GEOLOGY AND OIL AND GAS PROSPECTS OF THE HUNTLEY FIELD, MONTANA.

By E. T. Hancock.

INTRODUCTION.

The Huntley field is in Yellowstone and Big Horn counties, south-central Montana, and embraces an area of about 650 square miles, part of which lies northwest and part southeast of Yellowstone River. The field has railroad facilities that are exceptionally good for this general region, being traversed by the main lines of the Northern Pacific and the Chicago, Burlington & Quincy railroads. These roads furnish excellent shipping facilities at Huntley, Warden, Ballantine, Pompeys Pillar, and other points.

Acknowledgments.—In presenting this report the writer desires to express his thanks to David White for valuable suggestions and criticisms, to T. W. Stanton and F. H. Knowlton for the identification of fossils, and to C. E. Dobbins for assistance in the detailed mapping. He also wishes to call attention to the public service rendered by oil and gas operators who have furnished records of deep borings and by individuals who have contributed in various ways to the success of the investigation.

Earlier investigations.—The Huntley field is in reality an extension of the Lake Basin field, which was mapped by the writer during the summer of 1916.[1]

The geologic investigation of the region including the Lake Basin and Huntley fields began 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 to these fields, 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 (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

[1] Hancock, E. T., Geology and oil and gas prospects of the Lake Basin field, Mont.: U. S. Geol. Survey Bull. 691, pp. 101–147, 1918 (Bull. 691–D).

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.

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,[1] and the Bull Mountain field is discussed by others.[2] The Bull Mountain coal field joins the Huntley field on the north. A detailed report by Stone and Woolsey on the geology of the Musselshell Valley has been prepared but not yet published. While the writer was mapping the geology and studying the oil and gas possibilities of the Lake Basin field in 1916 C. F. Bowen[3] was doing similar work in the Musselshell Valley farther north. In October, 1913, G. S. Rogers[4] examined the northern part of the Pine Ridge coal field in T. 3 N., Rs. 32 and 33 E.

Purpose of present investigation.—The present investigation was undertaken primarily to make a detailed study of the stratigraphy and structure in order to locate such structural features as have elsewhere been found to bear a definite relation to accumulations of oil and gas.

Field work.—The field examination that furnished the basis for this report was made during July, August, and September, 1917, under the immediate supervision of the writer, who was assisted by C. E. Dobbins. In the mapping nearly all locations were made by triangulation and elevations were determined by means of vertical angles. The work was begun in the vicinity of Osborn, a station on the Northern Pacific Railway. A base line 12,240 feet long was measured along the railroad track southwest from Osborn. From the two ends of this base line points were located by intersection on the pine-covered ridge to the southeast and also on the basal Lance escarpment north of the Yellowstone. From the points

[1] Stone, R. W., U. S. Geol. Survey Bull. 341, pp. 78–91, 1909.
[2] Woolsey, L. H., idem, pp. 62–77. Woolsey, L. H., and others, U. S. Geol. Survey Bull. 647, 1917.
[3] U. S. Geol. Survey Bull. 691, pp. 185–209, 1918 (Bull. 691–F).
[4] U. S. Geol. Survey Bull. 541, pp. 316–328, 1914.

thus located, a system of control points was extended throughout all except the northern and extreme southeastern portions of the field. Later in the season a second base line 10,746 feet long was measured from the coal elevator in Billings northeastward along the main line of the Northern Pacific Railway. From the extremities of this new base line several prominent points were located by intersection—for example, the smokestack at the sugar refinery and certain high points in the elevated region from 3 to 5 miles to the south. The locations of these points being rather accurately established, the task of mapping the Colorado-Eagle and Eagle-Claggett contacts for several miles southeast of Billings became very simple. From points definitely located on the top of the prominent Eagle sandstone escarpment southeast of Billings it was possible to intersect points previously located from the original base line, thereby tying together the two systems of triangulation points. The elevation of the railroad track at Huntley was first ascertained, and all subsequent elevations were based upon that, but it was possible to check the elevations by intersecting numerous points along the Northern Pacific and Chicago, Burlington & Quincy railroad lines and reading the vertical angles to them.

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 bed, and especially where the beds are inclined at a very low angle, the structure was determined from elevations determined at short intervals. Where the strata are broken by faults it was 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 area, the details were mapped by the use of the stadia rod, after the plane table had been located by intersection. The Lance-Lebo shale contact in the northern part of the field was mapped entirely by stadia traverse from section corners.

Land surveys.—Practically all the township corners and a considerable number of the section corners were located by intersection. Some of the section and quarter corners were very difficult to find, but it is probable that by careful search most of them could be found. In fact, where the surface is moderately even some of the wagon roads are laid out along the section lines. Inasmuch as the Huntley field lies entirely within the valley of the Yellowstone, which trends northeast, and a bordering area dissected by streams which flow in a direction almost at right angles to the valley itself, very few of the principal roads follow the section lines. The principal highway—the Yellowstone trail—runs very close to the Northern Pacific tracks all the way from Huntley to Pompeys Pillar. The roads leading up into the regions southeast and northwest of the valley of the Yellowstone as a rule follow the valleys of the smaller streams.

TOPOGRAPHY.

SURFACE FEATURES.

The Huntley field is part of a large area of moderately low country, which is in striking contrast with the Crazy Mountains on the west, the Big Snowy Mountains on the north, and the Prior Range on the south. A similar contrast is exhibited within the field itself between the valley land along the Yellowstone and the dissected areas on either side. Indeed, the contrast may be carried still further, for there are some very striking differences between the dissected area southeast of the valley and that on the northwest. Thick deposits of gravel, much of which is embedded in a matrix of coarse sand, forming a well-defined conglomerate, constitute a perfect line of terraces bordering the rich alluvial deposits along Yellowstone River and extending several miles up the valleys of the smaller streams. The contrast in surface features is due, not to these lower gravel deposits, but to others, which lie at a much higher altitude and are of somewhat different origin. These higher gravel deposits occur southeast of the Yellowstone but not on the northwest side. They appear to have been laid down on a very gently sloping plain, and they protect the underlying rocks from the ordinary agencies of erosion, so that the interstream areas southeast of the Yellowstone are commonly high table-lands at elevations ranging from 3,900 to 4,000 feet. Most of the area extending from the edges of these elevated table-lands down to the Yellowstone flat is highly dissected by numerous small streams. Immediately north of the Yellowstone is a continuous even terrace, and from this terrace the ground rises very gradually to the foot of the prominent escarpment formed by the basal sandstones of the Lance formation.

DRAINAGE.

From what has been said it is obvious that all the drainage of this region flows toward the Yellowstone. That from the Bull Mountain area reaches the Yellowstone by way of Crooked Creek, Razor Creek, or Pompeys Pillar Creek. The area south of the Yellowstone is drained almost entirely by Pryor, Arrow, and Fly creeks.

GEOLOGY.

STRATIGRAPHY.

GENERAL SECTION.

The lowest beds in the sedimentary series exposed in this field are those near 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. Fortunately, there are exposures of these beds not far distant which, taken in conjunction with the records of certain deep borings, furnish considerable information concerning the lithology of the beds not exposed in this field. The sedimentary rocks described in this report have been separated into formations on the basis of lithologic and paleontologic character. These formations are shown in colors on the accompanying geologic map (Pl. XIV). The nature, thickness, and relations of the formations which crop out in the Huntley field are shown in the following table:

Rock formations exposed in the Huntley field, Mont.

Era.	System.	Series.	Group and formation.	Character.	Topographic expression.	Thickness (feet).
Cenozoic.	Tertiary.	Eocene.	Fort Union formation.	Yellowish to buff sandstone and sandy shale. Lebo shale member. Dark olive-green to brown sandy shale and thin-bedded arkosic sandstone; contains a thick bed of carbonaceous shale, including thin layers of coal near the middle.	Forms broad, more or less gentle slope extending back from the Lance formation to the massive sandstones forming the upper part of the Fort Union formation.	100± 200–300
(?)	Tertiary(?)	Eocene (?)	Lance formation.	Light yellowish-gray sandstone; gray, yellow, and drab clays and shales; and grayish sandy shale. The upper part contains some thin streaks of coal.	Basal beds of the Lance formation commonly form a prominent escarpment along the margin of the depressed area underlain by the Bearpaw shale. Higher sandstones form scarps along the low ridges.	700–1,500
Mesozoic.	Cretaceous.	Upper Cretaceous.	Montana group. Bearpaw shale.	Dark marine shale containing numerous calcareous concretions. Abundantly fossiliferous.	In many places weathers down to broad valleys and shallow basins between the more resistant sandstones of the Judith River and Lance formations. Also forms the sides of elevated ridges where protected by a cap of gravel and conglomerate.	Undetermined; 500 to 600 feet in the adjoining Lake Basin field.
			Montana group. Judith River formation.	Light-yellow soft massive sandstones containing considerable dark carbonaceous material and dark shale. At the base is a brown, irregularly jointed and hackly sandstone, alternating with zones of greenish-gray sandy shale, which seems to be the approximate equivalent of the sandstone included in the upper part of the Claggett formation in its type area; but for convenience of mapping and because of lithologic similarity this sandstone is here included in the Judith River formation.	If dipping rather steeply the beds form rather prominent ridges between the valleys eroded out of the Bearpaw above and the Claggett below. Where nearly flat lying the hard basal sandstones form rather prominent escarpments around the broad valleys eroded out of the Claggett formation.	100–500
			Montana group. Claggett formation.	Dark-gray marine shale, including zones of thin-bedded sandstone which locally become very massive and form prominent cliffs. The sandy zones are generally characterized by a growth of evergreens.	Commonly occupies broad valleys and low depressions between the escarpment formed by the basal sandstone here included in the Judith River formation and that formed by the massive Eagle sandstone.	550±
			Montana group. Eagle sandstone.	The upper 100 feet consists of moderately soft light-yellow sandstone alternating with beds of sandy shale. The lower 100 feet is massive sandstone.	The massive basal sandstone forms a vertical cliff for several miles east of Billings.	200
			Montana group. Colorado shale.	The upper 200 or 300 feet exposed in this field is composed of dark marine shale containing scattered calcareous concretions.	Is eroded into a deep valley southwest of the prominent Eagle sandstone escarpment.	200 or 300 exposed.

The formations exposed in this field were laid down during the closing stages of the Mesozoic and the early part of the Cenozoic era. In the following pages the writer has endeavored to point out briefly the nature of these formations and the conditions of land and water in the Huntley field while the sediments of which they are made up were being deposited. In considering the origin and concentration of oil and gas, however, it is necessary to inquire into the probable nature of the lower part of the Colorado shale and the underlying beds at least as far as the base of the Morrison (?) formation. In other words, we must seek an answer to the question, Is it probable that the necessary sands are present to act as reservoirs for the accumulation of oil and gas, provided the requisite conditions are present for the origin of those substances? To answer this question satisfactorily necessitates a careful study of drill records, as well as of sections of beds exposed in neighboring fields.

CRETACEOUS (?) SYSTEM.

MORRISON (?) FORMATION.

The beds which are believed to represent the Morrison formation, as it is mapped farther south, are not exposed in the Huntley field. The formation is well exposed on both sides of the Big Horn Basin, Wyo., and in the vicinity of Bridger, Mont., and the following stratigraphic sections ought to furnish strong evidence concerning the nature of the beds that are believed to represent it in the Huntley field. The following section of the Morrison was measured by Hewett[1] along Shoshone River near Cody, Wyo.:

Section of Morrison formation on Shoshone River, near Cody, Wyo.

	Feet.
Shale, maroon and gray, sandy	50
Sandstone, buff	6
Shale, gray, sandy	12
Sandstone, buff	4
Shale, gray, sandy	10
Sandstone, buff, cross-bedded	8
Clay, gray, sandy	50
Sandstone, buff, fine grained, evenly bedded, and ripple marked	6
Clay, maroon and yellow, sandy	44
Clay, dark brown to black, containing saurian vertebrae, limb bones, and gastroliths	20
Sand, gray, argillaceous, only locally indurated, containing wood silicified in place, as well as rounded pebbles of similar material; carbonized plant remains and small calcareous concretions	50
Clay, maroon, sandy	55

[1] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, p. 95, 1914.

	Feet.
Sandstone, white, homogeneous, only locally indurated	25
Clay, prevailing gray and olive-colored but with three broad maroon bands, sandy	100
Shale, green, sandy, transitional to upper sandstone of the Sundance formation	140
	580

The following section of the Morrison formation was measured by Darton [1] on the opposite side of the Big Horn Basin, about 8 miles northwest of Cloverly, Wyo.:

Section of Morrison formation on Alkali Creek about 8 miles northwest of Cloverly, Wyo.

	Feet.
Pale-green massive shale (overlain by Cloverly sandstone)	50
Thin-bedded gray sandstone, brown on surface	15
Pale-green massive shale	5
Blue-black shale	10
Maroon massive shale	10
Variegated masssive shale	45
Thin-bedded gray sandstone	6
Variegated massive shale, drab, purple, and maroon	65
Pale-green to white sandstone	6
Pale-green and maroon massive shale	85
Pale-green massive sandstone	45
Red sandy shale (lying on Sundance formation)	40
	382

The following section measured by W. B. Emery [2] about 9 miles southeast of Bridger, Mont., shows the character of the Morrison formation much nearer the Huntley field:

Section of Morrison formation about 9 miles southeast of Bridger, Mont.

	Feet.
Shale, light colored	13
Shale, reddish brown and maroon	7
Shale, light sandy	16
Sandstone, light colored, fine to medium grained; weathers yellowish. In places massive and locally in beds from 1 foot to 1½ feet thick	26
Shale, variegated, commonly light colored. Has a thin maroon streak near the base and a dark-gray streak near the top	26
Sandstone, single bed, very argillaceous	½
Shale, dark to reddish brown; weathers reddish; exhibits 1 foot of light shale near the top	10
Sandstone, light colored	5
Shale, variegated from light to reddish brown	13
Sandstone, light colored	13

[1] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Bald Mountain-Dayton folio (No. 141), p. 7, 1906.

[2] Personal communication.

	Feet.
Shale, maroon; contains some interbedded sandstone; weathers light to yellowish brown	10
Shale, dark; weathers light. Greenish, light brown, and drab and common shades	10
	149½

Calvert,[1] in his discussion of the Lewistown coal field of central Montana, applies the name Morrison to a group of beds which he describes 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.

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 applied by Sir William Dawson to a succession of sandstones, shale, conglomerates, and coal beds occurring along the Rocky Mountain front range in Alberta between the fortieth parallel and Medicine Bow River.

Weed[2] regarded about 300 feet of beds, chiefly sandstones and constituting what he called the "Cascade formation," in the Great Falls region of Montana, as of Kootenai or Lower Cretaceous age. Fisher[3] 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 Bighorn 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,[4] and that name was later used in the same sense by

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

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

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

[4] Darton, N. H., Geology of the Bighorn Mountains: U. S. Geol. Survey Prof. Paper 51, pp. 50–53, 1906.

Fisher.[1] In another paper Fisher[2] shows the character of the coal-bearing Kootenai 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. Inasmuch as only the uppermost beds of the Colorado shale are exposed in the Huntley field, it is obvious that the Kootenai, or its approximate equivalent, the Cloverly formation, is many hundred feet below the surface. At least a part of the formation, however, is exposed in a small eroded dome 8 or 9 miles southeast of Harlowton, Mont., between American Fork and Fish Creek, where, according to Bowen,[3] 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 and 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.	

The Cloverly formation is well exposed along Shoshone River near Cody, Wyo., on the west side of the Big Horn Basin, and also about 1½ miles west of Cloverly, Wyo., on the east side of the basin. The following sections not only show the nature of the Cloverly formation in those localities but furnish a basis for comparison:

Section of Cloverly formation on Shoshone River near Cody, Wyo.[4]

	Feet.
Sandstone, buff, indurated, characteristically thin bedded and ripple marked. The beds range from half an inch to 20 inches in thickness and are composed of angular and subangular grains of quartz, with traces of muscovite near the top	60
Shale, gray, sandy	25
Sandstone, buff, massive	25
	110

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

[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] Bowen, C. F., unpublished notes.

[4] Hewett, D. F., The Shoshone River section, Wyo., U. S. Geol. Survey Bull. 541, p. 96, 1914.

Section of Cloverly formation 1½ miles west of Cloverly, Wyo.[1]

	Feet.
Light-buff sandstone (overlain by Colorado shale)	10
Tan-colored sandstone	10
Maroon clay	4
Reddish tan-colored sandy shale	20
Deep-maroon sandy clay	20
Hard tan-colored sandstone	3
Deep-maroon to purple variegated clay	12
Lens of maroon sandstone	3
Deep-maroon sandy clay	20
Olive-green soft cross-bedded sandstone with hard layers, lying on maroon and drab-gray Morrison shale	10
	112

The beds that make up the Cloverly formation in the Elk Basin field of Montana and Wyoming, as it is described by Hares,[2] are susceptible of a fourfold division. At the base is a chert conglomerate, which grades upward into a light-brown coarse sandstone and ranges in thickness from 5 to 60 feet. Above the conglomerate is a zone of very brilliantly colored shales, including deep-red, maroon, purple, pink, green, blue, brown, and other bright colors. The shales contain nodules of lime, opalized quartz, radiating crystals of barite, and numerous gastroliths. This variegated shale member ranges from 95 to 130 feet in thickness. It is overlain by a variable, fairly coarse-grained sandstone, to which the name Greybull sandstone member is applied. This sandstone is sufficiently indurated to form a low ridge. Its thickness ranges from 1 to 30 feet. At the top of the Cloverly formation are about 130 feet of rusty-colored beds composed chiefly of reddish-brown thin-bedded fine-grained micaceous sandstone alternating with brown shale.

UPPER CRETACEOUS SERIES.

COLORADO SHALE.

In the Huntley field, as in the Lake Basin field, farther west, only a few hundred feet of the Colorado shale is exposed. Some drilling has been done in the Lake Basin field, however, and the available well logs were of considerable value in determining the nature of the lower part of the Colorado shale. Apparently no deep wells have ever been drilled in the Huntley field, but in endeavoring to ascertain the possibilities of obtaining oil and gas in that field it is of the

[1] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Bald Mountain-Dayton folio (No. 141), p. 7, 1906.
[2] Hares, C. J., unpublished manuscript.

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. In order to convey an adequate notion of the probable lithology of the lower half of the Colorado shale in the Huntley field, it is necessary to show, in a way that will allow comparison, the conditions which exist in neighboring fields. The stratigraphic sections given in Plate XV show the composition of the lower half of the Colorado shale, and some of them also that of the overlying formation in north-central Wyoming and south-central Montana. Some of these sections were measured in detail 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 part of the oil and gas produced at these localities as distinguished from other sands 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 they exhibit certain features which ought to be mentioned briefly because of their relation to certain stratigraphic problems presented by the Lake Basin and Huntley fields and because of the possibility that they may furnish 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 field, the top of the sandy portion of the Colorado shale becomes progressively lower 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 much higher 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, 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 about 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 generally 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 it includes five or six sandstone beds. This fact is also 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. The shale that overlies the Mowry in the Powder River field[3] contains several sandstone beds in its upper part. Wegemann says that these sandstone beds are highly 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.

According to Hares[5] the sandstones can generally be recognized, although they vary a great deal from one place to another.

MONTANA GROUP.

SUBDIVISIONS.

The rocks of the Montana group, of the late Upper Cretaceous, occupy about three-quarters of the Huntley field. The four forma-

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[1] Hewett, D. F., and Lupton, C. T., Anticlines in the southern part of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 656, p. 20, 1917.

[2] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, p. 45, 1911; Bull. 670, p. 17, 1918.

[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.

[5] Personal communication.

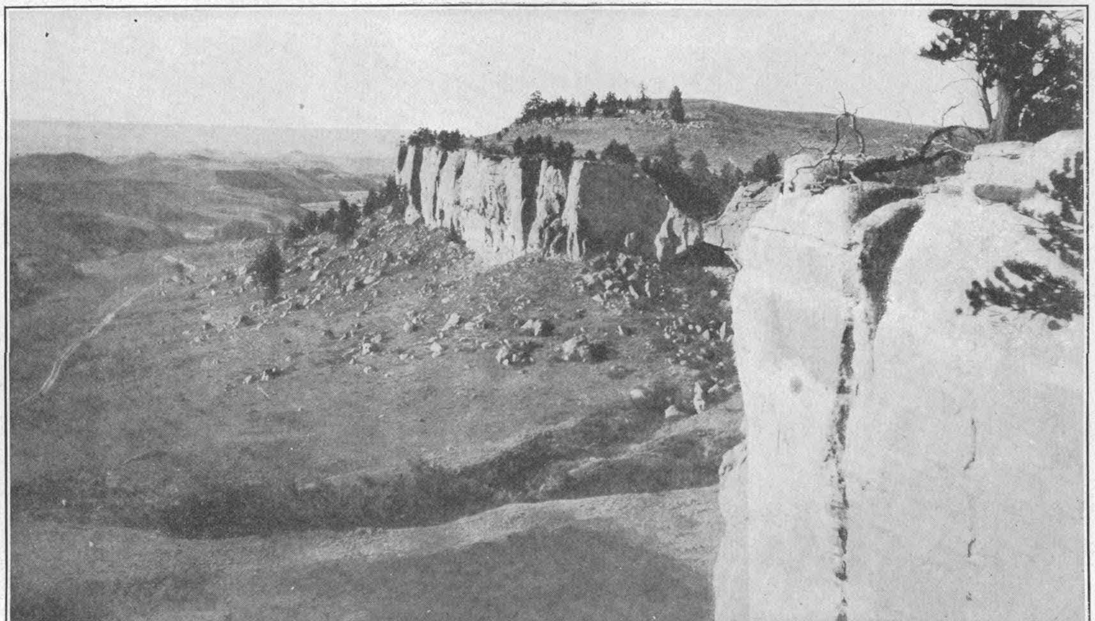
tional subdivisions of the Montana which are present are, in ascending order, the Eagle sandstone, Claggett formation, Judith River formation, and Bearpaw shale.

The nonpersistence of the lithologic units in this group is indicated by the conditions in the Lake Basin field, immediately west of this area, where 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 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; and these coastal-plain deposits are separated by the marine shales of the Claggett and Bearpaw formations, indicating oscillatory movements of the shore and a corresponding advance of marine waters. In the field work it was clearly recognized that some of the formations change their character very materially within very short distances in the Huntley field, and were it not for the river valley, the presence of faults, and the consequent element of uncertainty involved in tracing individual beds across the Yellowstone, together with the surface covering of gravel east of the river, the map of the Lake Basin field would have been extended to cover the Huntley field, for the purpose of showing the nonpersistence of the formations in the Huntley field and also the exact relations of these formations to those of the Lake Basin field. Owing to the difficulties involved it was thought advisable not to attempt to represent the nonpersistence of lithologic units diagrammatically, but to show it, if possible, by means of stratigraphic sections. The lithology of the different formations is made clear by the following detailed descriptions:

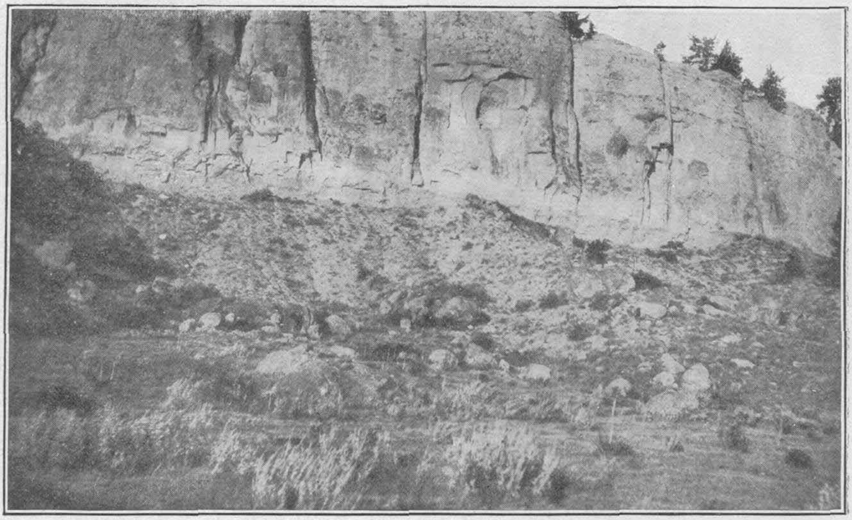
EAGLE SANDSTONE.

The name Eagle sandstone was used by Weed[1] for 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 is 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 it—the Virgelle sandstone member of the Eagle sandstone. For several miles southeast of Billings the Eagle sandstone maintains

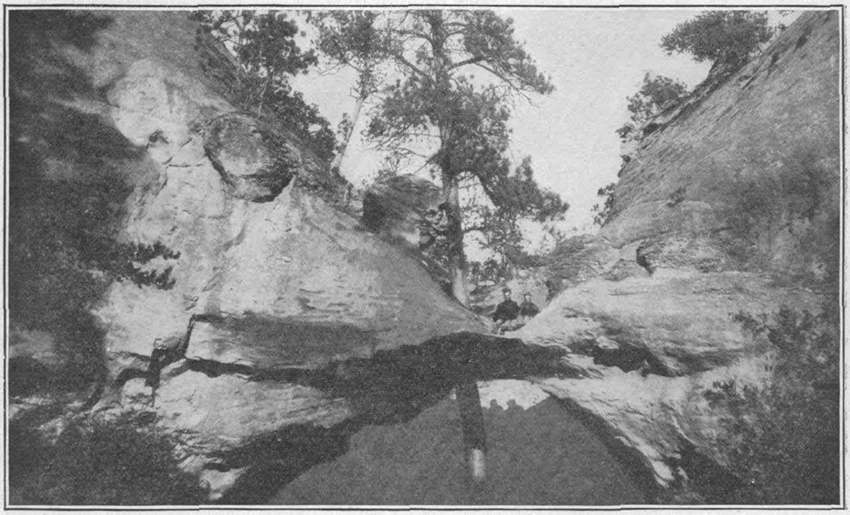
[1] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Fort Benton folio (No. 55), 1899.



EAGLE SANDSTONE AS SEEN LOOKING NORTHWEST FROM THE TOP OF THE STEEP CLIFF IN THE NE. ¼ SEC. 19, T. 1 S., R. 27 E., MONTANA.



A. VERTICAL CLIFF ABOUT 100 FEET HIGH FORMED BY THE MASSIVE SANDSTONE AT THE BASE OF THE EAGLE FORMATION NEAR THE NORTH LINE OF SEC. 19, T. 1 S., R. 27 E., MONTANA.



B. MASSIVE SANDSTONE AT THE BASE OF THE EAGLE FORMATION, SHOWING A NATURAL BRIDGE OF SANDSTONE WHERE THE TWO MEN ARE SITTING.

An opening has been eroded through the sandstone back of the natural bridge, and a very large pine tree has grown up through the small opening since it was formed.

a rather uniform character and is well represented by the following stratigraphic section:

Section of Eagle sandstone about 3 miles southeast of Billings, Mont., in the NW. ¼ sec. 18, T. 1 S., R. 27 E.

Base of Claggett formation.	Feet.
Sandstone, yellowish brown, very thin bedded	20
Shale, sandy	7
Sandstone, light yellow, massive	3
Shale, light gray, sandy	26
Sandstone, light yellow, soft	5
Sandstone, light yellow, massive	15
Sandstone, yellowish brown	25
Sandstone, light yellow, very massive; exhibits practically no bedding planes; forms a vertical wall	100
	201

As indicated by the above section and Plates XVI and XVII, *A*, the Eagle sandstone in the western part of the Huntley field is very similar to that formation in the type locality. The massive sandstone at the base forms in many places vertical cliffs about 100 feet high, as shown in Plate XVII, *A*, but locally it weathers out, forming immense caves. (See Pl. XVII, *B*.) At Pryor Creek, however, the sandstone at the base has lost its massive character to such an extent that its presence is scarcely indicated by the topography. It changes very rapidly toward the east from a hard massive sandstone to soft sandy shale.

CLAGGETT FORMATION.

The largest area of the Claggett formation in the Huntley field extends from Billings east and north down the Pryor Creek valley. The name Claggett was given by Stanton and Hatcher[1] to the formation overlying the Eagle sandstone, 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 Huntley field indicates a rapid change from the deposition of coarse sand to that of sands and clays in quick succession and finally to conditions 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 coarse grain of the Eagle sandstone, the presence of false bedding, the numerous impressions of the fossil seaweed *Halymenites major*, and the almost universal distribution of small flattened chert pebbles near the top indicate deposition near

[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.

the shore. Furthermore, the shallow-water origin of the sandy shales and thin-bedded sandstones of the Claggett is indicated by the presence of ripple marks at several horizons in the formation. The presence of lenticular sandstones in the shale would seem to indicate not only shallow-water deposition but also the accumulation within very small areas of great quantities of coarse sand. The Claggett formation in the Pryor Creek valley is characterized by numerous lenticular sandstones. The sandstones of the Claggett are commonly thin bedded, but locally, as in the Huntley field, they are massive and form prominent cliffs. They weather out into peculiar forms and develop large caves. Two such sandstones, one about 100 feet above the other, were mapped in the southern part of the field. Even where the sandstones are not sufficiently massive to form conspicuous cliffs, there is sufficient sand in the shale to support a considerable growth of evergreens. Farther north toward the Yellowstone the sandstones in the Claggett are not nearly so persistent. They occur mainly in the form of lenticular masses in the shale and crop out very conspicuously for some distance south of Huntley. The marine origin of the sandy shale lying immediately below the sandstone that forms the prominent escarpment in the SE. ¼ sec. 9, T. 1 N., R 28 E., is proved by the following species of marine invertebrates collected from it:

Actaeon? sp.
Avicula americana Evans and Shumard.
Baculites sp.
Cardium speciosum Meek and Hayden.
Leptosolen sp.
Liopistha undata Meek and Hayden.
Mactra formosa Meek and Hayden.
Mactra sp.
Modiola sp.
Odontobasis? sp.
Tellina equilateralis Meek and Hayden.
Tellina sp.

Such marine invertebrates as *Cardium speciosum* Meeks and Hayden and *Mactra* sp. are abundant in the sandstone that crops out near the northeast corner of sec. 6 of the same township, and in addition to these species, *Pholadomya* sp. and *Legumen* sp. occur abundantly in the prominent ledge of sandstone near the township corner about a mile farther west. In addition to the marine invertebrates already enumerated, the following species were obtained about 25 feet below the sandstone here mapped as basal Judith River near the west line of sec. 33, T. 1 N., R. 27 E.:

Anatina sp.
Avicula nebrascana Evans and Shumard?
Cardium speciosum Meek and Hayden.
Leptosolen sp.
Mactra formosa Meek and Hayden.
Tellina equilateralis Meek and Hayden?

From the facts previously stated it is obvious that the Claggett formation is composed mainly of marine shale. Interbedded with the shale are belts of sandy shale and shaly sandstone. In certain localities the sandy constituent is so abundant and the sandstones have become so thoroughly indurated as to form very conspicuous cliffs. Even where the sandy constituent is not sufficiently abundant to affect the topography, its presence is commonly indicated by a sparse growth of evergreens.

JUDITH RIVER FORMATION.

The Judith River formation overlies the Claggett formation and underlies the Bearpaw shale. The area underlain by the Judith River formation is generally somewhat higher than those occupied by the Claggett and the Bearpaw. The sandstones of the formation are, as a rule, inclined at very low angles and form a succession of minor escarpments. Notable exceptions occur, however, within the intensely faulted area, where blocks of the Judith River formation are upturned as steeply as 30°. The most resistant sandstone, and consequently the one which has had the greatest influence in the development of land forms, is the one which seems to be the approximate equivalent of the upper part of the Claggett formation in its type area but for convenience of mapping is here treated as the base of the Judith River formation. It forms a rather prominent escarpment around the area of the Judith River formation between the valleys of Pryor Creek and the Yellowstone, and also along the east side of the Pryor Creek valley.

The term Judith River was first applied 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. The Judith River formation changes in character materially within a very short distance in the Huntley field. The basal sandstone of the formation is commonly made up of rather brittle, irregularly jointed reddish-brown sandstone interbedded with layers of greenish-gray sandy shale. These lower beds ordinarily present a reddish-brown aspect in contrast with the light-colored sandstones higher up. Where the formation is highly tilted and faulted near the southeast corner of T. 2 N., R. 29 E., the basal sandstone contains considerable dark carbonaceous shale and a few thin streaks of coal. Between the basal sandstone of the Judith River and the next prominent ledge-making sandstone above is from 60 to 100 feet of soft light-colored sandstone and sandy shale, includ-

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

ing some carbonaceous material, which, like the overlying sandstones, changes to shale in the eastern part of the field. The greatest change in the Judith River formation occurs in the vicinity of Fly Creek. Near the east side of sec. 2, T. 1 N., R. 28 E., where the formation is highly tilted, it was carefully measured and found to contain about 500 feet of beds, as shown in the stratigraphic section on page 123. Near the southeast corner of T. 2 N., R. 29 E., where the formation is highly tilted and faulted, it still maintains a similar thickness; but east of Fly Creek it is composed of a single massive white sandstone. Above that sandstone lie about 400 feet of beds composed almost entirely of sandy shale containing marine fossils near the base. The following stratigraphic sections illustrate the composition of the Judith River formation in this field:

Section of the upper part of the Claggett and the lower part of the Judith River formation in sec. 28, T. 1 N., R. 27 E., Mont.

	Ft.	in.
Sandstone, yellowish brown, massive; forms top of very conspicuous cliff	25	
Sandstone, light gray to brown, fine grained; contains many circular nodules; forms base of very prominent cliff	15	
Shale, gray, contains numerous light-gray circular nodules of fine-grained sandstone	3	
Shale, soft and sandy	8	
Shale, dark, carbonaceous	3	
Sandstone, platy	2	2
Shale, soft and sandy	5	6
Sandstone, thin bedded, platy		10
Shale, somewhat sandy; forms talus slope below sandstone	36	
Sandstone, soft, gray, coarse grained; contains a large percentage of some dark constituent; in some places forms a ledge	4	
Sandstone, fine grained, somewhat clayey; entire mass presents a banded appearance, greenish-gray and yellowish-brown colors predominating	44	
Sandstone, greenish gray, soft; contains some brown nodules; not resistant enough to form a cliff	26	
Sandstone, yellowish, rather massive	15	
Concealed; probably sandy shale	8	
Sandstone, yellowish brown, in thin beds	3	6
Sandstone, yellowish to brown, somewhat platy	1	2
Shale	2	6
Sandstone		8
Shale	3	
Sandstone, yellowish brown, fine grained, brittle (base of Judith River formation)	2	
Shale, dark gray, becoming more sandy toward the top	39	
	247	4

Section of Judith River formation in secs. 1 and 2, T. 1 N., R. 28 E., Mont.

	Feet.
Bearpaw shale.	
Sandstone, light colored and soft; contains some brown layers and concretions	60
Concealed; probably shale or soft sandstone	65
Shale, gray	20
Sandstone, massive, light yellow; top weathers to cavernous forms; contains some flat layers of brown sandstone	60
Sandstone, light yellow, very soft; contains thin belts of bluish-gray sandy shale	75
Shale, very sandy; contains considerable carbonaceous material	25
Shale, dark; contains sandy and calcareous concretions, which include *Corbicula occidentalis* Meek and Hayden	35
Sandstone, shale, and sandy shale; sandstone layers contain considerable carbonaceous material	35
Sandstone, very white	10
Sandstone, brown, massive, alternating with belts of greenish-gray sandy shale and becoming light toward the top; contains plant fragments	115
Claggett formation.	
	500

The following stratigraphic section illustrates the rapid change in the formation in the eastern part of the field. That the massive light-colored sandstone at the base of the section is probably the basal sandstone of the Judith River is inferred from the existence of pure shale immediately below and the persistence of the basal sandstone elsewhere in the field. Upon that assumption, after the lowermost beds of the Judith River formation were laid down there was a pronounced change in sedimentation within a very short distance in the eastern part of the field, and while clays and silts with a certain admixture of sand were being deposited east of Fly Creek almost pure sand was being laid down a little farther west.

Section including the Judith River formation and overlying beds near the east line of T. 1 N., R. 30 E., Mont.

	Ft.	in.
Shale, sandy, extending up to the top of the ridge, which is covered with gravel	28	
Sandstone; forms shelf		9
Shale, containing some sand	16	
Shale, gray, almost entirely free from sandstone layers	105	
Sand, light yellow, rather unconsolidated; contains streaks of shale and is capped by a hard 5-foot rusty-colored sandstone	35	
Shale, sandy; contains thin layers of sandstone in the lower half; upper half composed of soft and fine sandy material containing reddish-brown concretions	150	
Shale, sandy	2	6
Sandstone, soft, gray	4	

	Ft.	in.
A zone not well exposed but believed to be composed mainly of sandy shale; includes some petrified wood near the top	60	
Massive white sandstone	65	
Claggett shale.		

BEARPAW SHALE.

Overlying the fresh-water and brackish-water beds of the Judith River formation is an undetermined thickness of marine shale. The thickness is in all probability not very different from that in the adjoining lake basin field, namely, from 500 to 600 feet. This shale was named from the Bearpaw Mountains by Stanton and Hatcher,[1] who determined its stratigraphic relation. It underlies the massive sandstones of the Lance formation and occupies Hoskins Basin and all of the Yellowstone Valley northeast of Huntley, as well as smaller areas farther south. It is composed almost entirely of dark-gray shale, including an abundance of grayish to reddish brown calcareous concretions, many of which contain marine invertebrate fossils.

TERTIARY (?) SYSTEM.

LANCE FORMATION.

The name Lance formation is an abbreviated form[2] of "Lance Creek beds," a term used by Hatcher[3] in 1903 to apply to the "*Ceratops* 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.

The lowermost sandstones of the Lance formation, in contrast with the underlying Bearpaw shale, form a rather conspicuous escarpment a short distance north of Yellowstone River and around part of the large circular area commonly known as Hoskins Basin. Pompeys Pillar, a low butte near the south bank of the Yellowstone, about 2½ miles west of a station by the same name on the Northern Pacific Railway, is composed of the sandstone near the base of the formation. The area occupied by the Lance formation is somewhat higher than that of the Bearpaw shale, and where the sandstones are nearly flat lying, as they are in this field, they form a series of scarps. Unlike the Bearpaw shale, which is covered with sagebrush, the

[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.

[2] 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.

[3] 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.

sandy beds of the Lance formation furnish a favorable habitat for evergreens. The formation consists of alternating beds of light-yellow to grayish sandstones, bluish to gray sandy shale, drab, yellow, and gray clays, and clay shale. The composition of the formation is quite accurately expressed by the following stratigraphic section, measured a short distance west of Hoskins Basin:

Section of the middle portion of the Lance formation in the deep gulch near the north line of sec. 24, T. 4 N., R. 24 E., Mont.

	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; contains 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 Lance formation contains a few thin beds of coal, especially in the upper part. In the Bull Mountain field, immediately north of this area, however, where the primary object of the Geological Survey's work was the mapping of the coal, the thin coal beds of the Lance formation were considered of insufficient value for detailed mapping.

TERTIARY SYSTEM.

FORT UNION FORMATION.

The Fort Union formation was named in 1862 by Meek and Hayden [1] from a former military post on Missouri River in North Dakota, about 3 miles from the Montana State line, where the formation is typically exposed. The beds in the Huntley field which are now referred to the Fort Union were described by the geologists of the Transcontinental Survey but were placed by them in their "Upper Laramie or Bull Mountain series." [2]

Immediately overlying the Lance formation is the Lebo shale member of the Fort Union, a group of beds which have a thickness of 200 to 300 feet and which are apparently conformable both with the Lance below and with the overlying part of the Fort Union. These beds are exposed only in a small area near the north edge of the Huntley field. They are distinguished from the rest of the Fort Union by differences in color and physical character. In the reports on the different parts of the Bull Mountain coal field these beds have been referred to by Woolsey [3] as "beds on Dean Creek," by Richards [4] as "somber-colored beds," and by Lupton and others [5] as "Lebo shale member of the Fort Union formation."

The rocks consist of olive-green, yellow, brown, and dark sandy shale interbedded with some soft sandstone. The dark or olive-green color and the absence of resistant sandstones distinguish the Lebo member from the overlying beds of the Fort Union and also from the Lance formation. The Lebo member contains two carbonaceous zones, the more prominent of which is known in the Bull Mountain coal field as the Big Dirty coal bed. The horizon of the Big Dirty coal bed was recognized in the Huntley field, but wherever the rocks

[1] Meek, F. B., and Hayden, F. V., Description of new lower Silurian (Primordial), Jurassic, Cretaceous, and Tertiary fossils collected in Nebraska by the exploring expedition under the command of Capt. W. F. Reynolds, U. S. Top. Eng., with some remarks on the rocks from which they were obtained: Acad. Nat. Sci. Philadelphia Proc., vol. 13, p. 433, 1862.

[2] Eldridge, G. H., Geology of the Laramie (Montana) coal fields: Tenth Census U. S., vol. 15, p. 744, 1886.

[3] Woolsey, L. H., The Bull Mountain coal field, Mont.: U. S. Geol. Survey Bull. 341, p. 62, 1909.

[4] Richards, R. W., The central part of the Bull Mountain coal field, Mont.: U. S. Geol. Survey Bull. 381, p. 60, 1910.

[5] Lupton, C. T., The eastern part of the Bull Mountain coal fields, Mont.: U. S. Geol. Survey Bull. 431, p. 170, 1911. Woolsey, L. H., Richards, R W., and Lupton, C. T., The Bull Mountain coal field, Musselshell and Yellowstone counties, Mont.: U. S. Geol. Survey Bull. 647, pp. 24–27, 1917.

at that horizon were examined they were found to be composed almost entirely of carbonaceous shale.

The composition of the Lebo member is fairly well represented by the following detailed stratigraphic section:

Section of Lebo shale member of the Fort Union formation in sec. 4, T. 4 N., R. 27 E., Mont.

	Ft.	in.
Sandstone, light-yellow, rather massive; apparently mapped as base of upper part of Fort Union formation north of range line	25	
Shale, sandy	2	6
Shale, carbonaceous; contains some coal	1	
Shale, grayish yellow	22	
Sandstone, light yellow, hard; forms a prominent cliff	3	6
Shale, sandy	10	
Sandstone, brown, very hard	1	1
Shale, sandy	1	
Sandstone, hard, flinty	1	2
Shale, gray	1	6
Sandstone, hard, fine grained	1	8
Shale, gray	18	
Sandstone, thin bedded, shaly	6	
Sandstone, light yellow, very soft; crumbles easily	22	
Shale, dark gray to black, carbonaceous	22	
Sandstone, soft; weathers reddish brown	1	4
Shale, sandy; contains some concretions	6	
Sandstone, rusty-colored	1	8
Shale, somewhat sandy in places, carbonaceous	8	
Shale, carbonaceous, including streaks of impure coal	4	
Shale, sandy, carbonaceous		4
Coal, impure	1	1
Shale concretions		2
Shale, sandy	13	
Shale, carbonaceous; contains some coal		11
Sandstone, shaly	3	
Sandstone, thin bed, shaly	5	
Shale, gray; contains carbonaceous streak	6	
Sandstone, soft	2	
Shale, gray to black, carbonaceous	4	
Sandstone, thin bedded	1	6
Shale, sandy	9	6
Sandstone, yellowish brown	1	4
Shale, sandy	9	
Sandstone	1	4
Shale, carbonaceous	2	
Shale, sandy	10	
	229	7

The part of the Fort Union formation that overlies the Lebo member is represented in the Huntley field by a single massive sandstone occurring in only two localities near the north line of the field, as shown on the map.

MIOCENE (?) OR PLIOCENE (?) SANDSTONES AND GRAVELS.

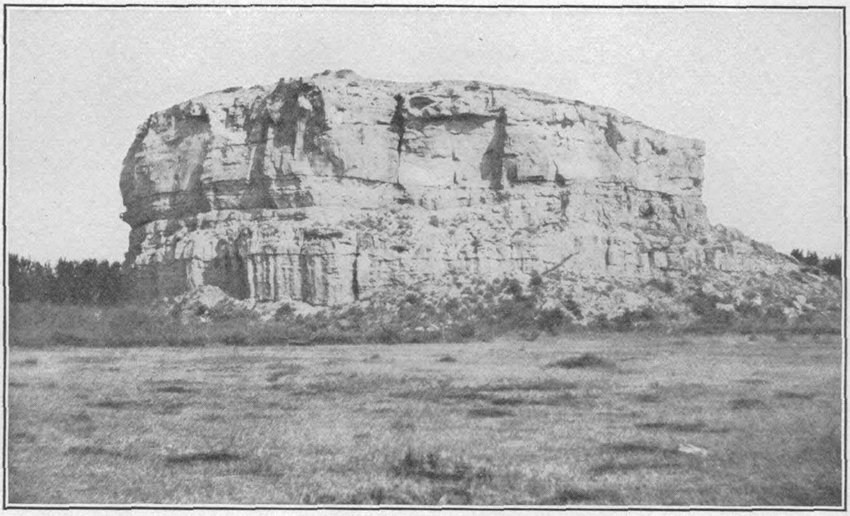
Deposits of gravel and conglomerate, in places underlain by soft sandstone, cap many of the higher elevations south of the Yellowstone. They appear to have been spread out upon a comparatively even surface that sloped very gently toward the north, and, owing to their superior resistance to erosion, they now form the "flat tops" of the interstream areas, whose altitude ranges from 3,900 to 4,000 feet, or about 1,000 feet above Yellowstone River. These flat tops are very conspicuous both east and west of Pryor Creek and between Arrow Creek and Fly Creek. The presence of the higher gravels was recognized very soon after the field work was begun, and some time later the pebbles and boulders were found embedded in a coarse sand matrix, forming a true conglomerate. The conglomerate was first recognized at the south edge of the flat top in sec. 10, T. 1 S., R. 27 E. The thick bed of conglomerate shown in Plate XVIII, *B*, is exposed in the SW. ¼ sec. 34, T. 2 N., R. 28 E., where there is about 8 feet of conglomerate, some of the pebbles of which are 10 inches in diameter. The pebbles appear to consist mainly of light and dark colored chert, quartzite, vein quartz, granodiorite, aplite, latite, andesite, and basalt.

The high ridge in sec. 23, T. 2 N., R. 29 E., is capped by a massive orange-yellow sandstone which is everywhere overlain by a great thickness of the higher gravels. The sandstone overlies the Bearpaw shale, but in its lithology and color is not at all like the basal sandstone of the Lance formation. It is probable, therefore, that the sandstone is of the same age as that underlying the higher conglomerates and gravels at different points around the margins of the flat tops. Recent work by Collier and Thom[1] in northeastern Montana has shown that there are three erosion levels represented there. A still higher level is marked by the gravels which cap the Cypress hills in Canada. Fossils collected from these gravels by McConnell and Weston[2] and by Lambe[3] show them to be of Oligocene (White River) age. The next lower level is marked by the Flaxville gravel,

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

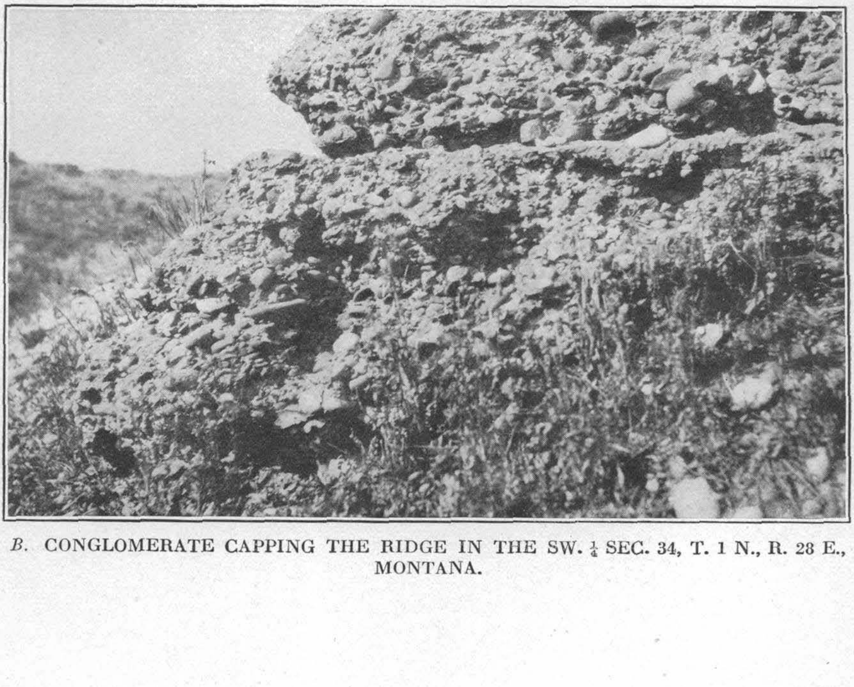
[2] McConnell, R. G., On the Cypress Hills Wood, Mountain, and adjacent country: Canada Geol. Survey Ann. Rept., new ser., vol. 1, pp. 1c–78c, 1886.

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



A. POMPEYS PILLAR, MONTANA.

A low butte formed by the sandstone at the base of the Lance formation. It is near the south bank of the Yellowstone, about 2½ miles west of a station by the same name on the Northern Pacific Railway.



B. CONGLOMERATE CAPPING THE RIDGE IN THE SW. ¼ SEC. 34, T. 1 N., R. 28 E., MONTANA.

named from the town of Flaxville. It caps a series of even-topped plateaus ranging in altitude from 2,600 to 3,200 feet. Fossils obtained from the Flaxville gravel and the associated sandstones indicate that the formation can not be older than Miocene nor younger than early Pliocene. On a lower plane than the Flaxville gravel are stratified gravels and silts which are younger than the Flaxville gravel but older than the Wisconsin stage of glaciation (late Pleistocene) and therefore of late Pliocene or early Pleistocene age. Finally the present streams have eroded valleys from 100 to 500 feet below the late Pliocene gravels and silts.

The topographic relation of the Yellowstone and its tributaries to the plain of erosion upon which the highest gravels of the Huntley field were deposited suggests that these gravels were laid down at about the same time as the Flaxville gravel of northeastern Montana. If so, they are probably of Miocene or early Pliocene age.

QUATERNARY SYSTEM.

PLEISTOCENE (?) DEPOSITS.

Bordering the Yellowstone flat on the south and to some extent on the north and extending southward on both sides of the streams which are tributary to the Yellowstone is a well-defined system of gravel terraces. Along the south edge of the main flat these terraces are from 100 to 200 feet above the river, but they rise very gradually as they extend southward along the smaller streams. The north bank of the Yellowstone shows from 60 to 80 feet of Bearpaw shale, ordinarily capped by 10 to 20 feet of gravel. This gravel probably corresponds to that of the terraces south of the river. It is quite probable that these terraces are the uneroded portions of an outwash plain spread out by the streams from the melting ice during early Pleistocene time, or possibly during the late Pleistocene (Wisconsin) stage of glaciation. If that is true, the amount of erosion which took place during late Pliocene and early Pleistocene time is expressed by the distance between the higher gravels of the flat tops and those of the terraces lower down, and the amount of postglacial erosion is expressed by the interval between the terraces and the present bed of the Yellowstone.

RECENT DEPOSITS.

Sands, silts, and fine gravels have been deposited along the Yellowstone wherever that stream has overflowed its banks. Deposits formed in this way produce some of the richest soil in the Huntley field.

STRUCTURE.

GENERAL FEATURES.

The structure of the rocks is the attitude which they have acquired since they were formed. 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."

Most sedimentary rocks have been laid down by water in an approximately horizontal position, but sometimes in the process of mountain building immense thicknesses of these sedimentary beds have been uplifted many thousands of feet. The conditions which produce the forces acting within the earth's crust are too complex to be discussed in a report of this nature, but it is well to keep in mind a few fundamental facts in order to understand more clearly the detailed descriptions of the structural features. In any region the shape, magnitude, and relation of the structural features depend primarily on the nature and relation of the formations involved, the amount of load which they sustain, the direction and magnitude of the forces of deformation, and the length of time these forces are acting. When the rocks are deformed the beds either bend or break, and the fact that moderately hard and brittle beds, such as sandstones and limestones, will often break, whereas soft beds, such as shales and clays, adjust themselves to the existing forces by bending, is of the utmost importance to the petroleum geologist. In a region like that including the Lake Basin and Huntley fields, where hard and soft formations alternate, any evidence bearing on the origin of the force of deformation and the extent to which these forces are transmitted from one hard formation to another, through an intervening mass of soft shale, is extremely desirable. Wherever erosion has exposed the Eagle sandstone in the faulted belt in the Lake Basin field, it seems to have been faulted to about the same extent as the Judith River formation, and hence it was assumed in preparing the structure map that almost all the faults which cut the Judith River formation in the Huntley field have affected the Eagle sandstone in a similar manner. The extent to which the faults have displaced the underlying Colorado shale and the interbedded sands, which in many localities are oil and gas bearing, and also the extent to which the fault fissures have remained open for the free circulation of solutions are problems concerning which there is very little direct evidence.

RELATION TO MAJOR AND MINOR UPLIFTS.

Before the structural features of the Huntley field are described in detail it is well to consider the relation of the Lake Basin and Huntley fields, as a whole, to some of the most important structural features of the region.

Throughout this region 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 era 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 that acted during the formation of the Rocky Mountain Front Range certain major uplifts occurred 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 influence 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. These mountain masses are clearly outlined on the accompanying key map (fig. 6). 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

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

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 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 asymmetric anticline, but in the Big Snowy Mountains the steep dips are on the south side,

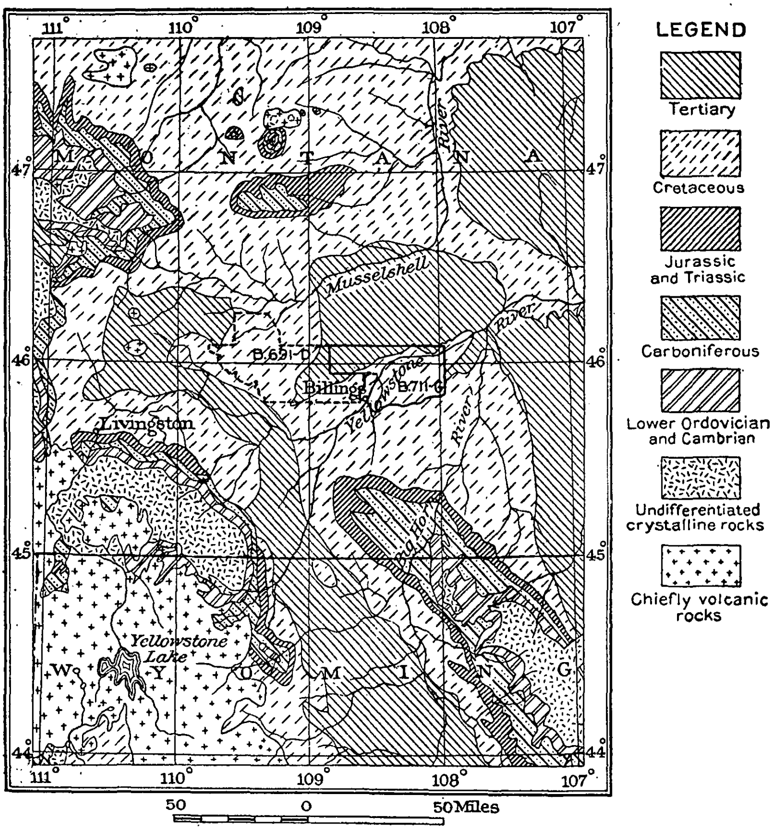


FIGURE 6.—Map showing relation of the Lake Basin and Huntley fields, Mont., to the major structural features of the region.

whereas in the Little Belt Mountains the fold is overturned to the north. 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 Huntley and Lake Basin fields. The region between these fields 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.

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—for example, mean sea level. In the preparation of the accompanying map (Pl. XIV, in pocket) the base of the Eagle sandstone was chosen as the horizon to be represented, and each contour is drawn to indicate successive points of the same elevation on this horizon. 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

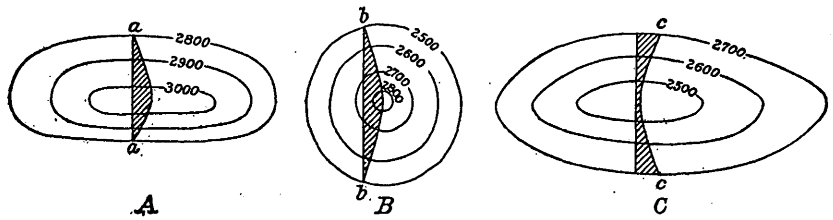


FIGURE 7.—Diagrams illustrating anticline (*A*), dome (*B*), and syncline (*C*) structure. The shape and height or depth of the folds are shown by contours. The sequence of numbers on the contours shows whether the central or axial portion of the fold is depressed (synclinal) or raised (anticlinal). The shaded areas *a–a*, *b–b*, *c–c* in the respective diagrams represent cross sections through the folds.

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. These structure contours, when clearly understood, present a complete picture of the warped surface at the base of the Eagle sandstone. In order to assist in the interpretation of the structure in the Huntley field and also to explain the meaning of certain structural terms commonly used in oil and gas literature the accompanying diagrams (fig. 7) are introduced.

In figure 7, *A*, the contours close around a central area, and toward the axis each successive contour is 100 feet higher than the one lying toward the outside. This means that the surface is arched, forming an anticline, and as the contours are more closely spaced on one side than they are on the other, the slope of the surface is inclined much more steeply on that side. In figure 7, *C*, the contour lines represent a fold of the opposite kind. The highest points in the fold are on the outside rims and the center is the deepest point. This diagram therefore represents a trough or syncline, and as the contours are about evenly spaced the slope toward the middle is about the same on both sides and the fold is symmetrical. In figure 7, *B*, as in figure 7, A, the contours close around a central area, but instead of forming an ellipse they form a circle, and the structural feature is what is commonly called a dome. Toward the center each succeeding contour is 100 feet higher than the one lying on the outside. As the contours are equally spaced, the surface is inclined equally in all directions from the apex of the dome. However, few domes are even approximately circular in outline.

STRUCTURE IN THE HUNTLEY FIELD.

FOLDS.

The sedimentary formations involved in this field form a part of the northwest flank of the Big Horn anticline. As that great anticline was developed the formations in the north half of the field were inclined northward approximately 100 feet in 1 mile. Elevations on the base of the Lance formation from the southwestern part of T. 3 N., R. 26 E., to Pompeys Pillar show that the formation is also inclined downward toward the east at a rather uniform rate of about 12 feet to the mile. Toward the south line of the field the beds rise somewhat more steeply. For example, the basal sandstone of the Judith River formation rises from the Northern Pacific Railway near Lockwood toward the south at a fairly uniform rate of 127 feet to the mile, but south of the area of the Judith River formation the beds are inclined upward toward the south at a much greater angle. The Judith River formation east of Pryor Creek is, in general, inclined toward the north at a very low angle, as the structure contours show, but toward the faulted area the structure becomes very complicated. Throughout the faulted area faults and minor folds are very intimately associated, and hence the minor folds are described in connection with the detailed descriptions of the faults.

FAULTS.

The most striking feature of the structure of the Lake Basin field, immediately west of this area, is the long, narrow belt of shearing that crosses the field from the northwest corner southeastward to Huntley. During the field season of 1917 the same belt was traced eastward entirely across the Huntley field, this work demonstrating the existence of a continuous belt of faulting almost 100 miles in length. Notwithstanding the great length of this belt the faulting is confined to an area in general not more than 6 miles in width. The two dominating folds in the Lake Basin field are the Big Coulee-Hailstone dome and the extreme northwest end of the Big Horn anticline. It is apparent from the key map (fig. 6) that the east end of this great belt of shearing occurs along the north flank of the Big Horn anticline. As the great structural features of this region were being formed and the stresses produced in the process were relieved by shearing the beds that constitute the steeply dipping south flank of the Big Coulee-Hailstone dome and the north flank of the Big Horn anticline were the ones to be affected. The relation of these two major structural features to each other and also to the great belt of shearing suggests torsional movement as a probable cause of localized folding and faulting throughout that narrow belt.

The abundance of gravel distributed over the surface from Huntley eastward not only added to the difficulty of working out the details of the structure but in certain localities introduced more or less uncertainty. Wherever the evidence is reasonably conclusive the structure contours are shown by unbroken lines, but where the details of the structure are obscured by overlapping gravel deposits or by recent deposits of alluvium the structure contour lines are broken. For convenience of description the principal faults are designated by letters (A–A′, B–B′, etc.).

LOCAL DETAILS.

FAULTS AND FOLDS IN THE VICINITY OF HUNTLEY.

A rather conspicuous sandstone about 250 feet above the base of the Judith River formation crops out continuously, as shown on the accompanying map (Pl. XIV), from the north line of sec. 9 to the NE. ¼ sec. 3, T. 1 N., R. 27 E. At the north line of sec. 3 the top of the sandstone is about 250 feet above the Yellowstone, but it abruptly dips northeastward and at fault A–A′ almost reaches the level of the river. On the northeast side of the fault the basal Judith River beds are upturned against the fault at an angle of 16°, but they flatten within a short distance and rise toward the east, exposing Claggett shale in the south bank of the Yellowstone. The stratigraphic relations of the beds at the fault plane indicate a vertical displacement of about 250 feet. The hard rocks are buried beneath the alluvium of the river bottom, but the variation in strike and dip of the massive sandstone exposed in the steep bank immediately west of the river bottom indicates that fault A–A′ extends west from the locality where the displacement was actually observed, about as indicated on the map. The shallow syncline observed in the south bank of the Yellowstone northeast of fault A–A′ is more or less continuous from the river southeastward across the Pryor Creek valley to fault O–O′. It merely represents a low sag in the rocks between the northwestward-dipping Judith River beds on the southwest and the highly faulted and incompletely developed dome on the northeast. These structural features have been cut by a number of small faults and a few whose displacement is measured in hundreds of feet. Along the line B–B′ a prominent bed of sandstone is cut by a fault on the east side of the gully near the north line of sec. 36. The sandstone on the north side of the fault plane is upturned at an angle of 21°. The fault was traced west as far as the river, and it is probable that the hard beds beneath the alluvium have been displaced for some distance farther. Apparently the movement did not extend far enough eastward to displace the prominent sandstone immediately east of Pryor Creek. The massive sandstone which forms a conspicuous ledge east of Pryor Creek has been cut by certain small faults (C–C′) in which the downthrow is on the north side of the fault plane.

Immediately west of the main wagon road in the SW. ¼ sec. 6, T. 1 N., R. 28 E., one of the sandstones in the Claggett formation is cut off by fault G–G′. The shear planes are inclined down toward the northwest at an angle of 60°. To the casual observer the conditions shown here would present little if anything of especial interest, but to anyone whose business it is to trace these faults on the surface they are of peculiar significance. The trace of the fault plane is indicated by a long, gently curving ditchlike depression in which the boulders have gradually collected, whereas the sandstone on the left of the fault plane has given rise to a long sweeping embankment.

The basal sandstone of the Judith River formation is also cut by fault F–F′. The displacement of the sandstone begins as represented on the map, and the beds north of the fault plane are dropped 75 feet within a very short distance, but the fault could not be traced in the shale northeastward for any great distance. A massive bed of sandstone is well exposed west of the main wagon road about a mile south of Huntley. This sandstone is believed to be the same as the one that forms the prominent ledge east of the main road near the village. It has been displaced by faults D–D′ and E–E′, but it dips beneath the Pryor Creek valley a few hundred feet southeast of fault E–E′ and may be the same sandstone as the one cut by fault G–G′. If the two sandstones are equivalent the amount of vertical displacement along fault G–G′ at Pryor Creek is approximately 300 feet. From the point where the sandstone emerges from the valley it rises rapidly to fault E–E′, where there is an upward displacement of 50 feet. The highest point on this sandstone is about midway between faults E–E′ and D–D′, where it dips west at an angle of 5°. From the highest point it is inclined north very gently and finally dropped 75 feet at fault D–D′.

The uppermost sandstone of the Judith River formation is well exposed along the west bank of the Yellowstone at the bridge on the main road leading west from Huntley. There the sandstone dips north at an angle of about 2°. There are no exposures of the hard rocks between that point and a locality a mile east of Huntley, where two massive sandstones overlain by shale are upturned at an angle of about 20°. These massive sandstones and the sandy beds beneath are evidently continuous with those south of the triangular fault block in sec. 32. There the upper one of the sandstones forms a very conspicuous pine-covered ledge from the fault block south to fault K–K′, where there are three massive sandstones dipping from 10° to 14° E. East of this sandstone belt none of the older sandstones were observed, and the formation apparently consists of dark marine shale overlain by deposits of gravel and the soft reddish-brown sandy beds so commonly associated with them.

The relation of the beds indicates that a block of the formation between faults G–G′ and H–H′ has been dropped and that the greatest amount of vertical displacement is along fault H–H′. In places along these faults the sandstones have been literally sliced along shear planes, indicating movement along a great number of parallel planes. At fault G–G′ the upper sandstone is steeply upturned, as shown by the right-angled turn in the direction of the outcrop. At fault H–H′ the massive upper sandstone is cut off abruptly and along the fault plane is in contact with dark marine shale.

The structure contours show that the course of Yellowstone River between Billings and Huntley is near the axis of a syncline. The relation of the beds southeast of the river to those northwest of it indicate that the hard rocks beneath the alluvial deposits have undergone more or less displacement. On the west side of the river the abrupt termination of a massive Judith River sandstone near the north line of sec. 5, T. 1 N., R. 27 E., the steeply eastward-dipping beds in sec. 33, T. 2 N., R. 27 E., and the almost flat upper sandstone of the Judith River at the bridge in comparison with the steeply dipping beds a mile east indicate some displacement along the line A–A, althuogh no conclusive evidence of such displacement was observed.

FAULTS AND FOLDS WEST OF ARROW CREEK VALLEY.

In the description of the faulting between Acton and Rattlesnake Butte given in the Lake Basin report the fact was mentioned that along many of the faults the beds on the northwest side of the fault plane have sagged down, while those on the opposite side are arched upward. The structural conditions west of Arrow Creek are of a somewhat similar nature and are probably due to similar forces. The forces that were active in the complexly faulted belt seem to have had a tendency to develop anticlinal folds with their major axes trending nearly east, but evidently the forces were related in such a way that the beds, instead of being free to arch upward, were broken at frequent intervals, and those northwest of the fault planes were forced downward. Finally, as fault K–K′ was produced, the beds northwest of the fault plane moved downward and toward the southwest, and this movement resulted in a steepening of the dips along the northeast flank of the dome. The results of the field observations are briefly as follows: Fault L–L′ begins practically at the Judith River escarpment in sec. 3, T. 1 N., R. 28 E. The basal sandstone of the Judith River crops out for about three-fourths of a mile, dipping 12°–15° SE., and there is a narrow belt of the Claggett formation exposed between the sandstone and the fault. Eastward from the west end of the fault successively higher Judith River sandstones are encountered, but the greatest vertical displacement is about at the section line. The upper sandstone of the Judith River is well exposed in the bottom of the gully in the NW. ¼ sec. 35, T. 2 N., R. 28 E., where it dips 5° NE. It was traced only a short distance farther north, and north of fault K–K′ its position seemed to be occupied by dark marine shale.

The southeast corner of sec. 35 is on the uppermost massive sandstone of the Judith River formation where the sandstone dips southeast into fault O–O′ at an angle of 13°. Dips of 8° and 10° NE. were recorded on the top of the same sandstone, and the Judith River formation between faults N–N′ and O–O′ forms a part of a southeastward-pitching anticline. Fault N–N′ begins a few hundred feet southwest of the northeast corner of sec. 3. From the first evidences of displacement eastward the Judith River formation has dropped very rapidly, as shown by successively higher Judith River beds in contact with the Claggett shale. At the west end of the fault plane movement seems to have taken place along almost vertical planes, but farther east the fault planes are inclined considerably to the northwest. At the east end of the area of Claggett formation the reddish-brown basal sandstone of the Judith River is in almost direct contact with a massive light-colored sandstone well up in the Judith River formation, but the maximum vertical displacement is probably west of that point, not far from the center of the area of the Claggett formation. In the process of deformation the massive light-colored sandstone has evidently been strongly compressed by forces acting from the southeast, for the sandstone has broken in three places at M–M′ along planes seemingly inclined about 60° SE., and the mass on the southeast side of the fault plane was thrust over that on the opposite side.

The basal sandstone of the Judith River formation is inclined toward the southeast and is well exposed from a point near the southeast corner of sec. 9, T. 1 N., R. 28 E., to the SW. ¼ sec. 36, T. 2 N., R. 28 E. In the SE. ¼ sec. 2 most of the Judith River formation is well exposed, as shown in the stratigraphic section on page 123. The beginning of the displacement along fault O–O′ begins a short distance southwest of the escarpment formed by the basal sandstone of the Judith River east of Pryor Creek. At the contact with the Claggett formation there is a vertical displacement of about 60 feet along planes inclined about 58° NW. The amount of displacement along the fault planes increases toward the east, for in the NW. ¼ sec. 2 one of the upper light-colored sandstones of the Judith River dips southeastward toward the fault at an angle of 13°. The lowest sag in the Judith River beds probably occurs near the point where the dip was measured, and at that point there is probably the greatest amount of displacement. Near the east end of fault O–O′ the Claggett shale and successively higher Judith River beds have evidently been thrust toward the northwest and have overridden the upper Judith River beds north of the fault. At fault P–P′ some of the beds immediately north of the fault plane dip into the fault at angles as steep as 37° and have in a similar manner been overridden by the beds south of the fault plane.

The large fault Q–Q′ and the three smaller ones R–R′, S–S′, and T–T′ all displace a somewhat elongated dome. The basal sandstone of the Judith River formation is well exposed from the southeastern part of sec. 2, T. 1 N., R. 28 E., northeastward to the conspicuous triangulation point in the SE. ¼ sec. 1, where it is cut off abruptly along fault Q–Q′. From that point the outcrop of the sandstone falls very rapidly toward Arrow Creek. The steep slope northwest of the triangulation point, between that and the southeastward-dipping Judith River beds, exhibits a homogeneous mass of dark marine Bearpaw shale. East of the high point the Claggett shale and Bearpaw shale are in contact for some distance, showing that the amount of displacement along the fault plane is very considerable. In the process of folding and faulting a block of strata between faults R–R′ and S–S′ was uplifted nearly 300 feet, and the beds north of fault T–T′ were dropped about half that amount.

FAULTS AND FOLDS EAST OF ARROW CREEK VALLEY.

The relation of the sandstones and sandy shales of the Judith River formation to the Bearpaw shale in the northeast corner of T. 1 N., R. 29 E., suggests at once considerable displacement (fault U–U′). Along the east edge of the gravel-covered area in sec. 2 the sandy beds are tilted at angles ranging from 22° to 29°. The basal sandstone of the Judith River is well exposed from the edge of the gravel as far east as the township line. Northeastward from the township line the upper sandstones also terminate abruptly, the rocks are very much disturbed, and the formation southeast of the fault is all marine shale. Owing to the abundance of gravel on the flat tops and the few exposures at the head of the valley of Tenmile Creek, the westward extension of fault U–U′ is purely hypothetical. From the prominent gravel terrace near Corinth westward for some distance the nature and attitude of the rocks are obscured by the overlapping gravel deposits. Enough of the beds were observed, however, to make out the structure with reasonable certainty. North of Tenmile Creek the uppermost beds of the Judith River formation dip north beneath the Bearpaw shale at an angle of about 10°. South of Tenmile Creek a persistent sandstone about 60 feet beneath the Bearpaw shale dips 4°–15° SE. Near the section line on the east side of sec. 15, T. 1 N., R. 30 E., sandstones near the base of the Judith River formation dip 10° N. It is evident, therefore, that the structure is that of an anticline and a syncline whose axes are more or less parallel and pitch eastward. As a result of the stresses that were produced when the rocks were folded the beds gave way along the lines V–V′ and W–W′ and a triangular block of the Judith River formation was forced up through the overlying Bearpaw shale, the maximum displacement occurring where the two faults intersect. Fault V–V′ is best exhibited near the west line of sec. 9, where the 17° dip was recorded. At that point a ledge of sandstone exposed for several hundred feet along the west slope of the hill terminates with an intensely sheared zone in contact with the Bearpaw shale. East of Fly Creek the Judith River sandstone dips about 15° N. and is cut by faults X–X′, Y–Y′, and Z–Z′. At fault X–X′ there is only a slight amount of displacement, but along faults Y–Y′ and Z–Z′ the outcrops are offset nearly 1,000 feet.

POSSIBILITIES OF OIL AND GAS.

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 in the Elk Basin field on the Wyoming-Montana State line, about 55 miles south-southwest 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 boundary. Oil has been obtained in commercial quantities at several localities in Wyoming, but the larger part of the oil produced in 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 Lander district, 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 Huntley field.

SIMILARITY OF STRATIGRAPHY TO THAT OF NEIGHBORING PRODUCTIVE FIELDS.

Plate XV (in pocket) shows 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" (p. 116). Some of the stratigraphic sections were carefully measured where the strata are especially well exposed. Others are based principally on 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. XV) 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 oil and gas bearing sands below the Colorado—for example, the Greybull sand, at the top of the Cloverly formation, at Basin, Wyo., and the Dakota sandstone and 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—for example, the Shannon sandstone of the Powder River and Salt Creek fields, Wyo. The lack of continuity of the sands of Frontier age is mentioned under the heading "Colorado shale," on page 116. At Salt Creek and some other localities there is but one important oil-producing sand (Wall Creek sandstone) in the beds of Frontier age, 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. 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 Huntley field. It is also reasonably certain that the sandstones in the Colorado and Kootenai formations are sufficiently near the surface there to be tested by the drill, provided the structural conditions are promising enough to warrant drilling to the depth of the commonly productive sands. The principal element of uncertainty for the oil prospector is the nature and extent of these sands. In the absence of any deep borings in the Huntley field, it is necessary to compare the logs of certain deep wells in the Lake Basin field with the composition of the Colorado shale and underlying beds in various localities in south-central Montana and north-central Wyoming, as shown in Plate XV. From the small 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 and Huntley fields 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, 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 drill hole No. 1, 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. 47, T. 3 N., R. 21 E.

Driller's interpretation.	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. From the records it appears that no sandstones were encountered at all comparable with those farther south, as for example, at Elk Basin or Basin, Wyo., and only meager showings of oil and gas were obtained. It may be that future work will prove that the Colorado sands of Frontier age are better developed south and east of Billings, and if so, there are probably better sands in the beds of this age in the Huntley field than the well logs farther west indicate. There is evidently a progressive lowering of the sands toward the south and east, for at the 79 Oil Co.'s well immediately north of the

Lake Basin 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 wells probably penetrated the main sandstones of the Kootenai as well as all those in the lower part of the Colorado shale.

SURFACE INDICATIONS OF OIL AND GAS.

There are very few surface indications of oil and gas in the Lake Basin and Huntley fields. 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., in the Lake Basin field, 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. A resident of Worden reported that gas was encountered at a depth of 150 feet in a well which was drilled to a depth of 200 feet in the west edge of Worden about 100 feet southeast of the township corner. At a depth of 150 feet the gas is said to have escaped with sufficient force to make a roaring sound. When a match was applied to the top of the casing at a depth of 200 feet the gas would blaze up for an instant to a height of 6 feet; it would then die down and after a brief interval would blaze up to about the same height again. Natural gas in sufficient volume to supply the domestic needs of one family is also obtained from a well on the ranch of Charles M. Blair near Hardin, Big Horn County, on the Crow Indian Reservation, about 20 miles southeast of Corinth.

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, commonly known as the 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 the anticline, the oil separates out below, and the water seeks the deeper portions of the beds. It is a well-recognized fact that oil and gas have entered porous sands from adjacent beds and that they have in many places migrated long distances to the points of concentration, but it is not clearly understood just what forces are the most active in causing oil, gas, and water to migrate from the fine clays and shales into the porous sands. Neither has it been proved beyond controversy to what extent gravity and capillary attraction influence the movement of those substances along porous sands which are inclined at an extremely low angle.

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 to one another in the manner stated above. 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 forces obstructing the movement of particles of oil are equal to or in excess of those which promote such movement.

In saturated rocks the ideal structural form is the dome, which includes a thick bed of sand effectively sealed above and dipping gently for considerable distances, but such a form is not common in nature. In many domes the dips are limited by other structural features, and in consequence the collecting area is small. The oil sands may be lenticular, or again, continuous sands may be offset along fault planes. If the fault remains partly open fluids migrating through the porous sands may rise to the surface and escape. It has been found that many oil seeps are characterized by deposits of asphalt. If the fault is sealed by clay, asphalt, or some other impervious substance the oil and gas may concentrate in the sand near the fault plane, and the result is practically the same as when the sand is lenticular. Thus an open fault fissure may prevent concentration at the top of an anticline or dome, and a fissure effectively sealed my produce local concentration at some point along the flank. The migration of oil, gas, and water through porous sands up along the flank of the most ideal structural feature may be retarded where the beds suddenly flatten or where the porosity of the sand decreases, and it may be entirely obstructed where a dike of igneous rocks cuts across the sands. From the facts above outlined it is not surprising that some concentrations of oil and gas occur where, from all surface indications, the conditions are unfavorable, whereas some areas that appear to have the most favorable structure are barren. These conditions are mentioned briefly, not with a view of questioning the value of the anticlinal theory as a working hypothesis, but merely to emphasize the necessity for making in every field a thorough study of all the conditions which may in any way retard the movement of fluids and result in concentration.

In attempting to apply what has been said to the Huntley field, certain facts are at once apparent. In the first place, outside of the faulted area, the beds practically everywhere dip gently toward the north. Throughout the area of gentle dips there is a possibility of local accumulations of oil and gas as a result of certain features not apparent at the surface—such, for example, as lenticular sands, variation in porosity, or slight change in dip—but without any surface indications of oil or gas the discovery of such local accumulations is mainly the work of the drill after the presence of oil and gas has been demonstrated in areas of favorable structure.

The very much faulted and imperfectly developed dome southeast of Huntley is separated from the northwestward-dipping Judith River beds by a low sag in the rocks. At the top of the dome the Eagle sandstone could be tested by means of the drill at a depth of 300 or 400 feet, but in order to test all the sands in the lower part of the Colorado shale and those of the underlying Kootenai formation, it would be necessary to drill to a depth of at least 2,500 feet. If either oil or gas should work its way into the Eagle sandstone or any of the sands near the base of the Colorado shale, a moderate amount might become trapped in the top of the dome. Much depends, however, upon the depth of the syncline along the southwest side of the dome, and it must be kept clearly in mind that the structure of the sands in the lower part of the Colorado shale, where oil and gas are the most likely to occur, may be quite different from that of the sandstones in the Claggett formation, more than 2,000 feet higher up.

As explained on page 140 there is an anticline south of Tenmile Creek in the western part of T. 1 N., R. 30 E., and the eastern part of T. 1 N., R. 29 E., but the axis of the anticline pitches steeply eastward, and apparently the structure contours do not close around the southwest end. Owing to the syncline immediately south the principal collecting area for this anticline lies to the north and is doubtless limited somewhat by the large fault U–U′. On the axis of the anticline, at the contact between the Judith River formation and the Bearpaw shale, the top of the Eagle sandstone probably lies at a depth of about 1,000 feet, and the top of the sandy belt in the lower part of the Colorado shale at a depth of approximately 2,800 feet. Any particles of oil and gas which might enter any of the porous sands along either flank of the anticline would probably rise to the crest of the anticline, but as there is apparently no reverse dip on the west, and as the beds rise gently toward the south, the fluids might continue to rise in that direction. It is possible, however, that the flattening of the anticlinal axis near the east side of T. 1 N., R. 29 E., would impede the movement of fluids sufficiently to cause a slight amount of concentration, but the prospects of any considerable accumulation of oil and gas are not very promising.

As shown on Plate XIV numerous faults displace the formation between Huntley and Corinth. These are all described in considerable detail under the heading "Structure." Field observations did not reveal any unmistakable seepages of oil or gas along the fault planes, so it is quite evident either that no oil or gas has come into contact with the faults, or that there are no openings within the zone where movement took place. It seems probable that such faults as K–K′, Q–Q′, and U–U′ must have displaced whatever sands there are in the lower part of the Colorado shale. Whether the displacement is as great there as it is at the surface depends on whether the forces producing movement originated from above or below. At any rate, it seems probable that the movement which took place in the soft shale of the upper part of the Colorado was distributed throughout a wide zone and was in the nature of rock flowage. Under those circumstances no well-defined openings would be produced and there would be no opportunity for oil or gas to rise to the surface. For this reason the absence of surface indications does not, in the opinion of the writer, prove that neither oil nor gas has accumulated at any point along the fault planes. If there are porous sands in the lower part of the Colorado shale and the underlying Kootenai formation, and if these sands are displaced along any of the faults, they are likely to be left in contact with impervious shale and thus, so far as the movement of fluids is concerned, to be as effectively sealed as they are elsewhere by the overlying and underlying shale. North of the faulted area the formations are inclined northward probably as far as the Bull Mountain coal field, so that in that direction there is a considerable collecting area. If the conditions in that area are favorable for the origin and migration of oil and gas, it is not improbable that these substances have accumulated to some extent near some of the fault planes. Of all the faults shown on the geologic map (Pl. XV) and described in the text, fault U–U′ is probably the most favorably situated. A well drilled just northwest of the fault plane near the center of the area of Claggett shale would probably reach the uppermost sands in the lower part of the Colorado shale at a depth of 1,600 to 2,000 feet.

The purpose of what has been said above has been merely to point out certain structural conditions which might, if all other conditions are favorable, result in the concentration of oil and gas. Anyone who is contemplating the expenditure of time and money in searching for oil and gas in the Huntley field, however, would do well to keep in mind the following facts: (*a*) 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, but from all reports no commercial quantities of oil have been found in Montana north of the Elk Basin field; (*b*) the logs of wells near the Huntley field do not indicate the presence of sands in the lower part of the Colorado shale at all comparable with those of some of the productive fields in Wyoming, and what sands there are seem to contain nothing more than a showing of gas; (*c*) there are in this area very few surface indications of oil and gas; and (*d*) the Broadview dome and the Big Coulee-Hailstone dome, in the Lake Basin field, are better adapted for the accumulation of oil and gas than any of the structural features in the Huntley field here described, and yet they seem to have yielded only showings of gas.