings; merges downward into shale; contains impressions suggestive of *Halymenites;* prominent ledge-making sandstone in the NW. ¼ sec. 27 | 6 | |
| Shale, bluish, fissile; contains the following typical Bearpaw invertebrates about 75 feet below the top: *Leda scitula* Meek and Hayden, *Lucina* sp., *Mactra gracilis* Meek and Hayden, *Dentalium* sp., *Lunatia* sp., *Baculites compressus* Say | 165 | |
| Conglomerate composed of gray matrix, in part firmly cemented, in part friable; contains mud balls and occasional gray, black, and yellowish chert pebbles half an inch or less in diameter; also many kidney-shaped ferruginous masses; very imperfectly bedded and merging upward into sandy shale | 9 | |
| Shale, yellow, sandy | 20 | |
| Shale, carbonaceous to bony; contains lignite, thin beds of sandstone, and abundant petrified wood (lignite belt of sec. 27) | 6 | |
| Sandstone, yellowish, fairly hard; weathers into thin slabs | 1 | 4 |
| Shale, fissile, carbonaceous | 8 | |
| Sandstone, yellowish, soft, false bedded, somewhat andesitic. | 7 | |



*A.* SANDSTONE AT TOP OF RIDGE IN BEARPAW SHALE NEAR SECTION LINE BETWEEN SECS. 33 AND 34, T. 2 N., R. 21 E., MONT.



*B.* BASAL PORTION OF RIDGE-FORMING SANDSTONE IN BEARPAW SHALE NEAR MIDDLE OF SEC. 35, T. 2 N., R. 21 E., MONT.

| | Ft. | in. |
|---|---|---|
| Shale, fissile, somewhat carbonaceous | 3 | |
| Sandstone, hard, argillaceous; contains plant remains | | 6 |
| Shale, brown to black, fissile | 4 | |
| Sandstone, yellowish, hard; contains plant remains | 1 | |
| Shale, rather carbonaceous, especially near the top | 5 | |
| Sandstone, tuffaceous, hard, dark, false bedded; breaks into thin irregular slabs; contains mud balls, fragments of petrified wood, and other plant remains near the top (cap sandstone of long ridge) | 17 | |
| Sandstone like that below but without concretions | 13 | |
| Sandstone, light colored when unweathered but rapidly weathering to a yellowish-brown color, rather soft and coarse-grained; occurs in thin layers which are sweepingly false bedded, seeming to indicate stream action. In this section are developed great numbers of hard concretions that weather to a yellowish-brown color and split horizontally into thin disklike masses. These concretions mark a broad zone of outcrop and in places stand on pinnacles of softer matrix | 20 | |
| | 318 | 10 |

One of the most prominent ridges extends from sec. 30, T. 2 N., R. 21 E., southeastward to sec. 10, T. 1 N., R. 22 E. Near the center of sec. 35, T. 2 N., R. 21 E., about 86 feet of rather soft light-yellow massive sandstone is exposed beneath a thin cap of hard reddish-brown, somewhat tuffaceous sandstone. The lower 50 feet of the sandstone is characterized by the absence of bedding and the presence of large reddish-brown concretionary masses, the appearance of which is shown in Plate XX, *A* and *B*. The capping sandstone of this ridge dips west at a very small angle beneath the flat area underlain by shale and the more recent alluvial deposits. One of these peculiar sandstones of the Bearpaw caps the long ridge whose east end is known as Gray Hill, in sec. 20, T. 2 N., R. 22 E. A well at the house a short distance southwest, about 30 feet below the capping sandstone, is reported to have penetrated about 120 feet of almost continuous sandstones.

The uppermost beds in the stratigraphic section of the Judith River formation measured 1½ miles south of Acton and given on page 118 are overlain by about 150 feet of dark-gray shale containing thin layers of sandstone. It is believed that careful search would reveal marine fossils in this shale and that it marks the influx of marine waters, although the shale is overlain by 85 feet of almost pure sandstones that dip steeply eastward beneath the great body of marine shale occupying the valley down which the main Acton-Billings road passes. Owing to the very peculiar development of fresh-water and brackish-water sandstones in the Bearpaw shale it has been thought best to show in the following lists not only the different species of marine fossils that were obtained from the Bearpaw formation but also the exact locality where each collection was obtained.

NW. ¼ sec. 5, T. 2 N., R. 19 E., in sandy shale about 106 feet below the top of the Bearpaw formation:

Ostrea pellucida Meek and Hayden?
Inoceramus sagensis Owen.
Nucula cancellata Meek and Hayden.
Veniella sp.
Thracia subgracilis Whitfield.
Scaphites nodosus var. plenus Meek and Hayden.

SE. ¼ sec. 32, T. 3 N., R. 19 E., in beds from 100 to 150 feet below the top of the Bearpaw shale:

Baculites compressus Say.

Side of main wagon road on section line between secs. 13 and 24, T. 3 N., R. 19 E.:

Avicula linguaeformis Evans and Shumard.
Lunatia sp.
Baculites compressus Say.

NW. ¼ sec. 27, T. 1 N., R. 21 E., in the shale shown in the stratigraphic section measured north of Antelope Point (p. 122):

Leda scitula Meek and Hayden.
Lucina sp.
Mactra gracilis Meek and Hayden.
Dentalium sp.
Lunatia sp.
Baculites compressus Say.

West line of sec. 34, T. 1 N., R. 21 E., on the shale slope below the prominent bench of sandstone south of Antelope Point:

Ostrea sp.
Lunatia sp.
Baculites compressus Say.
Portions of the vertebra of a large plesiosaur.

In general the Bearpaw formation occupies a low-lying area between the slightly elevated portion of the field underlain by the older rocks and the escarpment formed by the overlying Lennep sandstone. It occupies the greater part of Lake Basin and a long, narrow belt extending from Broadview southeast to Huntley

### LENNEP SANDSTONE.

The name Lennep sandstone was adopted by Stone and Calvert[1] for a group of andesitic beds which lie stratigraphically between the Bearpaw shale and the Lance formation along the north flank of the Crazy Mountains. Lennep, from which the formation takes its name, is a station on the Chicago, Milwaukee & St. Paul Railway at the north end of the Crazy Mountains, in the immediate vicinity of a ridge formed by these beds. In the type locality the Lennep sandstone is composed of dark-colored tuffaceous sandstone intercalated with dark shale, and at several places near the middle a band of

[1] Stone, R. W., and Calvert, W. R., Stratigraphic relations of the Livingston formation of Montana Econ. Geology, vol. 5, p. 746, 1910.

brown nodules 8 to 12 inches in diameter was observed. It occupies the approximate stratigraphic position of the Fox Hills sandstone, but its lithology is different and it lacks the characteristic Fox Hills fauna. It is transitional from the marine Cretaceous to the fresh-water "*Ceratops* beds" (Lance formation).

There is a very rapid thinning and also a marked change in the character of the Lennep formation from west to east across the Lake Basin field. In sec. 28, T. 4 N., R. 18 E., it can be readily separated into three belts. The lower belt consists of about 35 feet of massive light-colored and in places false-bedded sandstone. This belt is overlain by one of light yellowish-brown andesitic rock, and this in turn by an upper rim of very tuffaceous material. A thin coal bed was observed a short distance above the lower light-colored sandstone near the coulee south of the house in sec. 30, T. 4 N., R. 18 E., in secs. 34 and 36, T. 4 N., R. 18 E., and in secs. 4 and 5, T. 3 N., R. 19 E. The details of the Lennep formation in the northwestern part of the field are shown in the following stratigraphic section:

*Section of the Lennep sandstone in sec. 29, T. 4 N., R. 18 E.*

| | Ft. | in. |
|---|---|---|
| Tuff, dark colored, hard, underlying Lance beds | 1 | |
| Sandstone; weathers to a dark rusty color; contains numerous concretions | 4 | |
| Shale, sandy | 8 | |
| Sandstone, grayish; bedding fairly well defined | 1 | |
| Shale, sandy, tuffaceous | 4 | |
| Tuff, dark, thin bedded; weathers out, leaving dark concretionary masses | 5 | |
| Shale, sandy | 10 | |
| Sandstone; readily breaks out into slabs | | 6 |
| Shale | 8 | |
| Sandstone, fairly massive and light colored, irregularly bedded | 14 | |
| Concealed | 8 | |
| Sandstone, light colored, massive, fairly hard | 2 | 6 |
| Tuff, sandy, light yellowish brown | 18 | |
| Sandstone, dark, hard, tuffaceous | 1 | |
| Tuff, yellow, sandy, soft | 43 | |
| Tuff, yellow, more resistant than the bed above; forms a ledge | 6 | |
| Tuff, soft, sandy, yellowish brown | 25 | |
| Tuff, hard, in places very massive; commonly forms the top of the Lennep ridge | 16 | |
| Tuff, fairly soft, sandy; contains bone fragments | 48 | |
| Sandstone, friable, irregularly bedded | 6 | |
| Sandstone, hard | | 8 |
| Shale, yellowish, sandy; contains some andesitic material | 27 | |
| Sandstone, hard, argillaceous; forms distinct beds; contains plant remains | 3 | |
| Sandstone, gray, massive bedding, extremely irregular; shows channeling at the base; rusty concretionary masses prominent | 44 | |
| Sandstone, thin bedded, merging downward into Bearpaw shale | 10 | |
| | 313 | 8 |

The thickening of the Lennep toward Fish Creek by the development of sandstones in the top of Bearpaw shale is mentioned on page 120. The section is known to be much thinner in the scarp immediately west of Shorey Basin, in sec. 3, T. 3 N., R. 19 E., and east of Comanche the Lennep beds can scarcely be recognized. In sec. 28, T. 5 N., R. 23 E., the following section was recognized immediately above the Bearpaw shale:

*Section of basal part of Lennep sandstone in sec. 28, T. 5 N., R. 23 E.*

| | Feet. |
|---|---|
| Sandstone, gray, thin bedded | 5 |
| Sandstone, gray, massive | 10 |
| Shale, gray to buff, containing belts of greenish-yellow, apparently slightly andesitic material | 38 |
| Sandstone, brown, coarse grained, massive, irregularly contorted | 4 |
| Sandstone, reddish brown, coarse grained, very andesitic | 6 |
| | 63 |

Fragments of ceratopsian and dinosaur bones were obtained immediately below the upper sandstone in this section, and a fragment of a turtle plastron and a portion of the frill of a ceratopsian dinosaur were obtained about 200 feet higher up, from the typical Lance beds in sec. 21 of the same township.

It seems quite evident that some of the formation boundaries as determined in the west become higher and higher in the section toward the east, and that the Lennep beds gradually finger out into marine Bearpaw shale. This fact is shown diagrammatically by the generalized stratigraphic section of Plate XVIII (p. 114). The evidence concerning the Bearpaw-Lennep contact is lacking, owing to the extent of denudation, but the evidence concerning some of the lower contacts appears to be conclusive. For example, the the belt of thin-bedded sandstone immediately above the Claggett-Judith River contact around the Broadview dome becomes less and less conspicuous, until near the center of T. 2 N., R. 25 E., it is only from 10 to 15 feet thick. At that point there begins to appear about 40 feet higher up a dark massive Lennep-like tuffaceous sandstone, which gradually thickens and becomes more and more conspicuous toward the southeast. Finally, in sec. 29, T. 2 N., R. 26 E., the belt of thin-bedded sandstones has entirely disappeared and the upper dark sandstone has become very prominent, the entire interval below being occupied by shale. Toward the southeast the dark sandstone gradually loses its identity, and its horizon appears to be occupied by marine shale.

Again, the top of the Judith River formation near Broadview lies about 100 feet below a thin layer of rock in the Bearpaw shale which can generally be recognized by the odor of petroleum which it emits, the interval being occupied by pure shale. Immediately east of Acton the top of the Judith River formation is marked by a massive sandstone which lies about 40 feet below the oil-rock horizon and about 25 feet below the dark tuffaceous sandstone supposed to be the same as the one that caps the ridge near Big Lake. A short distance farther east the Judith River formation contains three or four very massive sandstones, the upper one of which is in direct contact with the tuffaceous sandstone cap. About 100 feet higher, the interval being occupied by pure shale, appears another dark ridge-making sandstone. The intervening shale, however, becomes more and more sandy toward the east, and it seems very probable that along the Yellowstone the interval is occupied by a rather massive sandstone.

The following collections of plants and bones were obtained from the Lennep beds in different parts of the field:

SE. ¼ sec. 1, T. 3 N., R. 17 E., from the base of a massive sandstone in the Lennep sandstone:

Fragments apparently of a ginkgo, a conifer, probably a sequoia, and several dicotyledons.

NE. ¼ sec. 7, T. 3 N., R. 19 E., from a yellowish badland slope near the middle of the Lennep sandstone, near a small fault:

Fragments of teeth of a carnivorous dinosaur; shell fragments of a turtle; bone fragments, none determinable.

Sec. 26, T. 2 N., R. 19 E., from badlands near the middle of the Lennep sandstone:

Fragments of dinosaur bones, none determinable.

NW. ¼ sec. 6, T. 3 N., R. 19 E., about 80 feet below the top of the stratigraphic section measured in sec. 29, T. 4 N., R. 18 E. (p. 125):

Worn fragments of dinosaur bone, none determinable.

Near southwest corner of sec. 34, T. 4 N., R. 18 E.:

A large part of one individual of a turtle belonging to the genus Basilemys.

The Lennep sandstone forms a prominent escarpment along the west margin of the field, but in contrast with the deeply eroded Bearpaw shale it is the most conspicuous as a ridge maker along the west side of Lake Basin. Within the principal fault zone the formation occurs as a series of fault blocks about 13 miles east of the main escarpment. The formation is meagerly represented in the eastern part of the field, occurring only as a narrow ridge of upturned sandstone immediately east of the Bearpaw shale valley in which Broadview is situated.

## TERTIARY (?) SYSTEM.

### LANCE FORMATION.

The name Lance formation is an abbreviated form[1] of "Lance Creek beds," a term used by Hatcher[2] in 1903 to apply to the "*Cera-*

[1] Stanton, T. W., Fox Hills sandstone and Lance formation ("*Ceratops* beds") in South Dakota, North Dakota, and eastern Wyoming: Am. Jour. Sci., 4th ser., vol. 30, p. 172, 1910.

[2] Hatcher, J. B., Relative age of the Lance Creek (*Ceratops*) beds of Converse County, Wyo., the Judith River beds of Montana, and the Belly River beds of Canada: Am. Geologist, vol. 31, p. 369, 1903.

*tops* beds." The name is taken from the principal stream in the region where the beds are best represented, in Niobrara County, formerly part of Converse County, Wyo.

Only a few hundred feet of the Lance formation is exposed in the Lake Basin field. In contrast with most of the other formations of the field, the Lance has a distinctly light-colored aspect, for the reason that it is made up almost entirely of light-yellowish sandstones and bluish to grayish sandy shales. The alternating succession of shales and sandstones is exhibited in the following detailed stratigraphic section:

*Section of a part of the Lance formation in the deep gulch east of the northeast corner of sec. 25, T. 4 N., R. 24 E.*

| | Ft. | in. |
|---|---|---|
| Sandstone, light yellow, very massive | 12 | |
| Shale, bluish to grayish, sandy | 9 | |
| Sandstone, light yellow | 3 | 6 |
| Shale, sandy | 5 | 6 |
| Sandstone, light gray | | 8 |
| Shale, somewhat carbonaceous | 5 | |
| Sandstone, light yellow, massive | 15 | |
| Shale, bluish to gray, sandy | 7 | 9 |
| Sandstone, light gray | 2 | |
| Shale, bluish to grayish, with 6-inch sandstone near middle | 23 | |
| Sandstone, in thin platy layers, with seams of shale | 6 | |
| Shale, bluish to grayish, sandy | 25 | 8 |
| Sandstone, light yellow | 1 | 10 |
| Shale, very sandy, with thin layers of sandstone | 12 | |
| Sandstone, light yellow, lenticular | 10 | |
| Shale, sandy; contains nodules of sandstone | 6 | 6 |
| Sandstone, brown | | 8 |
| Shale, bluish, sandy | 6 | 9 |
| Sandstone, light gray to brownish | 2 | 3 |
| Shale, sandy | 12 | |
| Sandstone, brown, hard | | 5 |
| Shale, bluish | 5 | |
| Sandstone, light gray | 2 | 6 |
| Shale, bluish gray, sandy | 10 | |
| Sandstone, light gray, massive, medium to coarse grained | 15 | |
| Shale, gray, sandy, including seams of gypsum | 1 | 4 |
| Sandstone, yellowish brown, nodular; contains some clay | 3 | 9 |
| Shale, gray, sandy | 2 | |
| Sandstone, light yellowish brown, hard | 2 | |
| Shale, bluish to gray, sandy, containing thin layers of sandstone | 38 | |
| Sandstone, light yellow, moderately hard | 6 | |
| Shale, gray, sandy | 2 | |
| Sandstone, light brown, hard | 2 | |
| Shale, bluish and greenish, sandy | 7 | |
| | 264 | 1 |

The following is a list of the vertebrate and invertebrate fossils collected from the Lance formation during the progress of the field work:

VERTEBRATES.

Sec. 28, T. 5 N., R. 23 E., immediately below the upper sandstone in the strati graphic section on page 126:

Fragments of ceratopsian and dinosaur bones.

Sec. 21, T. 5 N., R. 23 E., about 200 feet above the base of the formation:

A portion of the frill of a ceratopsian dinosaur.

Fragment of a turtle plastron.

INVERTEBRATES.

SE. ¼ sec. 33, T. 4 N., R. 18 E., about 25 feet above the base of the Lance formation:

Unio sp.
Sphaerium sp.
Planorbis (Bathyomphalus) planoconvexus Meek and Hayden?
Thaumastus limnaeformis Meek and Hayden?
Goniobasis tenuicarinata Meek and Hayden.
Goniobasis sp.
Viviparus sp.
Campeloma producta White?

According to T. W. Stanton, "This lot suggests Fort Union rather than anything older. The only species positively identified is found in both Lance and Fort Union, and those identified with a query are not well preserved."

Sec. 21, T. 5 N., R. 23 E., from 200 to 250 feet above the top of the Bearpaw shale:

Unio sp.
Sphaerium sp.
Viviparus sp.
Campeloma? sp. cf. C. producta White.
Physa sp.
Goniobasis tenuicarinata Meek and Hayden.

In regard to this collection Mr. Stanton says: "This lot suggests Fort Union and apparently belongs to the same fauna as lot 17," referring to the collection immediately preceding.

Sec. 17, T. 2 N., R. 25 E., from beds immediately overlying the Bearpaw shale:

Physa sp.
Campeloma sp.
Goniobasis? sp.
Viviparus sp.

Near the center of sec. 5, T. 2 N., R. 26 E., from a mud-ball conglomerate about 50 feet above the base of the Lance formation:

Unio aesopiformis Whitfield.
Unio pyramidatoides Whitfield.
Unio, two or more undetermined species.
Viviparus sp.

According to Mr. Stanton, "The unios are characteristic Lance forms."

The Lance formation occupies a small area in the western part of the field, where it occurs as a series of fault blocks, and also a small area east of Broadview. The predominance of sandstones in this formation, in comparison with the underlying Bearpaw shale, produces in some localities a prominent escarpment.

## RECENT DEPOSITS.

The deposits of recent origin in the Lake Basin field may be separated into two classes, alluvial deposits and terrace gravels. Some of the alluvium occurs as a thin blanket over the lowest parts of Lake Basin and the extensive flats around Comanche. It is probably composed of the fine sediments that have been transported by the intermittent streams during times of flood and discharged into shallow lakes, which have recently become extinct. Another portion of the alluvium is being deposited from time to time over the low flats adjacent to the Yellowstone by the flood waters of that stream. Extending back from the flood plain for an indefinite distance is a well-defined terrace about 80 feet above the river which is capped by a layer of coarse gravel from 10 to 15 feet in thickness.

## PROBABLE RELATIONS OF LAND AND WATER DURING THE DEPOSITION OF THE MONTANA GROUP.

The top of the Colorado shale probably marks the period of maximum westward extent of the Upper Cretaceous sea in this region, and the lithology and fossil content of the formations that constitute the Montana group indicate a series of advances and retreats of the sea on the westward or landward side of the interior basin. The Eagle sandstone represents a wedge of continental and littoral sediments built seaward after the end of Colorado time, probably as the result of a recession of the waters of the interior sea. The sudden change from the deposition of fine silts to that of moderately coarse sand probably resulted from land uplift with an increase in stream gradients. After about 250 feet of sandstone was laid down the area of deposition was lowered as the marine waters advanced, and the marine shales and thin-bedded sandstones of the Claggett formation were deposited. Either as a result of the accumulation of sediments or as a result of land uplift and a recession of sea waters the sea became shallow. Simultaneously a sandy barrier beach was developed east of Acton, partly shutting off a shallow embayment or lagoon, whose quiet waters, rendered brackish by the influx of land waters, afforded a favorable habitat for multitudes of oysters, which were later buried beneath the fine silt that accumulated in the quiet waters of the bay. Still later, as sedimentation gained upon subsidence, the site of the oyster bed became a coastal swamp, in which were formed the beds of lignite and carbonaceous shale so characteristic of the upper part of the Judith River formation for some distance west of Acton. Crustal subsidence temporarily restored the old embayment, into the south end of which a large river built a delta at the same time that marine shales of the Bearpaw were being laid down in the deeper waters of the bay a little farther north. Further subsidence of the area carried marine waters farther westward, and finally the Bearpaw sea covered the whole area.

After a period during which fine silts were the prevailing sediments the marine waters again receded, probably as a result of land uplift, for the streams must have acquired much steeper gradients, which enabled them to transport great volumes of coarse sediments. While these sediments were being laid down the streams received large quantities of tuffaceous materials from the volcanoes of the region, as is shown by the high percentage of volcanic material in the Lennep sandstone.

## *STRUCTURE.*

Few of the sedimentary rocks of the earth's crust are now in the position in which they were originally laid down. Some have been wrinkled by compression. Others have broken, and the part on one side of the fracture plane has risen or fallen with reference to that on the opposite side. The simple process of bending is known as folding, but where the beds break and there is an actual displacement of the strata the fracture plane is called a fault and the process is known as faulting. The attitude which the rocks have acquired is known as their structure.

Some petroleum geologists use the term in a slightly different sense; they speak of a "structure" in some particular locality when in reality they mean a structural feature of a particular kind, as an anticline or dome or a feature of some other type that is favorable for the accumulation of oil and gas. Such double usage makes for confusion and obscurity in expression, and the term should preferably be confined to its general meaning—that is, it should be used as an abstract term, like "stratigraphy" or "topography."

### RELATION TO MAJOR AND MINOR UPLIFTS.

Throughout the region surrounding the Lake Basin field the basement complex is overlain by many thousands of feet of sedimentary rocks, from the oldest definitely recognized sediments to those of recent origin. During the Paleozoic and most of the Mesozoic era this portion of the continent was not subject to any great mountain-making disturbances. There were, however, minor oscillatory movements which resulted in the advance and retreat of the seas. The record of these movements is seen in the interbedding of coarse sediments of shallow-water origin with those composed of fine materials such as come to rest only in deep waters beyond the influence of waves and currents. At about the beginning of Tertiary time this great series of sediments was uplifted throughout the Rocky Mountain province and some of the most gigantic folds in the region were produced. These movements were accompanied, and the stresses were no doubt partly relieved, by the outburst of volcanic materials.

As a result of the complex forces existing during the formation of the Rocky Mountain Front Range certain major uplifts were developed in south-central Montana and central Wyoming. Their development was in all probability determined by the nature of the forces themselves and the character and relation of the beds against which these forces were applied. The relation of the axes of these major uplifts to one another suggests that they originated as a result of forces acting in various directions simultaneously and is of considerable assistance in helping to explain some of the peculiar relations which exist among the minor structural features that occur between those of greater magnitude. The mountain masses whose development has probably been the most active in determining the nature of the minor structural features in the vicinity of the Lake Basin field are the Big Snowy Mountains on the north, the Little Belt Mountains on the northwest, the Snowy Range on the southwest, and the Big Horn Mountains on the southeast. The uplifts that produced the Little Belt Mountains, the Snowy Range, and the Big Horn Mountains were so great that the pre-Cambrian complex—the floor upon which the many thousands of feet of Paleozoic and Mesozoic beds were laid down—is now exposed along the crest of each range. According to Fisher's estimate,[1] the greatest vertical displacement of the strata in the Big Horn Mountains, as indicated by the height at which the granite floor is now found, amounts to about 18,000 feet. Each of these major uplifts has a rather well-defined anticlinal structure, but they do not represent a series of parallel folds. The Big Snowy and Little Belt mountains are similar in that in each range the major axis extends nearly due east and the structure is that of an unsymmetrical anticline, but in the Big Snowy Mountains the steep dips are on the south side, whereas in the Little Belt Mountains the fold is overturned to the north.[2] The axes of the two major uplifts south of the Lake Basin field trend northwest, and the axis of the great anticlinal fold of the Big Horn Mountains, if continued northwest, would strike the west end of the great zone of shearing in the Lake Basin field. The region between the Lake Basin field and the Big Snowy uplift appears to contain a series of elongated domes, but the almost absolute lack of parallelism in their major axes is a notable feature.

## METHODS OF REPRESENTING STRUCTURE.

Structure is generally shown either by structure sections or by structure contours. Structure contours were adopted for this report for the reason that they give the reader at a glance a comprehensive view of the structural features in their proper relations.

[1] Fisher, C. A., Geology and water resources of the Bighorn Basin, Wyo.: U. S. Geol. Survey Prof. Paper 53, p. 36, 1906.

[2] Calvert, W. R., Geology of the Lewistown coal field, Mont.: U. S. Geol. Survey Bull. 390, p. 46, 1909.

Structure contours are lines drawn on a map to show the elevation of the different points of a chosen horizon or stratum above or below a certain datum plane, as, for example, mean sea level. In the preparation of the accompanying map (Pl. XVI, in pocket) the base of the Eagle sandstone was chosen, as the horizon to be represented and the contours are drawn to indicate successive points of the same elevation on this sandstone. The contour interval is 100 feet—that is, within the area represented between two adjacent contours the base of the Eagle sandstone rises or falls just 100 feet. It follows, therefore, that where the contour lines are closely spaced the beds dip steeply, but where they are far apart the beds are more nearly horizontal. Any particular contour is the line of intersection between the base of the Eagle sandstone and a horizontal plane a certain distance (for example, 4,000 feet for the 4,000-foot contour) above mean sea level. Across fault planes the structure contours are obviously discontinuous, and the amount of vertical displacement can be ascertained by comparing the contours on the two sides of the fault.

## STRUCTURE IN THE LAKE BASIN FIELD.

### FOLDS.

#### PRINCIPAL FEATURES.

The two dominating folds in the Lake Basin field are the Big Coulee-Hailstone dome and the northwest end of the Big Horn Mountain anticline. The highest point of the dome appears to be near the center of the east side of T. 4 N., R. 19 E., and from that place the dome is somewhat elongated in the direction of the Broadview dome, a local uplift about 7 miles southwest of Broadview. The direction indicated will be considered as the trend of its principal axis. From the crest of the dome the beds are inclined very gently toward the east, north, and northwest, but south of the main axis they dip southward at angles ranging from 5° to 40°. The strikes and dips vary considerably, owing to the displacements caused by a great number of faults.

The direction of the principal axis of the Big Horn anticline is not so apparent, for the reason that the field only includes a few of the formations that curve around the northwest end of the main anticline. It is obvious, however, from the key map (fig. 31) that the axis if extended northwest would fall some distance south of the Big Coulee-Hailstone dome and form a small angle with the main axis of that uplift. The oldest formation exposed in this field around the northwest end of the Big Horn anticline is the Colorado shale west of Billings. The Colorado shale area is surrounded by outcrops of the Eagle, Claggett, Judith River, and Bearpaw formations. These two dominant structural features are related to the great zone of shearing discussed in considerable detail on pages 136–141. When the stresses produced by the process of deformation were relieved by shearing the beds forming the steeply dipping south flanks of the Big Coulee-Hailstone dome and the north flank of the Big Horn anticline were the ones to be affected. The significance of this fact

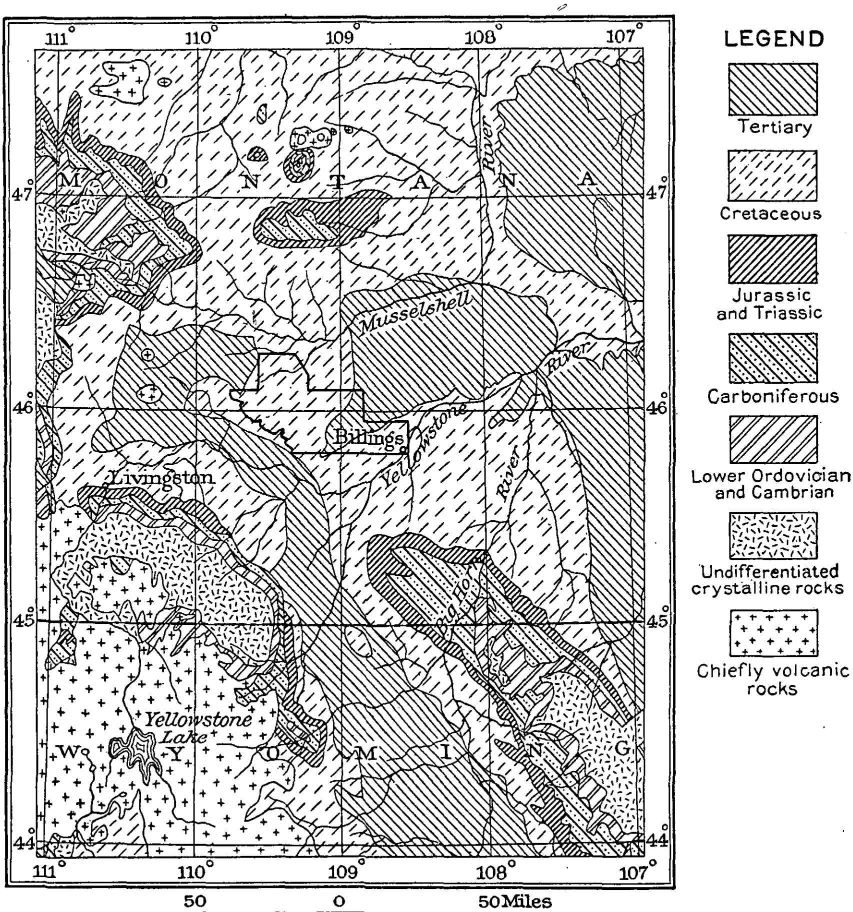



FIGURE 31.—Key map showing relation of Lake Basin field, Mont., to major structural features of the region.

is referred to on page 133, in the discussion of origin of some of the principal folds.

East and north of the two main uplifts the beds dip rather steeply beneath Comanche Basin. On the southwest also they dip in like manner and flatten out under Lake Basin. The abrupt change in the direction of the Lennep sandstone escarpment near the southwest corner of T. 2 N., R. 20 E., is due to the presence of a synclinal axis extending from sec. 33 northeastward toward Halfbreed Lake. The only additional structural features due to folding are the minor rolls in the formations, which are brought out clearly by the structure contours.

### STRUCTURE OF THE BIG COULEE-HAILSTONE DOME.

As the Big Coulee-Hailstone dome is a possible reservoir for the accumulation of oil and gas its exact structure and its relation to other folds demand careful consideration. The principal features of this dome are outlined above. Its highest point is believed to be near the center of the east side of T. 4 N., R. 19 E. From the structure contours it is obvious that there is but little variation in the elevation of the base of the Eagle sandstone all around the rim of Hailstone Basin except where the formation has been disturbed by faults. The same is true of the sandstone south and east of Locomotive Butte and along the upper branches of Painted Robe Creek. The south flank of the dome has been faulted very extensively. Along the south rim of Hailstone Basin the beds dip rather steeply to the south, but they flatten within a short distance, and minor irregularities interrupt a continuous monoclinal dip in that direction. In all other directions, however, the conditions are very different.

Beyond the upper flat portion of the dome the beds are inclined toward the east, northeast, north, and northwest at the average rate of about 175 feet to the mile, equivalent to a dip of 2°, for distances ranging from 5 to 20 miles. On the east the uniform easterly dip is terminated by a small syncline immediately west of the Broadview dome. In the direction of Broadview the beds are inclined at the usual angle of about 2° for about 10 miles, and finally at Broadview the dip steepens to about 20° and the beds continue their easterly dip for an unknown distance. Toward the north and northwest the 2° dip continues for 15 to 20 miles and is finally terminated by the steeply upturned beds along the southwest side of the Woman's Pocket anticline and the southeast side of the Shawmut anticline.

### STRUCTURE OF THE BROADVIEW DOME.

In the direction of the principal axis of the Big Coulee-Hailstone dome about 7 miles southwest of Broadview there is a circular uplift which may be called the Broadview dome. Its position is indicated by the structure contours and also by the small area of Eagle sandstone shown on Plate XVI. Along the west flank the beds dip toward the axis of a small syncline at an angle of 2° to 3° and then rise along the east flank of the Big Coulee-Hailstone dome. In going around the north side of the dome the dip gradually becomes steeper, and finally along the east flank the beds are inclined in some places as steeply as 21° but soon flatten under Comanche Basin. The southeast side of the dome has been cut dy a number of small faults which have interrupted the continuity of the beds in that direction. As is shown by the structure contours, the top of the dome is considerably lower than that of the Big Coulee-Hailstone dome.

### FAULTS.

The most striking feature of the structure of the Lake Basin field is the long, narrow belt of shearing that crosses the field from the northwest corner southeastward about 8 miles north of Billings. The most intense shearing occurred along the steeply dipping south flank of the Big Coulee-Hailstone dome and around the southeast side of the Broadview dome. From the Broadview dome to Acton very few faults were observed, but from Acton to Rattlesnake Butte the stresses produced by the forces of deformation again appear to have been relieved by the development of a considerable number of parallel faults. In order to facilitate description the principal faults are indicated on Plate XVIII by letters (A–A′, B–B′, etc.).

#### FAULTING FROM THE VICINITY OF GIBSON TO HAILSTONE BASIN.

Extending from Gibson eastward along Six Shooter Creek for several miles and thence southeastward toward Battle Butte is an area where the strata have been slightly uplifted, as is indicated by the exposures of the Judith River formation. Between this minor uplift and the Big Coulee-Hailstone dome is a small syncline, whose axis is shown by the patches of the Lance formation, which has been folded down upon the underlying beds. The torsional stresses affecting the rocks of this field were apparently relieved by the development of a great number of shear planes. These shear planes cut not only the rocks involved in the synclinal structure but also those forming the steeply dipping south flank of the Big Coulee-Hailstone dome. Between Hailstone Basin and the west edge of the field the principal movement has taken place along faults A–A′, C–C′, E–E′, and F–F′, but interspersed among these are a large number of smaller faults. In most of the faults the formations on the southeast side of the fault plane have been dropped with reference to those on the northwest side. Along the principal faults the deformation has resulted in a combined downward and northeastward movement of the beds on the southeast side. Where the syncline was faulted and the principal movement was the dropping of the beds on the southeast side of the fault plane, the Lance area is much wider on the southeast side of the fault but practically continuous with the area on the opposite side. Where the downward movement was the principal one there is obviously very little horizontal offset in the axis of the syncline. Furthermore, where the principal movement was downward, the beds on the southeast side of the fault are dropped with reference to those on the opposite side through practically the entire length of the fault, as along fault C–C′, where the synclinal axis appears to have been moved northeastward but very little and at the extreme southwest end of the fault the beds on the northwest side have been dropped only about 20 feet.

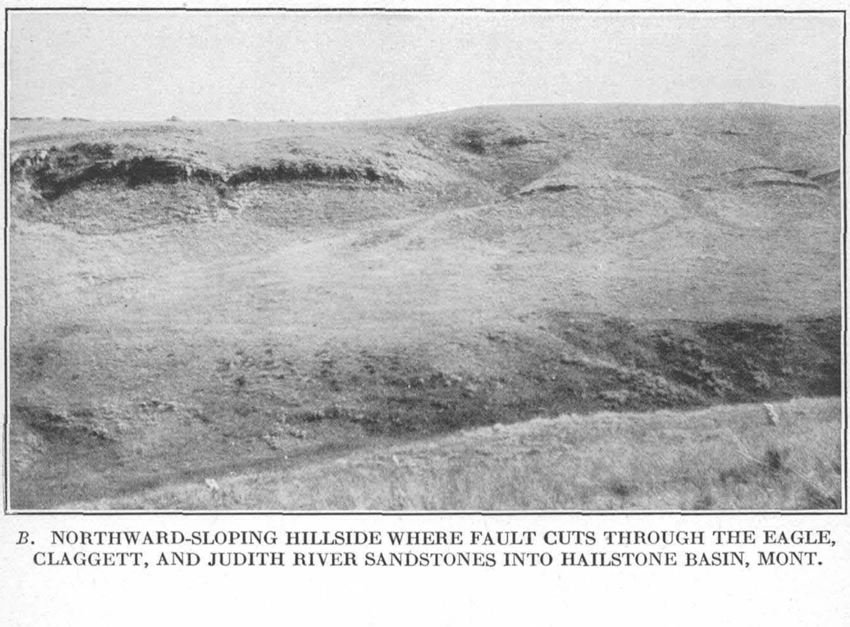
Along most of the principal faults, however, the conditions are very different. For example, along faults A–A′ and F–F′ the downthrow is to the southeast along the northeast end and to the northwest along the southwest end. These conditions suggest either a scissors movement or a dominant movement more nearly horizontal than the dip of the beds on the southwest limb of the syncline. In the block between faults E–E′ and F–F′ the beds appear to have been twisted considerably, but the principal axis of the syncline in all probability passes from a point near the northwest corner of sec. 9 to the southeast corner of sec. 11. In the fault block immediately to the south the synclinal axis almost coincides with the center line of the area of Lennep sandstone in sec. 18. Northeast of this axis the beds are downthrown on the southeast side of the fault F–F′, and toward the west they are dropped on the north side. This fact, together with the relation of the synclinal axes, indicates that the beds southeast of the fault F–F′ were not only dropped considerably but were carried eastward with reference to those on the opposite side of the fault plane. The block between faults E–E′ and F–F′ was probably thrust eastward somewhat with reference to the beds northwest of the fault plane E–E′, but it seems probable that the main direction of movement was along a line slightly steeper than the angle of dip of the south limb of the syncline, thereby producing but a small offset in the Lennep ridge at the southwest end of the fault, a small offset in the synclinal axis, and a large offset in the beds along the northeast end of the fault.

Very little can be said with absolute certainty regarding the inclination of the fault planes. Twenty-five observations of the strike and dip of well-defined shearing planes west of Hailstone Basin were recorded. The directions of these planes ranged from N. 12° E. to east, and 14 of them were found to trend between N. 35° E. and N. 65° E. Eight of the planes dip toward the northwest, and seventeen toward the southeast. The angles of dip ranged from 10° to 80°, and half of the planes were found to be inclined between 30° and 60°. The field notes also record considerable evidence of shearing along bedding planes and planes inclined to the bedding at a very small angle.

#### FAULTING FROM THE WEST SIDE OF HAILSTONE BASIN TO THE EAST SIDE OF BROADVIEW DOME.

The steeply dipping south flank of the main fold from the west side of Hailstone Basin to the east side of the Broadview dome has been cut by a large number of faults along some of which the displacement is considerable, as is shown by the structure contours. Most of the faults, however, are of small extent horizontally and do not represent much displacement. The principal movement has taken place along faults F–F′, G–G′, K–K′, and P–P′. On the map the unbroken lines represent the faults so far as it was possible to trace them with certainty, and the broken lines represent the portions that were merely inferred. For most of the small faults the unbroken line represents the extent to which the beds were found to be offset. The large fault G–G′ may or may not be continuous with the small one shown in the bed of Six Shooter Creek on the west line of sec. 30, T. 3 N., R. 20 E. If it is, the downthrow is on the opposite side of the fault plane, for at the township line the fault plane is inclined about 45° SE., and the beds on the southeast side of the fault are dropped 30 feet. Between faults G–G′ and K–K′ is a portion of the rim of Hailstone Basin which is more or less of a unit in itself. It is uplifted with reference to the beds on the southeast and the northwest. It has been cut by a series of small faults, the beds along the west sides of which have been dropped with reference to those on the east sides. In the north central part of sec. 15 the Eagle sandstone ends abruptly, and the valley to the east is apparently occupied by the Claggett shale. There is a line of displacement along the small fault cutting through the Claggett shale area, and the sandstone immediately west of it appears to be continuous for more than half a mile. The Eagle sandstone is cut off abruptly by fault J–J′, the plane of which is inclined 45° NW. From the fault plane the sandstones of the Eagle circle around toward the north, as indicated on the map, and dip west at an angle of about 8°. One of these prominent Eagle sandstones has been cut by numerous small parallel faults, one of which, in the northwest corner of sec. 14, is represented on Plate XVI. As a rule the beds on the north side of the fault have been dropped from 6 to 8 feet and offset toward the east. At one of the northernmost faults the sandstone is completely sliced by shearing planes and the beds on the north side of the line of disturbance are dropped from 50 to 75 feet and offset toward the east about 300 feet. Plate XXI, *A*, shows a view taken from the point on the Eagle sandstone in the northeast corner of sec. 9, T. 3 N., R. 20 E., looking southeast. The view shows the ridges formed by the lowest ledge of the Eagle sandstone and the upper ledge of sandstone in the Colorado shale as they are offset along the different fault planes. Plate XXI, *B*, gives a view taken from the Eagle sandstone on the west side of fault I–I′, looking south at the point on the north slope where the fault cuts through into Hailstone Basin. The fault plane, which is inclined about 25° NW., passes up the little gully shown in the center background of the picture. On the left is the massive Eagle sand-

*A*. VIEW LOOKING SOUTHEAST FROM POINT OF EAGLE SANDSTONE NEAR THE NORTHEAST CORNER OF SEC. 9, T. 3 N., R. 20 E., MONT.



*B*. NORTHWARD-SLOPING HILLSIDE WHERE FAULT CUTS THROUGH THE EAGLE, CLAGGETT, AND JUDITH RIVER SANDSTONES INTO HAILSTONE BASIN, MONT.

stone, and on the right the thin beds of sandstone in the Claggett formation. The fault plane J–J′ is inclined about 45° NW.

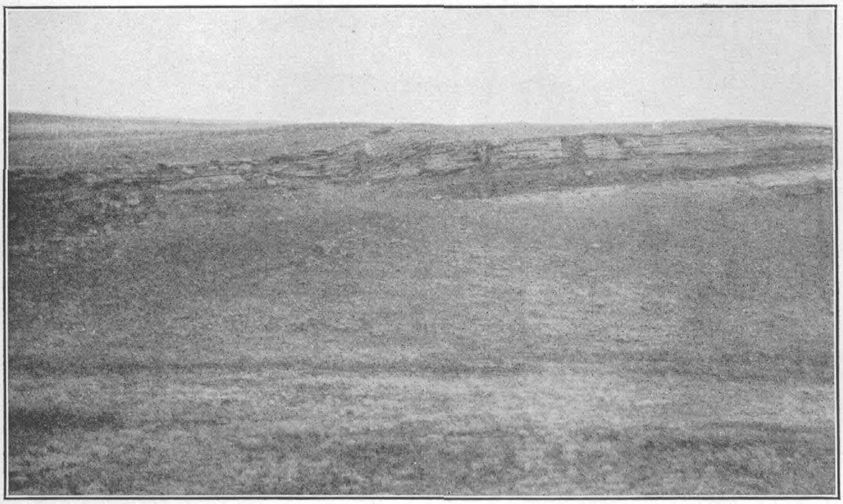
The formations immediately south of fault K–K′ bear a very peculiar relation to those on the northwest side of the fault. These formations as a whole are downthrown with reference to those on the north side of the fault plane, but instead of striking nearly east they strike almost north and dip west, and in this respect they resemble the Eagle sandstone west of fault J–J′. The valley extending southeast from the house on the east side of sec. 22, T. 3 N., R. 20 E., was examined carefully for evidence of the westward extension of fault K–K′, but no evidence was found. It seems very probable, therefore, that the downward torsional movement south of the fault K–K′ was represented farther west, by such a movement within the lower beds of the Bearpaw shale as occurs when any plastic substance undergoes deformation. East of fault K–K′ the formations have been intensely shattered by a series of parallel faults cutting the beds at a small angle with the strike. From the east line of sec. 19 to the east line of sec. 21 the distinguishing features of the Eagle sandstones are almost entirely destroyed, and at one point in the northwestern part of sec. 21 a large shattered and twisted mass of Eagle sandstone occurs out in the Colorado shale about 500 feet from the main escarpment.

For a distance of nearly a mile the formations have not been faulted, but along the south rim of Little Basin are a series of faults similar to those between faults G–G′ and K–K′. All the faults except O–O′ show the formations to be dropped on the northwest side of the fault plane.

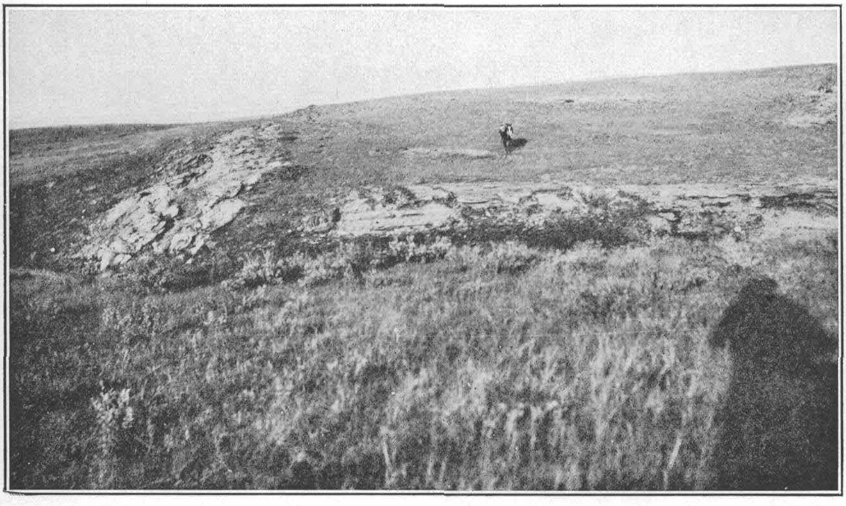
The combination of faulting with folding southeast of Little Basin causes some rather striking relations. Along line P–P′ a block of the Eagle, Claggett, and Judith River beds has been dropped so that the Judith River beds are in contact with the Colorado shale. This block is separated by fault R–R′ from the faulted anticline immediately southeast, and both blocks are cut by fault Q–Q′. Southwest of the Broadview dome there is a syncline whose axis passes from the west line of sec. 10, T. 3 N., R. 22 E., southward to the center of sec. 28, and probably still farther southwest. The same forces also produced an anticline whose axis passes from a point near the northwest corner of T. 2 N., R. 22 E., southeastward to sec. 3. Between this anticline and the Broadview dome is another broad syncline whose axis is parallel to that of the anticline. The formation of these folds evidently produced considerable buckling, which was partly relieved by faulting. Such action is indicated by the block of strata between faults R–R′ and S–S′. The southwest end of the block is a portion of the southward-dipping limb of an anticline, and the northeast end is a portion of the westward-dipping limb, the anticlinal axis being somewhat in the form of a crescent. The fault block between faults S–S′ and T–T′ is made up of a portion of the easterly anticline and a portion of the southeast limb of the main syncline west of the Broadview dome. The long faults T–T′, W–W′, X–X′, and Y–Y′ all cut the easterly anticline and the broad syncline between it and the Broadview dome. The southeast flank of the dome itself is cut by a series of parallel faults of small displacement, on most of which the beds are dropped along the northwest side. Plate XXII, *A*, is a view of one of the small thrust faults in the SE. ¼ sec. 18. The steeply dipping southeast flank of the Big Coulee-Hailstone dome is cut off from the northwest flank of the Big Horn Mountain uplift by fault Z–Z′, where the Bearpaw shale has been faulted down against the Judith River beds with a maximum displacement between 500 and 600 feet.

#### FAULTING BETWEEN BROADVIEW DOME AND RATTLESNAKE BUTTE.

Between the Broadview dome and Acton the structure is very simple and the formations have not been faulted to any considerable extent. One fault (*a–a′*) was observed, however, which passes from the north line of sec. 27, T. 2 N., R. 23 E., northeastward to the edge of Comanche Basin, where it is obscured by the recent lake deposits. The fault plane is best shown on the east side of the small gully northeast of the house in the SW. ¼ sec. 7, T. 2 N., R. 24 E. Plate XXII, *B*, is a view of the fault as seen at that point, looking northeast. The fault plane passes from the observer in line with the tripod. The basal Judith River sandstone beds on the right of the fault plane are almost horizontal, whereas those on the left side dip as steeply as 30°. The displacement appears to have occurred along a normal fault plane. Southwest from the point where the picture was taken the fault was traced for about half a mile by a zone of highly crushed sandstone. Farther southwest its position is indicated by little knolls of intensely sheared and crushed sandstone, in places dipping northwest as steeply as 30°. For a distance of about 5 miles east of the fault the beds strike rather uniformly a few degrees south of east and dip very gently north, and apparently they have not been faulted, but at Acton the outcrops of the Judith River sandstone turn suddenly toward the south and dip eastward at an angle of about 10°. They are cut off abruptly by fault *b–b′* in such a way that Judith River, Bearpaw, and Lance beds are in contact with the Claggett shale. The Claggett beds southeast of the fault do not exhibit much dip, but the Judith River beds southeast of the fault bear about the same relation to fault *c–c′* as the same beds north of the fault bear to fault *b–b′*. It is a very noticeable feature of the faults between Acton and Rattlesnake Butte that the beds on the northwest side of the fault plane have sagged down, while those



*A*. SMALL THRUST FAULT IN EAGLE SANDSTONE IN THE SE. ¼ SEC. 18, T. 3 N., R. 23 E., MONT.



*B*. FAULT IN SOUTHWEST CORNER OF SEC. 7, T. 2 N., R. 24 E., MONT.

on the opposite side were either arched upward or acquired a rather uniform northeasterly or easterly dip. The Eagle sandstone arch in sec. 21, T. 2 N., R. 25 E., is a striking illustration of the development of an arch south of the fault plane opposite a sag on the north side. Plate XXIII is a view from a sandstone point in the NW. ¼ sec. 16, T. 2 N., R. 25 E., looking southeast. The prominent sandstones in the center background of the picture form the arch of Eagle sandstone southeast of fault *c–c′*. The sandstones in the left background form the northeast flanks of the second and third arches of Eagle sandstone in sec. 23 of the same township, southeast of faults *d–d′* and *e–e′*. The northeast flanks of these arches of Eagle sandstone dip very steeply, but the dips on the opposite flanks are not so pronounced. From the southwest ends of faults *b–b′*, *c–c′*, *f–f′*, and *i–i′* the beds on the northwest side sag very rapidly, so that a block of Lance or Bearpaw shale occupies the lowest part of the sag.

## POSSIBILITIES OF OIL AND GAS.

In outlining the possibilities for obtaining commercial quantities of oil and gas in the Lake Basin field, four principal factors should be taken into consideration—proximity to productive fields, similarity of stratigraphy to that of neighboring productive fields, surface indications of oil and gas, and existence of favorable structure.

### PROXIMITY TO PRODUCTIVE FIELDS.

No productive oil field has thus far been found wholly within the State of Montana. Recently, however, an oil pool has been discovered on the Wyoming-Montana State line in the Elk Basin field, about 55 miles south and a little west of Billings, Mont. Commercial quantities of gas have been obtained near Baker and Glendive, in the southeastern part of Dawson County, and near Havre, in Hill County, north-central Montana, about 30 miles south of the Canadian boundary. Considerable quantities of gas have also been obtained in the Bow Island and Medicine Hat gas fields in Alberta, Canada, about 60 miles north of the Canadian boundary. Oil has been obtained in commercial quantities at several localities in Wyoming, but the principal production of the State comes from the Salt Creek field, in Natrona County. Among the other notable oil-producing localities in Wyoming are the Basin and Grass Creek districts, in the Big Horn Basin, and the vicinity of Lander, in Fremont County. Vast quantities of natural gas have been shown to exist in the strata underlying the Byron, Buffalo Basin, and Oregon Basin fields, in the Big Horn Basin. Practically all the above-named oil and gas producing localities, as well as others of less commercial importance, lie within a radius of 250 miles of the Lake Basin field.

## SIMILARITY OF STRATIGRAPHY TO THAT OF NEIGHBORING PRODUCTIVE FIELDS.

Plate XVII (in pocket) was prepared for the purpose of showing the stratigraphic position and relative thickness of sands in the Colorado shale in south-central Montana and north-central Wyoming. The relation of these sands is discussed under the heading "Colorado shale" (pp. 111–113). Some of the stratigraphic sections were carefully measured where the strata are especially well exposed. Others are based principally upon drill records in fields where oil and gas were found to exist in the sands.

Throughout the Western States the principal concentrations of oil and gas occur in moderately coarse sands which are included as lenses and well-defined beds in great bodies of shale. These sandy layers are commonly referred to as "oil sands." From the accompanying sections (Pl. XVII) it is obvious that the principal concentrations of oil and gas in north-central Wyoming occur in sands interbedded in the lower part of the Colorado deposits. There are, however, certain concentrations of oil and gas in sands below the Colorado, as for example in the Greybull sand, at the top of the Cloverly formation, at Basin, Wyo., and in the Cloverly sandstone and in sandstones in the Sundance formation in the Powder River field, Wyo. In certain localities sandstones many hundred feet above the sands of the Frontier formation, of the Colorado group, are known to be productive, as for example the Shannon sandstone of the Powder River and Salt Creek fields, Wyo. The lack of continuity of the Frontier sands is mentioned under the heading "Colorado shale" (pp. 111–113). In certain localities—for example, at Salt Creek—there is but one important oil-producing sand (Wall Creek sandstone) in the Frontier formation, and apparently there are no other sandstones of much value as oil reservoirs between that sand and the base of the Colorado, whereas at Basin, Wyo., on the east side of the Big Horn Basin, the Colorado group contains three well-defined sands in the Frontier formation, two in the Mowry shale, and one near the middle of the Thermopolis shale, each containing a certain amount of oil and gas. Finally, at Elk Basin, on the Wyoming-Montana State line, the Frontier formation includes two sandstones each of which is productive of oil.

There is little doubt that the formations present in north-central Wyoming extend northward and underlie the Lake basin field. It is also reasonably certain that the sandstones in the Colorado and Kootenai formations are sufficiently near the surface to be tested by the drill under the most favorable structural features in the Lake Basin field. The principal element of uncertainty for the oil prospector is the nature and extent of these sands. From the small

FAULTED ANTICLINE OF EAGLE SANDSTONE, LOOKING SOUTHEAST FROM A POINT ON THE SANDSTONE IN THE BEARPAW SHALE IN THE NORTHWEST CORNER OF SEC. 16, T. 2 N., R. 25 E., MONT.

number of well logs available it appears that well-defined sandstones such as those present in most of the productive Wyoming fields are lacking in the Lake Basin field. It may be, however, that the available drill records fail to represent the true nature of the Colorado sands and that future drilling will establish the existence of sandstones under parts of the Lake Basin field similar to those underlying certain portions of the Musselshell Valley, farther north. The following are the logs of wells drilled in and near the Lake Basin field:

*Log of Monarch Oil & Gas Co.'s well at Billings, Mont., near west line of sec. 34, T. 1 N., R. 26 E.*

| Driller's interpretation. | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Gravel | 40 | 40 |
| Brown shale | 60 | 100 |
| Sand | 10 | 110 |
| Brown shale | 1,390 | 1,500 |
| Black mud | 100 | 1,600 |
| Brown shale | 25 | 1,625 |
| Lime rock | 50 | 1,675 |
| Black shale | 15 | 1,690 |
| Lime | 20 | 1,710 |
| Sand | 30 | 1,740 |
| Shale | 60 | 1,800 |
| Black lime | 10 | 1,810 |
| Shale | 10 | 1,820 |
| Sand. Salt water came in at 1,840 feet and filled the hole about 1,200 feet | 20 | 1,840 |
| Black shale | 60 | 1,900 |
| Lime shells | 100 | 2,000 |
| Shale | 100 | 2,100 |
| Lime shells | 15 | 2,115 |
| Shale | 85 | 2,200 |
| Lime shells | 20 | 2,220 |
| Shale | 80 | 2,300 |
| [Formation not given] | 125 | 2,425 |
| Some gas comes in, apparently at a depth of 2,425 feet, and finds its way to the surface. | | |

*Log of well near top of Broadview dome, in the SE. ¼ sec. 13, T. 3 N., R. 22 E.*

| Driller's interpretation. | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Sandstone (Eagle) | 150 | 150 |
| Shale, black and brown | 1,400 | 1,550 |
| Sandstone, soft and brown, containing brackish water which flowed over top of casing | 27 | 1,577 |
| Shale, light | 13 | 1,590 |
| Shell limestone containing some gas | 7 | 1,597 |
| Shale, containing shells and bentonite | 153 | 1,750 |
| Sandstone, soft, brown, containing fresh water and a little gas | 27 | 1,777 |
| Shale, dark and light colored, containing bentonite and lime shell | 623 | 2,400 |
| Shale, variable in color, including lime shells | 200 | 2,600 |
| Shale, sandy | 50 | 2,650 |
| Shale, light colored (bailer and tools lost in hole at 2,680 feet) | 30 | 2,680 |

*Log of 79 Oil Co.'s, No. 1 drill hole, in sec. 35, T. 5 N., R. 19 E.*

| Driller's interpretation. | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Eroded below base of Eagle sandstone | 500 | .......... |
| Soil | 5 | 5 |
| Gravel and quicksand | 25 | 30 |
| Dark-green to black soft fissile shale (flow of water and some gas at 130 feet; small pocket of gas at 745 feet) | 750 | 780 |
| Gray to black hard, dense sandy shale to shaly sandstone, thin bedded (show of gas at 1,040 feet) | 312 | 1,092 |
| Greenish-black soft fissile shale (sandy streak with small show of oil at 1,135 feet) | 622 | 1,714 |
| Sandstone and shale, dark, thin bedded (show of oil at 1,760 feet) | 111 | 1,825 |
| Sandstone | 5 | 1,830 |
| Soft white shale | 10 | 1,840 |
| Soft gray-maroon shale (thickness estimated) | 215 | 2,055 |

*Log of well in Hailstone Basin, sec. 17, T. 3 N., R. 21 E.*

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Soil | 5 | 5 |
| Black shale | 927 | 932 |
| Sand (show of oil and gas with water) | 23 | 955 |
| Hard sandy shale | 132 | 1,087 |
| Sand (oil and gas with water) | 36 | 1,123 |
| Black shale | 303 | 1,426 |

The four well logs given above ought to represent fairly well the nature of the Colorado shale in the Lake Basin field, as the wells are rather uniformly distributed from northwest to southeast. At the 79 Oil Co.'s well in the northwestern part of the field, the first sandy beds recorded occur about 1,400 feet below the top of the Colorado shale, but at Billings, in the southeastern part of the field, sands were first encountered about 300 feet lower down. The first three of the wells probably penetrated the main sandstones of the Kootenai as well as all those in the lower part of the Colorado shale. From the records it appears that no sandstones were encountered at all comparable with those at Elk Basin or Basin, Wyo., and apparently only meager showings of oil and gas were obtained.

## SURFACE INDICATIONS OF OIL AND GAS.

There are very few surface indications of oil and gas in the Lake Basin field. The field notes record several reported occurrences of films of oil on springs and wells, but few of these reports were verified. At the fault near the west quarter corner of sec. 30, T. 4 N., R. 18 E., there are several strong springs, and according to reports oil has been seen floating on the water. The water was examined by one of the members of the field party, but no films of oil were detected.

A well was drilled 86 feet into the Bearpaw shale near the west quarter corner of sec. 25, T. 2 N., R. 19 E., and a black film on the water was believed at the time to be oil. Other wells in the vicinity are also reported to have shown signs of oil. A rumor was current that a drilled well 100 feet deep near the northwest corner of sec. 26, T. 4 N., R. 24 E., supplies water which has a very pronounced odor of petroleum, but apparently the report was not verified. Oil is also reported to have been seen on the water in secs. 13 and 14, T. 4 N., R. 20 E. Pockets of oil encountered in digging wells have been reported from several localities in the northern part of T. 2 N., Rs. 26 and 27 E. Evidently this oil must come from the Bearpaw shale.

## EXISTENCE OF FAVORABLE STRUCTURE.

A careful examination of the structure of the rocks and its relation to concentrations of oil and gas in many parts of the world has given rise to the structural or anticlinal theory. The conditions that control the accumulation of oil and gas, according to this theory, are briefly as follows:

(*a*) A reservoir rock. This is commonly known as an oil sand, although it may be a very sandy shale, a fractured rock of some kind, a loose conglomerate sufficiently porous to allow the accumulation of oil or gas, or a limestone composed largely of interlocking crystals of calcite.

(*b*) An impervious cap rock to seal over the reservoir rock and prevent the upward escape of the oil and gas.

(*c*) Folds in the rock favoring the accumulation of oil and gas in certain localities, these substances migrating from more extensive areas of adjoining beds less favorably situated for their retention.

(*d*) Saturation of the rocks by ground water, on which the oil and gas will move on account of their lower specific gravity and be forced into the upper parts of the folds. According to the anticlinal theory, if a porous rock containing gas, oil, and water is folded between other rocks which are nonporous, these substances, under the influence of gravity, separate and arrange themselves according to density. Gas, being the lightest, rises to the crest of an anticline, the oil separates out below, and the water seeks the deeper portions of the beds. Detailed field observations have shown not only that many of the concentrations of oil and gas are intimately related to anticlines and domes, but also that gas, oil, and water are related in the manner indicated. Although the recognition of these facts has caused most geologists to accept the anticlinal theory in its broader aspects, many geologists are willing to accept it only in a modified sense, as recent study has shown that accumulations of oil and gas occur not only in the crowns of the arches but also in many places on the flanks of the folds where the dips are interrupted for some distance, the interruptions forming structural terraces. Recent studies indicate also that the conditions of accumulation are entirely different in saturated and unsaturated rocks—that in thoroughly saturated rocks the oil and gas are borne upward on the sheet of underground water and are caught in the crowns of the arches, whereas in dry rocks the principal point of accumulation of oil is in the bottoms of the synclines or at any point where the slope of the rock is not sufficient to overcome friction.

The close relation which has been observed between anticlinal structure and accumulations of oil and gas suggests that two folds in the Lake Basin field should be carefully tested with the drill. These are the Broadview dome and the Big Coulee-Hailstone dome. The latter seems by far the more promising, for the reason that the Broadview dome is considerably lower than the crest of the Big Coulee-Hailstone dome and is virtually a part of it, being separated from it only by a small syncline. Even if sands are present beneath the Broadview dome and oil and gas have been formed in the shale of the surrounding region, the collecting area of this dome is very small compared with that of the Big Coulee-Hailstone dome. In the detailed description of the structure of the Hailstone dome (p. 135) attention is called to the fact that beyond the upper flat portion of the Big Coulee-Hailstone dome the beds are inclined toward the east, northeast, north, and northwest at the average rate of about 175 feet per mile (equivalent to a dip of 2°) for a distance ranging from 5 to 20 miles, and that toward the north and northwest the 2° dip continues from 15 to 20 miles and is finally terminated by the steeply upturned beds along the southwest side of the Woman's Pocket anticline and the southeast side of the Shawmut anticline. The real efficacy of an extensive collecting area depends on the presence and continuity of porous sands. Even if the conditions are favorable for the formation of oil and gas along the flanks of the dome, these substances can not eventually accumulate in the crest unless there are more or less continuous porous sands present through which the oil and gas can migrate. It is highly probable that if oil or gas has accumulated in the crest of either of these domes it is sealed in by the upper portion of the Colorado shale, for any sands that may be present in the lower part of the Colorado do not reach the surface in either dome. There seems to be no evidence of oil or gas having escaped along any of the fault planes, but that fact does not necessarily prove that no oil or gas has accumulated in the lower sands of the Colorado shale, for it is difficult to ascertain to what extent the lower sands have been faulted. It is the writer's belief that in all except a few of the larger faults the forces which effected a displacement of the harder sandstones resulted merely in distortion of the great body of soft shale. It is somewhat doubtful to what extent even the larger fault fissures remain open in the shale for the free transmission of fluids. The faults that cut the Eagle sandstone in the Broadview dome exhibit small displacement and probably do not extend far into the Colorado shale.

Considering the size of the Broadview dome, its relation to the Big Coulee-Hailstone dome, and the location and depth of the test well in the SE. ¼ sec. 13, on the Broadview dome, the writer would hesitate to recommend further drilling of the smaller dome until the Big Coulee-Hailstone dome had been thoroughly tested. In view of the size of the Big Coulee-Hailstone dome and the location of the 79 Oil Co.'s well (p. 144) and the well in sec. 17, T. 3 N., R. 21 E., in relation to the crest of the dome, together with the fact that many dry holes are found even in productive fields, it would seem that further drilling of the Big Coulee-Hailstone dome is justified. If that dome proves barren the possibilities of oil and gas in commercial quantities in the Lake Basin field are believed to be very slight.