# POSSIBILITIES OF OIL AND GAS IN NORTH-CENTRAL MONTANA.

By Eugene Stebinger.

## INTRODUCTION.

The search for oil and gas in Montana has become very active, and there is an insistent demand for information concerning the occurrence of these substances in the State. The extension into Montana of the Wyoming fields that are producing high-grade oils, the development of valuable gas fields in southern Alberta, the discovery of some oil within a few score miles of the northern boundary of Montana, and, finally, the recent drilling in of a large gas well at Havre, in Hill County, have led petroleum engineers and oil operators to give serious attention to "wildcatting" in this State. The thick bodies of Upper Cretaceous shale with which most of the oil and gas in both Wyoming and Alberta are associated are known to be continuous between these two localities under the plains portion of Montana, making it apparent that favorable structural features, in this area especially anticlines and domes similar to those that are productive in Wyoming and Alberta, offer a chance of success with the drill.

The purpose of the report here presented is to summarize all the available data concerning the possible occurrence of oil and gas in a considerable area in the north-central part of Montana, extending from the latitude of Great Falls northward to the international boundary. By no means all of this area has been searched for favorable structures, but the general character of the Cretaceous formations present under most of the area is well known. Furthermore, it is proposed to point out a number of anticlines and other upward-arching structures occurring in parts of Hill, Chouteau, Blaine, and Fergus counties which, according to experience at Havre, seem to be favorable for prospecting.

The facts observed seem to warrant the statement that considerable gas territory, on a scale comparable with the Alberta fields, may be found and also that the area shows some probability of yielding oil. It can not be too strongly emphasized, however, that a rational search for oil and gas in the State should begin with operations in the areas where the rocks are most strongly arched. Only after these areas have been successfully prospected should the areas be tested which involve a much greater risk, namely, those in which the deformation of the beds is less pronounced or the bedrock is concealed by glacial drift.

## LOCATION AND SURFACE FEATURES.

The part of north-central Montana herein described extends southward from the international boundary a distance of about 106 miles to the latitude of Great Falls and eastward a distance of 192 miles from R. 8 W. to R. 24 E. of the General Land Office surveys for Montana. (See fig. 11.) The area contains about 22,000 square

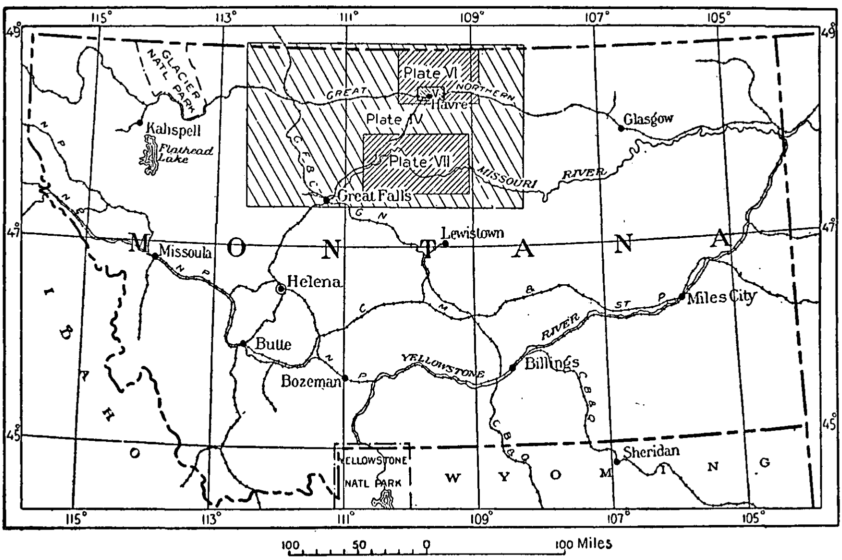



FIGURE 11.—Index map of Montana showing areas covered by Plates IV–VII.

miles. The principal towns are Great Falls, Fort Benton, and Havre. The area includes all of Blaine, Hill, Toole, and Chouteau counties and parts of Fergus, Cascade, Teton, and Phillips counties. Plate IV is a geologic sketch map of the entire region.

For the most part the region is a treeless plains country, slightly rolling and covered with glacial drift. Along the principal streams, Missouri and Milk rivers and their tributaries, there are extensive areas of badlands, affording excellent exposures of the Cretaceous formations present. The region is further diversified by four small mountain groups, the Sweetgrass Hills, Bearpaw Mountains, Little

Rocky Mountains, and Highwood Mountains, which are from 20 to 40 miles across and rise island-like 2,000 to 4,500 feet above the general level of the plains. They are partly forest covered and well watered, in contrast with the semiarid plains that surround them.

## BASIS OF THE REPORT AND MAPS.

Only a small part of the region here described has been examined with a view to reporting specifically on its oil and gas possibilities. Many of the map data and other details presented are taken from work done during the last 10 years by members of the Geological Survey while studying the coal resources of the region. These surveys cover about a quarter of the area here described. In the examinations for coal the general features of the geology, especially near the coal outcrops, were carefully mapped, but naturally many details that are of prime importance in the search for oil and gas, particularly those pertaining to structure and to possible surface showings of oil and gas, were not recorded. Fisher[1] in 1906 examined the area extending from the vicinity of Great Falls northwestward to and beyond Teton River. Much of the information concerning the Kootenai formation in Montana is based on his observations. In 1908 and 1909 Pepperberg[2] mapped the area along the Milk River valley from Harlem to a point a few miles west of Havre. Many of the data on Plate V, showing the geology in the vicinity of Havre, and on Plate VI, showing the tilted and folded rocks lying south of T. 35 N., were compiled from Pepperberg's maps and notes. In 1912 Bowen[3] examined 10 townships lying southeast of Big Sandy between Missouri River and the Bearpaw Mountains and also a considerable area near the east end of the mountains in the vicinity of Cleveland. The data on the area lying north of Missouri River shown on Plate VII are taken from Bowen's reports. E. R. Lloyd in 1914 mapped all the area south of Missouri River shown on Plate VII extending eastward to R. 17 E. Lloyd's work has not been published and the descriptions of the area here given are taken from his original notes and maps. During the summer of 1915 the writer, assisted by Wendell P. Woodring and Julian D. Sears, examined the area in the vicinity of Winifred, in northern Fergus County, and

[1] Fisher, C. A., Geology of the Great Falls coal field, Mont.: U. S. Geol. Survey Bull. 356, 1909; Geology and water resources of the Great Falls region, Mont.: U. S. Geol. Survey Water-Supply Paper 221, 1909.

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

[3] Bowen, C. F., The Cleveland coal field, Blaine County, Mont.; The Big Sandy coal field, Chouteau County, Mont.: U. S. Geol. Survey Bull. 541, pp. 338–378, 1914.

then spent the remainder of the season mapping the northern portion of the Milk River coal field, lying in the tiers of Tps. 35 to 37 N. Gas was discovered at Havre during this period, and a few days were spent in that vicinity. A description by the writer[1] of the geology of the northwestern part of the region here considered has already been published.

## GEOLOGY.

### SEDIMENTARY ROCKS.

#### GENERAL FEATURES.

The sedimentary rocks in north-central Montana range in age from Cambrian to Recent. The formations, older than the Kootenai formation (Lower Cretaceous), however, are exposed only in the mountain uplifts and offer meager prospects of yielding either petroleum or natural gas. These older rocks, of Jurassic or earlier age, are best exposed in the Little Rocky Mountains and the Sweetgrass Hills. They are mainly hard, compact limestones that are not known to be petroliferous at any point in the region. This character, together with the fact that in the plains areas they generally lie too deep to be readily reached with the drill, makes them of little interest to the oil and gas prospector. In southern Montana and Wyoming these older formations contain a larger proportion of shale, which in places attains a considerable thickness, and there they may be of some importance as a source of oil and gas.

The extensive plains of northern Montana are underlain within reasonable drilling depth almost exclusively by Lower and Upper Cretaceous formations, and the sandstone beds associated with the thick bodies of shale in these rocks offer the best reservoirs for oil and gas in the region. Generalized sections showing the sequence and character of the formations, one for the eastern part and one for the western part of the region, are given below. These sections are also shown graphically on Plate IV.

[1] Stebinger, Eugene, Geology and coal resources of northern Teton County, Mont.: U. S. Geol. Survey Bull. 621, pp. 117–156, 1915 (Bull. 621–K).

*Formations exposed in the plains of north-central Montana east of the 112th meridian in the area described in this report.*

| System. | Series. | Group and formation. | | Thickness (feet). | Character. |
|---|---|---|---|---|---|
| Quaternary. | Recent. | Alluvium. | | | Silt, sand, and gravel along flood plains of larger streams. |
| Quaternary. | Pleistocene. | Glacial drift. | | 0-200 | Bowlder clay, gravel, and lake silt and clay. Contains bowlders and cobbles of granite, gneiss, quartzite, etc., transported from the northeast. |
| Tertiary. | Eocene. | Fort Union formation. | | [a] 700+ | Clay shale, sandstone, and coal beds. Present only in small areas. Poorly exposed. |
| Tertiary (?). | Eocene (?). | Lance formation. | | 700-800 | Alternating gray clay shale and sandstone with irregular coal beds. Present in relatively small areas only. |
| Cretaceous. | Upper Cretaceous. | Montana group. | Bearpaw shale. | 500-800 | Dark-gray clay shale with a few limestone concretions. Contains many marine shells. Forms a subdued, rounded topography and gumbo soil. |
| | | | Judith River formation. | 450-550 | Light-gray clay and clay shale with irregular beds of gray or brown sandstone, and coal beds. Contains many oyster and other shells besides fossil bones. |
| | | | Claggett shale. | 350-500 | Like the Bearpaw in character of rocks and fossils, except for the occurrence of sandy beds near the top. |
| | | | Eagle sandstone with Virgelle sandstone member at base. | 250-400 | Upper part gray clay shale and sandstone with coaly shale and thin coal. Lower part white to buff thick-bedded massive sandstone, Virgelle sandstone member. *Contains gas in the Havre district.* |
| | | Colorado shale. | | 1,500-1,700 | Bluish-gray to black shale with a few limestone concretions. Contains many marine shells. Includes three or four sandy beds 5 to 70 feet thick in lower 800 feet. *Probably contains gas and oil in some localities of favorable structure.* |
| | Lower Cretaceous. | Kootenai formation. | | 400-600 | Red clayey shale and irregular gray sandstone with a few thin beds of limestone. Contains coal near the base and fossil plant remains of fresh-water origin. *Probably contains gas and oil in some localities of favorable structure.* |

[a] Estimated.

*Formations exposed in the plains of north-central Montana west of the 112th meridian in the area described in this report.*

| System. | Series. | Group and formation. | | Thickness (feet). | Character. |
|---|---|---|---|---|---|
| Quaternary. | Recent. | Alluvium. | | | Silt, sand and gravel along flood plains of larger streams. |
| | Pleistocene. | Glacial drift. | | 0-200 | Bowlder clay, gravel, and lake silt and clay. Contains bowlders and cobbles of granite, gneiss, quartzite, etc., transported from the northeast. |
| Cretaceous. | Upper Cretaceous. | Montana group. | Bearpaw shale. | 450-550 | Dark-gray clay shale with a few limestone concretions. Contains many marine shells. Forms a subdued, rounded topography. |
| | | | Two Medicine formation. | 1,900-2,100 | Gray to greenish-gray clay and soft irregular sandstone, which is most abundant in the lower 250 feet. In places thin beds of red clay and nodular limestone. Contains an abundant reptilian fauna of Judith River types, besides leaves and shells. Contains coal beds near the base and at the top. |
| | | | Virgelle sandstone. | 200-290 | Gray to buff coarse-grained, much cross-bedded massive sandstone, with many ferruginous concretions in upper half. In lower half slabby gray sandstone, becoming shaly toward the base. |
| | | Colorado shale. | | 1,600-1,750 | Bluish-gray to black shale with a few limestone concretions. Contains many marine shells. Includes three or four sandy beds 5 to 70 feet thick in lower 800 feet. *Probably contains gas and oil in some of the areas of favorable structure.* |
| | Lower Cretaceous. | Kootenai formation. | | 600-700 | Shale, red in upper part, but remainder grayish to black. Contains irregular sandy beds up to 100 feet thick. Fresh water. *Probably contains gas and oil in some of the areas of favorable structure.* |

As shown by the tables given above, the differences between the geologic sections of the eastern and western parts of the region occur in the Montana group in the interval between the Virgelle sandstone and the Bearpaw shale. This is due to the fact that the marine invasion during which the Claggett shale was deposited in the east did not extend westward beyond the 112th meridian. An account of these relations has already been published.[1]

[1] Stebinger, Eugene, The Montana group of northwestern Montana: U. S. Geol. Survey Prof. Paper 90, pp. 61–68, 1915 (Prof. Paper 90–G).

## FORMATIONS IMPORTANT IN THE SEARCH FOR OIL AND GAS.

### KOOTENAI FORMATION.

In this region all the strata so far examined lying between the marine Jurassic beds and the Colorado shale have been placed in the Kootenai formation. Farther south in Montana, however, on the flanks of the Little Belt Mountains and elsewhere, the variegated shales of the Morrison formation have been recognized in the lower part of this interval. The Kootenai formation crops out over a considerable area in the vicinity of Great Falls, on the outer slopes of the Little Rocky Mountains, and on the east end of the Bearpaw Mountains. It has also been penetrated by the drill near Kevin, in Toole County, and in the Sweetgrass Hills district. In the Great Falls area, where the fossil plants characteristic of the formation in the type area in Canada are present, the entire formation can be referred to the Kootenai with considerable certainty. In other areas where outcrops of these rocks have been examined in the mountain uplifts, although the typical fossil plants have not been found, the thickness and general sequence remain much the same. However, the distinctive red color of the shales present along the southern edge of the area mapped becomes less prominent toward the north and northeast.

In the Great Falls district the formation is between 400 and 500 feet thick and is made up of red sandy shale, clay, and gray sandstone, together with a few irregular limestone beds. The red color of the rocks is a prominent feature, the soils on its outcrop being strongly colored. The sandstones range in thickness from 10 to 60 feet, are more or less massive in character, and occur chiefly in the lower half of the formation. They contain a large amount of water.

Near Kevin, in Toole County, as shown by the well log given on page 90, there are beneath the Colorado shale 635 feet of beds that probably belong to the Kootenai. The section there is essentially an alternation of sandstone and shale, but the only red material present is near the top of the formation. There are in this sequence five sandstone beds between 30 and 70 feet thick.

In the Sweetgrass Hills district, as shown by the well log on page 89, there are at least 610 feet of strata containing near the top a prominent bed of red shale that should probably be assigned to the Kootenai. The sandstones at the base are reported to contain gas.

The Kootenai formation is not known to be petroliferous at any point on the outcrop in the areas mapped, although gas is reported from the locality just mentioned. The prominent sandstones in the formation seem to offer excellent reservoirs for either oil or gas if these substances are present at any locality.

### COLORADO SHALE.

The formation overlying the Kootenai is the Colorado shale, a great body of bluish-gray to black shale containing in its lower half a number of sandstone beds. This formation, which ranges between 1,500 and 1,750 feet in thickness in north-central Montana, is of marine origin—that is, it was laid down on a sea bottom and contains fossil sea shells in great variety. The rock materials deposited during this marine submergence are continuous northward into Canada and southward across Wyoming and beyond. The interval of time during which they were laid down is called the Colorado epoch, and the rocks themselves when divided into two or more formations constitute the Colorado group.

The Colorado shale seems to be of first importance as a possible source of oil and gas in Montana. The only surface showings of oil so far found in north-central Montana are seeps from the lower part of this formation, and pay sands either in the formation or associated with it have been found in adjoining areas both to the north and to the south of the State. In northern Wyoming the greater part of the oil produced in the Salt Creek field and most of the fields in the Bighorn Basin comes from sands lying mainly in the lower half of this group of rocks. In the Province of Alberta the gas of the important field at Bow Island, east of Lethbridge, is derived from a sand reported to be the Dakota. It is probable, however, that this sand is actually in the lower part of the Colorado shale. Likewise, as reported by Dowling,[1] the small quantity of high-grade oils obtained from several wells in two anticlines lying southeast of Calgary, in the same province, comes from sands at the same position with respect to this shale.

The similarity of the Colorado shale in northern Wyoming and Montana is also emphasized by the presence in both States of a peculiar shale or shaly sandstone carrying abundant impressions of fish scales. In Wyoming this shale, known as the Mowry shale, is about 200 feet thick and occurs in the lower half of the Colorado group. The presence of this fish-scale bed in so many productive oil fields has often been referred to as suggesting that fish remains may have been the source of at least part if not all of the oil found in the associated sands. These peculiar beds are present in at least the east half of the north-central Montana region. In the vicinity of Lewistown, in the central part of Fergus County, a short distance south of the area mapped, a bed about 900 feet above the base of the Colorado shale contains an abundance of fish scales and has been considered[2] as representative of the Mowry of Wyoming. About

[1] Dowling, D. B., Correlation and geologic structure of Alberta oil fields: Inst. Min. Eng. Bull. 102–A, pp. 1360–1364, 1915.

[2] Calvert, W. R., Geology of the Lewistown coal field, Mont.: U. S. Geol. Survey Bull. 390, p. 30, 1909.

75 miles northeast of this locality, on the outer slopes of the Little Rocky Mountains, there are, according to Weed and Pirsson,[1] in a thick shale formation occupying the stratigraphic position of the Colorado shale, some "white porcelanous beds in which there are abundant impressions of fish scales. This rock weathers into a porcelain-like débris whose light color attracts attention wherever the rocks are exposed." This description is typical of the Mowry throughout large areas in Wyoming. On the east end of the Bearpaw Mountains Bowen[2] found fish scales in abundance in the Colorado shale, at approximately the same horizon. In the Great Falls area the Mowry was noted by Fisher[3] but is not conspicuous. It has not been found elsewhere in the western part of the region here described, although it may be present, the lower part of the formation being poorly exposed and having been little studied.

Sandstone beds, in some places as much as 80 feet or more in thickness, are present in the lower half of the Colorado shale in all parts of central Montana where the formation has been examined along the outcrop or has been pierced by the drill. These sandstones, sealed in by great thicknesses of shale, seem to offer favorable receptacles for the accumulation and retention of oil and gas, and they may contain these substances in commercial quantities where inclination of the strata has permitted their concentration, forming the so-called pools of the oil industry. The sandstone beds in the Colorado shale noted in four widely separated localities in the region are shown graphically in figure 12. The first two of these sections were measured on outcrops of the formation and are taken from reports by Calvert[4] and Fisher.[5] The last two are made up from well logs, which are given in detail on pages 90 and 89. The general prevalence of sandstone beds in the lower half of the Colorado shale is evident from this diagram. It is very probable that these sands are more or less lenticular, for the arrangement and thickness of the beds in adjoining areas are such as to make it unlikely that individual sands persist throughout the intervening distances. In general character, thickness, and spacing or distribution in the shale these sandy beds are comparable with those in the Colorado group of the Bighorn Basin oil fields, in northern Wyoming.[6]

[1] Weed, W. H., and Pirsson, L. V., Geology of the Little Rocky Mountains: Jour. Geology, vol. 4, p. 409, 1896.

[2] Bowen, C. F., The Cleveland coal field, Blaine County, Mont.: U. S. Geol. Survey Bull. 541, p. 343, 1914.

[3] Fisher, C. A., Geology of the Great Falls coal field, Mont.: U. S. Geol. Survey Bull. 356, 1909.

[4] Calvert, W. R., op. cit., p. 30.

[5] Fisher, C. A., op. cit., pp. 36–37.

[6] Lupton, C. T., Oil and gas near Basin, Big Horn County, Wyo.: U. S. Geol. Survey Bull. 621, pp. 168–173, 1916.

The only noteworthy surface showing of oil so far reported from north-central Montana occurs, according to W. A. English,[1] of the United States Geological Survey, in one of the sandstones of the lower half of the Colorado shale on the north side of West Butte, in the Sweetgrass Hills, a short distance south of the Canadian boundary. Here, in a spring on the Roscoe ranch near the line between secs. 11 and 12, T. 37 N., R. 1 E., there are slight showings of light-greenish oil which collects to the extent of about a teaspoonful in 24 hours. Mr. English also reports that extraction tests made on samples from the sandstone outcrops in the lower part of the Colorado on West Butte give a good show of oil. The petroliferous

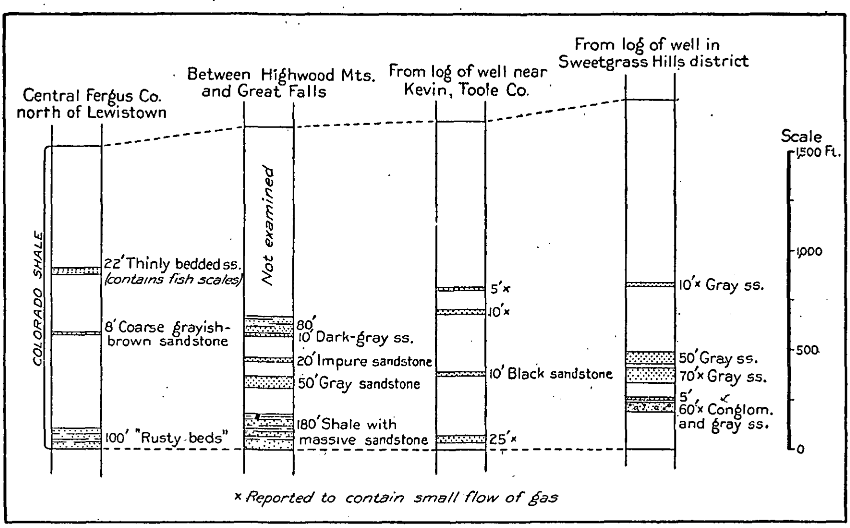



FIGURE 12.—Sections showing sandstones in lower half of Colorado shale, north-central Montana.

nature of the lower part of the Colorado shale in this portion of Montana seems to be clearly demonstrated by this occurrence.

The principal outcrops of the Colorado shale in northern Montana are shown on Plate IV. The largest one is in an extensive area occupying parts of five counties, extending from the vicinity of the Sweetgrass Hills southward to Great Falls. Over most of the interstream areas the shale is hidden under a cover of glacial drift, but along the streams it is generally well exposed.

### EAGLE SANDSTONE, INCLUDING VIRGELLE SANDSTONE MEMBER.

Above the Colorado shale throughout north-central Montana there is a group of sandy beds from 250 to 400 feet thick, which constitute the Eagle sandstone. The lower part consists of a persistent

[1] Personal communication.

unit of cliff-making massive sandstone from 100 to 225 feet thick, named the Virgelle sandstone member because of its excellent exposures along Missouri River below the town of Virgelle, in Chouteau County. The Virgelle sandstone is by far the most persistent of the sandstone strata in northern Montana and should serve as an excellent key rock in all drilling operations in the areas under which it is present. Its principal outcrop in the region mapped outlines a broad, oval-shaped area and extends from Missouri River in eastern Chouteau County northward and westward to the Sweetgrass Hills and then turns southward to a point beyond Sun River. (See Pl. IV.) West of the Sweetgrass Hills it forms the prominent escarpment known as "the rim," which extends from these hills southward for about 40 miles. Along the Missouri below Virgelle it forms the features long known as the "stone walls," which extend for about 30 miles along the river.

The strong flow of gas encountered at Havre (see p. 73) comes from the Eagle sandstone. The gas produced at Medicine Hat, in Alberta, is also found at about the same horizon. The porous nature of the Eagle sandstones, together with their position immediately above the Colorado shale, makes it probable that gas and oil in notable quantities are present where the structural conditions are favorable.

### FORMATIONS LYING ABOVE PROBABLE OIL AND GAS BEARING BEDS.

Above the probable oil and gas bearing formations there is a considerable thickness of shale, clay, and sandstone, comprising a number of formations of Upper Cretaceous and Tertiary age. They occupy all of the area indicated by the absence of shading on the map (Pl. IV), including nearly half of the region described in this report. East of the one hundred and twelfth meridian they include the Claggett shale, Judith River formation, Bearpaw shale, Lance formation, and Fort Union formation, and their total thickness is between 2,700 and 3,350 feet. West of the one hundred and twelfth meridian they include the Two Medicine formation and the Bearpaw shale, and have a total thickness between 2,350 and 2,650 feet. The thickness and character of the individual formations are given in the tables on pages 53–54.

The thickness of these overlying formations is very important to any one contemplating drilling to the base of the Colorado shale. Drilling from a horizon above the base of the Bearpaw shale to the base of the Colorado will involve depths greater than 3,000 feet. Obviously the addition of a large part of the 2,000 feet or more of the Bearpaw, Lance, and Fort Union formations would make the base of the Colorado far too deep for "wildcatting." The full thickness of the Bearpaw, not over 800 feet, might be added, but areas containing the Lance and Fort Union formations should be avoided. Fortunately, these formations occupy only relatively small areas in Blaine, Fergus, and eastern Chouteau counties. In Chouteau County the Fort Union rocks are present in a small area east of Big Sandy.[1] The Lance, and probably the Fort Union, are present in northern Blaine County in all of the area lying northeast of the Cherry Patch Ridge escarpment. In Fergus County the Lance formation is present along Missouri River east of Dog Creek.

### GLACIAL DRIFT.

Glacial drift[2] of Pleistocene age, consisting chiefly of gravels and bowlder clay containing pebbles and bowlders of all dimensions, including many of great size, is present over a large part of north-central Montana. It forms an effective cover, concealing the bedrock formations over large areas, and is of more than academic interest to one prospecting for oil and gas in this region. To its presence over so large a proportion of the area may be due the comparative scarcity of oil seeps or gas escapes coming from the underlying bedrock formations in north-central Montana, the compact bowlder clay readily concealing any indications that may have been present before it was laid down. The drift also makes it impossible to decipher the structure of the underlying formations over extensive areas lying between the principal streams.

The drift ranges from a thin veneer to deposits several hundred feet thick and is usually thickest in the morainic areas, which have a rough "kettle and knob" topography. All this material was laid down by a continental ice sheet that overrode the region, coming from a center lying west of Hudson Bay. At least two separate invasions of the ice in this region are recorded. The only parts of the plains of north-central Montana that have not been glaciated are (1) the area along Missouri River south of the Bearpaw and Little Rocky mountains and east of R. 15 E., the ice sheet being held back from this area by the topographic barrier formed by these mountains; (2) the area lying west of R. 4 W. in the part of southern Teton County shown on Plate IV.

### RECOGNITION OF FORMATIONS IN THE COURSE OF DRILLING.

The general similarity of the rock materials composing the Cretaceous and Tertiary formations of north-central Montana tends to

[1] Bowen, C. F., The Big Sandy coal field, Chouteau County, Mont.: U. S. Geol. Survey Bull. 541, pp. 364–365, 1914.

[2] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, 1906.

make uncertain the recognition of the various formations encountered in the course of drilling unless certain features are carefully observed. The rocks of the entire section are mainly shale, clay, and sandstone, repeated so many times in the succession of the beds that they are likely to be lumped together in large units of "shale and shells" by the driller.

The principal features on which the recognition of the various formations must depend are (1) differences in the color tone of the various bodies of gray or neutrally tinted rocks; (2) position of the beds of coal or black coaly shale; and (3) position of the thick beds of sandstone. The differences in the color of neutrally tinted shale and clay are the most important and consist of alternations in thick groups of strata of dark-gray, bluish-gray, or nearly black tones with those that are prevailingly light gray, ash gray, or nearly white. These differences are readily distinguished in the course of drilling as the material is poured from the bailer.

In starting at the top of the Judith River formation and going to the Kootenai, the drill will encounter the following succession in the color tones of the gray shale, clay, and sandstone: (1) Judith River formation, light; (2) Claggett shale, dark; (3) Eagle sandstone, light; (4) Colorado shale, dark until the easily recognized "red rock' of the Kootenai is reached. Coals or black coaly shale will generally be found near the top and near the base of the Judith River and at the top of the Virgelle sandstone member of the Eagle. The sandstone beds are apt to be confusing because of the frequent recurrence of beds of various thicknesses, but the general presence of sandy strata over 100 feet thick in the Eagle sandstone should make this formation easily recognizable.

### COMPARISON WITH CANADIAN CLASSIFICATION OF FORMATIONS IN SOUTHERN ALBERTA AND SASKATCHEWAN.

The general succession of formations present in northern Montana extends into Canada, where the rocks have been known for many years to the Canadian geologists. The changes in the Montana group, including the disappearance of the Claggett shale toward the west, which first became apparent in studying the section in Montana, are also present and are in every way similar in southern Alberta, where they have been recognized by Dowling.[1]

The differences in the formation names used on either side of the Canadian boundary relate chiefly, so far as the probable oil and gas bearing formations are concerned, to the Colorado shale and Eagle

[1] Dowling, D. B., Correlation and geologic structure of Alberta oil fields: Am. Inst. Min. Eng. Bull. 102, pp. 1355–1359, 1915. Dowling describes the stratigraphy in Montana but does not refer to the literature previously published on the subject.

sandstone, which the Canadian classification divides into three units—the Dakota sandstone, Benton shale, and Niobrara sands.[1] The "Niobrara sands" are identical with the rocks described as Eagle sandstone in this report. The fact that all fossil evidence is against using the name Niobrara in connection with this sandstone was long ago emphasized by Stanton.[2] Although in the early days the Dakota was supposed to be present in Montana, it is absent wherever the strata in which it should be present have been examined, and its existence in southern Alberta is believed to be equally uncertain. The sandstone at Bow Island and elsewhere referred to as Dakota by Clapp and others is very probably the sandstone in the lower part of the Colorado shale as described in this report and illustrated in figure 12. The fact that the logs of wells at Bow Island show dark shale beneath the pay sand called "Dakota" is very suggestive of this. Marine fossils found in the basal sandstones of the Colorado shale, described as "rusty beds" in the section from central Fergus County (see fig. 12), seem to prove the marine origin of all these sandstone beds. The use of the name Benton for shale overlying the supposed Dakota in northern Montana is also inadvisable, for no evidence has been found, either paleontologic or lithologic, to warrant recognition of the Benton and Niobrara subdivisions of the Colorado. The simple expedient of applying the term Colorado shale to all these strata in northern Montana has long been in use.

## IGNEOUS ROCKS.

Igneous rocks in large areas are present only in the mountain uplifts of north-central Montana, where they occur in laccolithic masses. According to Weed and Pirsson[3] the igneous rocks of all these detached mountain groups belong to a single general type of highly differentiated alkaline rocks, usually high in silica. Dikes and sills of these rocks radiate from the mountains, some of them to considerable distances, and cut the Cretaceous beds of the plains. They are especially abundant in a belt from 15 to 20 miles wide between the Highwood and Bearpaw mountains. These dikes and sills have had little effect on the inclosing strata, baking of the beds and displacement having occurred only to a minor extent. They may be of importance in relation to the occurrence of oil and gas, especially where they are abundant, but it is difficult to determine what effect they have had on any hydrocarbons that might be present.

[1] Clapp, F. G., and others, Petroleum and natural gas resources of Canada, vol. 2, pp. 265–272, fig. 27, 1915.

[2] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, p. 64, 1905.

[3] Weed, W. H., and Pirsson, L. V., Geology of the Little Rocky Mountains: Jour. Geology, vol. 4, p. 426, 1896.

## STRUCTURE.

### IMPORTANCE OF STRUCTURE IN THE SEARCH FOR OIL AND GAS.

The lay of the beds in sedimentary rocks is referred to as the structure. If a competent source of supply of oil and gas and a proper receptacle for their accumulation and retention—namely, "sands"—are at hand, structure that permits the concentration of these hydrocarbons into relatively small areas from an originally disseminated condition then becomes of paramount importance in the search for oil and gas. In order to permit the concentration of these substances into commercial pools, it seems necessary that the strata shall have been flexed, tilted, and folded in some manner. It can be said without reservation that oil and gas do not generally accumulate in commercial quantities if the rock layers are perfectly flat. Experience has amply proved the statement of the late Edward Orton that in horizontal beds "you will get a little oil, a little gas, and a little salt water, but not much of anything."

The structural forms that have proved the most productive are domes or anticlines, produced by upwarps or bulges in the strata. Others of less importance are terraces, monoclines, synclines, and strata bent by faulting. The essential factor is that the beds be tilted or bent, but the degree of tilting varies greatly. In many places it is so slight that it is imperceptible to casual inspection and can not be detected except by close instrumental work, as in the Kansas, Oklahoma, and Texas fields. Elsewhere the tilting may be strongly developed, as in the California and Wyoming fields, where its presence can be ascertained at a glance by a trained observer.

The presence or absence of water in the "sands" is a further qualifying factor in determining the location of pools. The following statements with reference to the presence of water have been proved again and again in developed fields: If the pay sands are saturated with water, the gas and oil, being lighter, will be found above the water in the crests of domes or anticlines or on the flats or terraces of monoclines. If the sands are only partly saturated with water, the gas and oil will be found down on the flanks at the upper level of saturation. If the sands are dry, the oil and gas will have migrated downward to the troughs of the synclines or to a point where further shifting has been prevented. Finally, it is generally although not invariably true that if oil and gas are present in the same stratum, gas, being the lighter, will be found above the oil—that is, farther up on the flanks of the fold.

It is very probable that in Montana large quantities of gas or oil will be found, if at all, only in strongly developed folds, with relatively high dips, such as those in Wyoming, rather than in folds having very low dips, such as are characteristic of the Mid-Continent fields. This belief is based on the fact that most of the oil fields so far developed in the Cretaceous rocks of the region adjacent to the Rocky Mountains, from Colorado to Alberta, are on strongly developed anticlines. There seem to be no conditions present in Montana which will make that State an exception to the general rule for the Rocky Mountain and Great Plains fields.

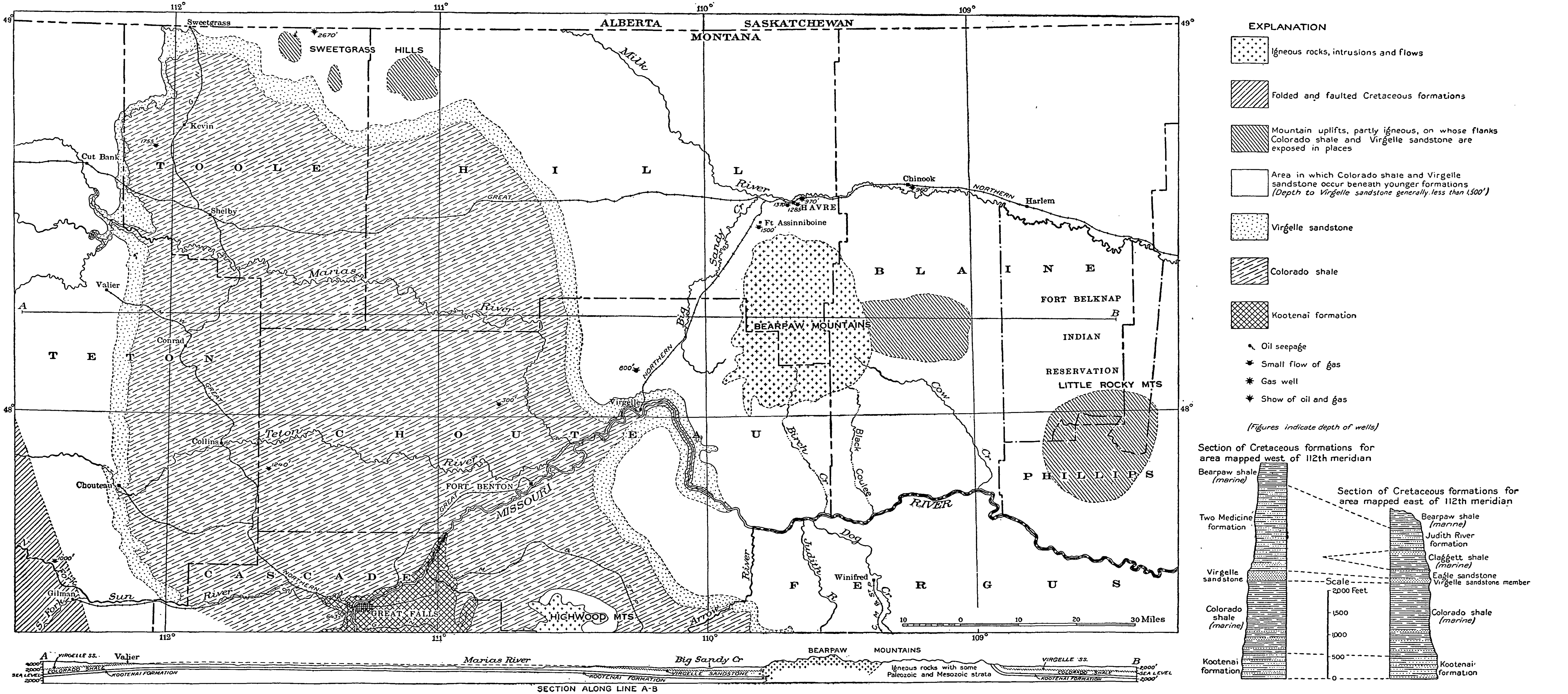
## STRUCTURE OF NORTH-CENTRAL MONTANA.

### GENERAL ASPECT.

Viewed as a whole the structure of north-central Montana is that of a large area of nearly horizontal beds of sedimentary rock that have been intruded by igneous rocks and uplifted in four isolated mountain groups. A general idea of these relations can best be obtained from the section extending entirely across the region through the Bearpaw Mountains, given on Plate IV. On a drawing covering so wide an area the vertical scale is necessarily exaggerated, making the dips in the areas of nearly flat strata appear greater than they really are. Sections made in the same manner, but in different directions, through others of the mountain uplifts, show the same general setting of large areas of nearly horizontal strata intruded and uplifted in the mountains. In relatively small tracts in the areas of nearly horizontal rocks, especially in the region surrounding the Bearpaw Mountains, the beds are much tilted and bent. These upturned beds, however, are nowhere extensive enough to offset the prevailing horizontality of the rocks.

### SWEETGRASS ARCH.

The structure of the western half of the region described is characterized by a very broad anticline or arch that extends in a general northerly direction and is here called the Sweetgrass arch. This broad uplift brings the Colorado shale to the surface in an area about 75 miles wide, surrounded on all sides but the south by outcrops of the Virgelle sandstone. (See Pl. IV.) The arch extends southward from the Sweetgrass Hills to the region beyond Teton River, where it flattens out because of the presence of gentle northward dips induced by the uplift of the Belt Mountains, still farther south. On the north this broad uplift extends to and beyond Belly River in Alberta, but it pitches slightly, allowing the overlying rocks of the Montana group to arch over its crest. On the geologic maps of southern Alberta it appears as a broad belt of "Belly River beds," flanked on each side by the overlying marine shale. The Bow Island gas field of southern Alberta lies near the center of this broad arch.




GEOLOGIC SKETCH MAP AND SECTION SHOWING OIL AND GAS PROSPECTS IN NORTH-CENTRAL MONTANA.

The location of the axis or crest of a very broad fold of this kind is extremely difficult. In fact, it is not improbable that this arch has no well-defined crest but culminates in an area of slightly undulating, nearly horizontal rocks along its middle part. (See section, Pl. IV.) Most of the arch in northern Montana has not been examined geologically. The possibility of the occurrence of minor folds within the area of the broader arch must be considered, and if any such are present they are important in relation to the occurrence of oil and gas, offering the possibility of getting oil from the Colorado shale at comparatively shallow depths. The oil and gas developments in this area are noted under the local descriptions in this report.

#### REGION OF TILTED AND FOLDED ROCKS SURROUNDING THE BEARPAW MOUNTAINS.

In the plains surrounding the Bearpaw Mountains for 30 to 40 miles on all sides there are many folds and faults in the nearly horizontal Cretaceous rocks that are irregular in their trend and distribution. The causes of this peculiar and irregular faulting are not well understood, but they are probably related to the extensive igneous intrusions in the Bearpaw Mountains. The faults are all of the thrust type, older formations having been carried upward beside younger rocks that lie for the most part undisturbed. The largest of these faults average about 12 miles in length, but most of them can not be traced more than 4 to 6 miles. The cross section of the Meili fault (Pl. V) illustrates the general type of these faults, although in many of them only the beds on one side of the break are tilted, those on the opposite side remaining undisturbed practically up to the fault plane. The trends of the faults cover all points of the compass, although in small areas a single direction may be dominant—for instance, south of the Bearpaw Mountains many of the faults trend about N. 55° W., while north of these mountains the two principal trends are approximately N. 40° E. and N. 70° W.

These faults have produced in the strata upward arches, which, if the impervious shales overlying the sands have not been broken by the faults, should be as effective reservoirs as anticlines for the storage of gas or oil, or if the impervious cap has been broken the movement along the fault plane has tended to seal the pores in the sand and thus retain any oil or gas that may have accumulated there. The discovery of gas at Havre seems to prove that these faults have not unsealed the underlying sands and suggests that conditions favorable at least for gas and probably for oil are present throughout the wide extent of territory occupied by these faulted structures.

On Plates VI and VII are represented 32 of these faults, including all the principal ones mapped in the areas north and south of the Bearpaw Mountains. Detailed accounts of these areas are given under the local descriptions.

#### DISTURBED BELT ADJACENT TO THE FRONT RANGE OF THE ROCKY MOUNTAINS.

A small area in the vicinity of the North and South Forks of Sun River, in the southwest corner of the region here described, forms a part of an extensive belt of strongly folded and faulted Cretaceous and Tertiary rocks lying adjacent to the front range of the Rocky Mountains. This disturbed belt extends northward into Alberta, to Calgary and beyond. The discovery of gas and oil in faulted anticlines in this disturbed belt in the vicinity of Calgary has led to considerable excitement in the last few years. Little is known of the details of the part of the disturbed belt lying in the area described in this report, but it is not improbable that anticlines are present there. If so, they are very likely to be much faulted and trend northwest. Where they are underlain by the Colorado shale and Kootenai formation at reasonable depths they offer a probability of obtaining oil and gas with the drill.

## LOCAL FEATURES.

### AREA OF TILTED AND FAULTED ROCKS NORTH OF THE BEARPAW MOUNTAINS.

#### HAVRE GAS FIELD.

##### INTRODUCTION.

The first recorded discovery of gas in the vicinity of Havre was made at Fort Assinniboine by the Quartermaster's Department, United States Army, between June, 1892, and November, 1893, while making a deep boring in the hope of getting artesian water. This well was drilled to a depth of 1,500 feet and obtained a small flow of gas, although no water was encountered below the gravel and sand of the glacial drift. Nothing further was developed until the Havre Natural Gas Co., composed of prominent citizens of Havre, finally obtained a large flow of gas under high pressure 2 miles northeast of the town in July, 1915. The company had previously drilled two wells in Havre, one at the race track and the other at the brewery, at opposite ends of the town. A small flow of gas was obtained in each of these wells, and with commendable persistence the company made a new location, which resulted in the important find just noted. All these locations were made at random, without regard to surface showings of gas or of geologic structure, the guiding principle of those interested being simply the firm conviction that the gas fields of southern Alberta extended southeastward into Montana.

Acknowledgments are due to Brig. Gen. J. F. Morrison, United States Army, for the well record and information concerning the drilling at Fort Assinniboine, made while he was in command of the post. The writer is also indebted to Dr. J. A. Wright, president of the Havre Natural Gas Co., and to other members of that company for information concerning their operations and for the gas analysis on page 74.

## GEOLOGIC FORMATIONS EXPOSED IN THE VICINITY OF HAVRE.

Three of the six Cretaceous formations present in north-central Montana crop out along the Milk River valley in the vicinity of Havre. These are the Claggett shale, the Judith River formation, and the Bearpaw shale. (See table, p. 53.) Because of the thick cover of glacial drift over all the level areas in the region, the exposures of these rocks are limited to the steeper slopes along the stream valleys and coulees. There they are well exposed in freshly eroded badlands, in which the identity of the various units is readily determinable.

The Claggett shale, the oldest formation in this vicinity, is exposed only in the faulted areas lying west of Havre. It consists of soft dark-gray clay shale, about 285 feet thick, characterized throughout by an abundance of the glassy crystals of selenite, a variety of gypsum. The thickness given was obtained in sec. 8, T. 34 N., R. 13 E., where the only complete section of the formation so far found in the Milk River valley is exposed. The shale weathers to a dark gumbo soil that becomes very tenacious when wet. Its most extensive outcrop in the Havre district is in the lower part of Meili Coulee, about 5 miles northwest of Havre, where it is well exposed north of the fault in that vicinity. (See map, Pl. V.)

The Judith River formation is the most extensively exposed formation in the region and crops out in the badlands that extend for many miles along the Milk River valley. It is composed of light-colored clay, clay shale, and sandstone containing lenticular coal beds near the top and a few thin seams at the base. Soft clay beds make up the bulk of the formation, and the rapidity of erosion in these soft strata has produced the extensive badlands. The sandstones are cross-bedded and ripple marked, but in no place are they persistent enough over considerable areas to serve as key rocks. Fossil shells of fresh and brackish water types are present at many horizons. The coal has burned along the outcrop, baking and fusing the overlying beds into prominent brick-red scoria or clinker, a common feature in the badlands of Montana, where coal or lignite beds are present. These "burnt-rock streaks" are clearly due to this cause, being present only at the coal horizons, and should not be attributed to the burning of oil-bearing shale, as has been maintained by persons interested in the oil prospects of the region.

The best exposures of the Judith River formation in the vicinity of Havre are on the north side of Milk River, where all the coulees leading to the river valley show continuous outcrops of these rocks. The total thickness of the formation in the vicinity of Havre is about 480 feet, according to a measurement made by V. H. Barnett in 1908 across the upturned edges of the formation, the Claggett shale appearing below and Bearpaw shale above, as exposed 3 miles west of Havre, near the mouth of Beaver Creek on the south side of the railway. This is the only exposure known in the Milk River valley, where a complete section of the Judith River beds apparently not disturbed by faulting can be measured.

The Bearpaw shale conformably overlies the Judith River formation. It is a dark gumbo-forming shale, very similar to the Claggett, and is the youngest purely marine formation in northern Montana. It is not distinguishable either by its fossils or by the character of its rocks from the Claggett unless a complete stratigraphic section is present and its position above the Judith River can be definitely determined. In the vicinity of Havre it is exposed only on the south side of Milk River, where it appears in numerous isolated areas, in most of them associated with faults. All these areas are shown on the map (Pl. V). Not more than 350 feet of this shale is present in the area mapped, although the total thickness of the formation is much greater.

Glacial drift covers a large part of the area in the vicinity of Havre, completely obscuring the structure of the underlying Cretaceous formations and therefore greatly increasing the difficulty of prospecting the area for gas and oil. The gravel and bowlder clay of this cover of drift are irregular in thickness but in places probably measure over 100 feet. They form the surface of all the areas shown without shading on Plate V. The areas along Milk River and its principal tributaries mapped as occupied by alluvium contain recent stream deposits of sand and silt and a little gravel.

#### EAGLE SANDSTONE AND COLORADO SHALE.

The Eagle sandstone and Colorado shale are not exposed in the vicinity of Havre, but they underlie most of the area within reasonable drilling depths and seem to offer the best possibilities for obtaining gas and oil. The large flow of gas obtained by the Havre Natural Gas Co. comes from the Eagle sandstone and proves that important quantities of gas are present in that formation. It is noteworthy that the gas at Medicine Hat, about 115 miles northwest of Havre, is produced from sands at the same geologic horizon.

The exposures of the Eagle sandstone nearest to the Havre area lie about 25 miles to the northwest, on Milk River, in T. 34 N., R. 13 E. Here, in the W. ½ sec. 8, the sandstone is brought to the surface in a prominently faulted area, shown on Plate VI. A section across the upturned strata, which strike N. 34° E. and dip 31° SE., is as follows:

*Section of Eagle sandstone in W. ½ sec. 8, T. 34 N., R. 13 E.*

| | Feet. |
|---|---|
| Claggett shale. | |
| Eagle sandstone: | |
| Sandstone, buff, indurated, with a 6-inch pebble bed near the middle | 23 |
| Shale, carbonaceous, brown to black | 15 |
| Clay shale, gray, with thin bands of buff sandstone | 220 |
| Sandstone, very massive, almost white | 30 |
| Sandstone, very massive, light gray, cross-bedded | 100 |
| Bottom not exposed. | |
| | 388 |

An inspection of the above section shows that the formation is composed essentially of two sandstone members, with a thick shale member between them. The sequence and character of the beds are identical with those of the same formation in the Missouri River section. The thickness, however, is somewhat greater. The 130 feet of massive sandstone at the base of the section corresponds to the Virgelle sandstone member of the Eagle and apparently differs little from that member in the type section on Missouri River, the 30-foot white sandstone being especially like the white sandstone forming "the stone walls" on the Missouri.

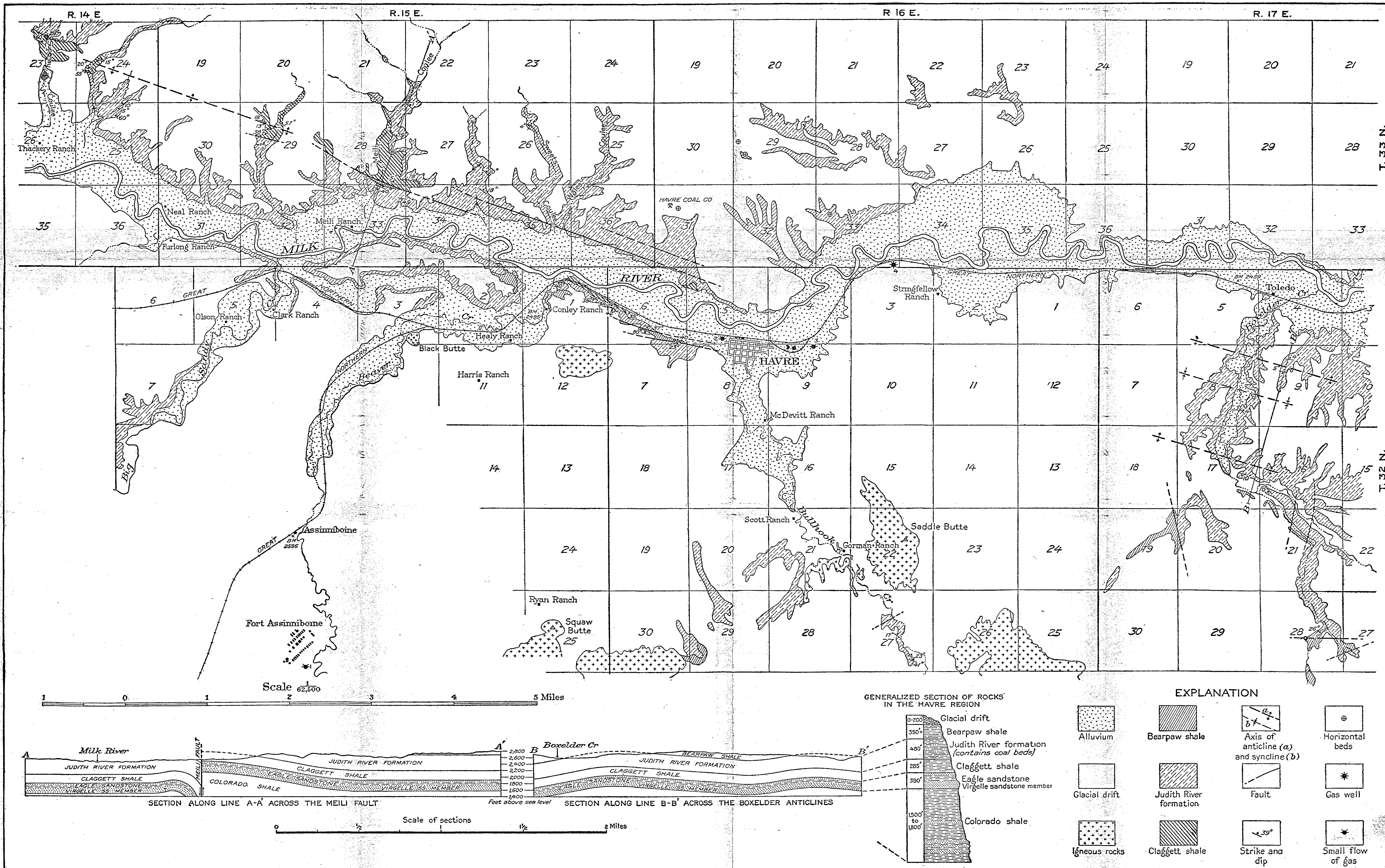
The details of the Colorado shale are not known in the vicinity of Havre. The formation has not been drilled through so far as known, but its main features are not likely to be very different from those it exhibits generally in north-central Montana, as described on pages 56–58. The presence of sandstones in the lower half of the Colorado shale, shown in the section on Plate V, is entirely inferential, being assumed from the general prevalence of sandstones in the Colorado in all parts of north-central Montana.

### STRUCTURE.

*Main features.*—The dominant structural feature in the vicinity of Havre is a belt of deformation in which the rocks are folded and faulted, extending about 15 miles in a northwesterly direction across the district. This belt is one of many of similar character and proportions on all sides of the Bearpaw Mountains. The deformation at its southeast end, on Boxelder Creek, seems to have produced two parallel gentle anticlines, here referred to as the Boxelder anticlines. Farther northwest the movement in the rocks appears to have been taken up by several parallel faults that have approximately the same trend as the anticlines. The most extensive of these is the Meili fault. (See sections on Pl. V.)

*Boxelder anticlines.*—The extensive exposures of the Judith River formation along Boxelder Creek and the adjoining coulees show two parallel anticlines extending across secs. 8, 9, 16, and 17, T. 32 N., R. 17 E. The outcrops affording the best exposures of the north anticline appear in the coulee that runs northward near the center of sec. 9. On the north side of the anticline dips of 4° NE. are apparent; on the south side the dips are at a maximum of 5° SW. These dips outline a rather narrow-crested fold, trending in a northwesterly direction. The dips outlining the south anticline appear on the east slopes of Boxelder Creek in secs. 8 and 17. In the SW. ¼ sec. 8 there is an average dip of 4° NE. in the Judith River beds on the northeast flank of the anticline. On the opposite flank the average dip is about 10°, as is shown in exposures in the SE. ¼ sec. 17. The Bearpaw shale is shown in two isolated outcrops surrounded by glacial drift in the S. ½ sec. 17 and seems to come in normally above the Judith River formation. Southwest of these outcrops there are probably some faults parallel with the general trend of the anticlines, for the next rocks exposed to the southwest are the Judith River beds, in such an attitude that the presence of a sharp synclinal fold with an axis lying near the outcrops of the Bearpaw shale does not seem probable. The axes of the two Boxelder anticlines are closely parallel. Their limits on the northwest and southeast are not determinable because of the cover of glacial drift, but they are doubtless parallel to the general trend of the Meili fault, and their extension toward the immediate vicinity of Havre, where the large quantity of gas has been found, is very probable.

*Meili fault.*—The Meili fault is the principal one of a group of parallel faults trending approximately N. 70° W., northwest of Havre. It can be traced continuously, except for several short covered stretches, for 2 miles, beginning at the edge of the alluvium in the NE. ¼ sec. 34, T. 33 N., R. 15 E., and extending to the west line of sec. 28 of the same township. To the southeast, under the cover of the extensive tract of alluvium along Milk River, it may extend a considerable distance parallel with the minor faults that are exposed on the adjacent sides of the Milk River valley. That this fault may extend as far southeast as the center of sec. 5, T. 32 N., R. 16 E., a point about half a mile north of Havre, is suggested by the small exposure of the Claggett shale lying in normal relations beneath the Judith River strata in the NW. ¼ sec. 5. This exposure of the Claggett is probably part of a larger tract uptilted by faulting, but now concealed by alluvium, and is comparable with the area of the Claggett shale on the north side of the fault in Meili Coulee.




GEOLOGIC MAP AND SECTIONS OF THE VICINITY OF HAVRE, MONT.

On the north side of the Meili fault at the place where it crosses Meili Coulee near the south line of sec. 28, T. 33 N., R. 15 E., there is a large area of the Claggett shale faulted in part against the Judith River beds and in part against the Bearpaw shale. The maximum stratigraphic displacement along this fault is about 800 feet. The dips in the area of the Claggett shale along Meili Coulee are all northeastward. They average about 5° near the fault, but farther north, near the middle of sec. 28, they become steeper, an observed dip of 16° being noted, and still farther north, about 1¼ miles from the fault, the dip has flattened to 1°. The structure thus shown is in effect that of a broad anticline which has been cut on the south by the Meili fault. (See section A–A′, Pl. V.) South of the Meili fault, at the same locality, the dips are also to the north, averaging as high as 40°, but a short distance to the southwest they reverse, making a sharp anticline, beyond which the beds assume a horizontal position.

West of sec. 28 the Meili fault may be continuous, though it changes slightly in trend, to a direction more nearly west, with the fault that crosses the coulee near the center of sec. 29, which also brings the Claggett shale into contact with the Judith River formation. A quarter of a mile north of the latter fault is a closely folded anticline that follows the trend of the Meili fault and extends northwestward as far as Supenau Coulee, a distance of over 3 miles. This fold is much covered by glacial drift between the coulees, but the close alignment of all the exposed parts makes their unity very probable. The dips on either flank of this anticline are steep but irregular, ranging from 18° to 75° on the north side of the fold and from 13° to 38° on the south side.

*Minor faults near Havre.*—Two faults paralleling the Meili fault and extending through secs. 35 and 36, T. 33 N., R. 15 E. (see Pl. V), have a much smaller throw than the Meili fault and do not at any point bring the Claggett shale to the surface. As in the Meili fault, the dips on the north side of these breaks are northward, away from the faults, and the degree of tilting is similar to that along Meili Coulee.

West of Havre, just south of the railway, faulted beds are exposed across secs. 1 and 6 in steeply tilted blocks which are visible from the west end of the town. The formations involved include the Claggett, Judith River, and Bearpaw. The trend of the faults and the strike of the beds in this disturbed area are all apparently parallel to the trend of the Meili fault. The beds north of the northern fault dip between 30° and 45° S. The tilted block north of this fault, if the strike continues, extends beneath Havre under the area covered by alluvium. This fact makes it probable that the gas well near the brewery at the west end of the town is located in tilted beds, and there is also some likelihood that the well at the east end of the town is in the same tilted block. South of the fault just mentioned the beds tilt northward, so that the structure here is in effect that of a syncline, broken along its axis by a fault.

#### GAS DEVELOPMENTS.

The gas in the well at Fort Assinniboine was encountered at a depth of about 1,200 feet.[1] The pressure was not great. The gas burned freely when lighted, but the flow lasted only a few days. It is probable that the bed yielding this gas was in the Eagle sandstone. The rocks penetrated in this well are shown in the following log:

*Log of well drilled by the Quartermaster's Department, United States Army, at Fort Assinniboine, Mont., between June, 1892, and November, 1893.*

[Altitude of surface, about 2,660 feet.]

| Probable formation. | Driller's description of the rock. | Thickness. | Depth. |
|---|---|---|---|
| | | *Feet.* | *Feet.* |
| Glacial drift. | Clay, gravel, and sand | 65 | 65 |
| Bearpaw shale. | Soft gray slate rock | 375 | 440 |
| Judith River formation. | Black shale, with small portion of coal mixed | 30 | 470 |
| | Gray fire clay, slate, and soapstone mixed | 108 | 578 |
| | Shale, white and black clay mixed | 312 | 890 |
| Claggett shale and Eagle sandstone. | Slate, soapstone, and chalk mixed | 170 | 1,060 |
| | Soapstone, very soft, porous, and full of seams | 440 | 1,500 |

The bedrock formations over a large area in the vicinity of the well are concealed by glacial drift, and therefore there is some uncertainty as to the formations pierced by the drill. The 375 feet of "soft gray slate rock" lying immediately below the gravel and sand of the glacial drift is very likely the Bearpaw shale. This is made fairly certain by the presence of the 30-foot member described as "black shale, with small portion of coal mixed," which, overlying a considerable thickness of gray rocks, is very likely the coal zone at the top of the Judith River formation. With these two formations determined the remainder of the log would follow in sequence as indicated above, unless the strata are much disturbed. The considerable thickness of material at the bottom of the well described as "soapstone, very soft, porous" very likely absorbed the drilling

[1] Personal communication from Brig. Gen. J. F. Morrison, U. S. Army.

water rapidly and, it seems probable, is the sandstone of the Eagle. True soapstone could not be described as porous and would not take up the drilling water.

The well at the west end of Havre, near the brewery, was drilled to a depth of 1,370 feet. Gas was obtained at 900 feet and again at the bottom of the hole, but each flow was small. The gas at the bottom of the hole gave a closed pressure of 540 pounds after 36 hours. The well at the east end of Havre, at the race track, is 1,285 feet deep. It yielded some gas at 885 feet and a larger flow at the bottom, which was estimated to be less than 1,000,000 feet a day. The gas from the lower sand gave a maximum closed pressure of 540 pounds in 24 hours.

The principal gas well of the Havre Natural Gas Co., brought in early in July, 1915, is in the SE. ¼ sec. 33, T. 33 N., R. 16 E., about 2 miles northeast of Havre, just south of the Great Northern Railway. This well is on a low terrace overlooking Milk River, in a large area in which the bedrock formations are concealed either by the alluvium along the river or by the glacial drift on the higher slopes, making it impossible to decipher the rock structure in the immediate vicinity of the well. However, as indicated by the surrounding exposures, it is very probable that the Judith River formation immediately underlies the glacial drift in most of this area. This well is 947 feet deep and at the bottom obtained a large flow of gas which was roughly estimated, by taking minute pressure readings, to amount to 10,000,000 feet in 24 hours. This method of obtaining the open-flow volume of a gas well is unreliable, and the figures are therefore only approximate. The initial closed pressure of this well in July, 1915, was about 490 pounds to the square inch. No later readings have been obtained.

The rocks encountered in drilling this well were described to the writer in a general way by Dr. Wright, of the Havre Natural Gas Co. There seems to be little reason to doubt that the drill went through part of the Judith River formation, all of the Claggett, and part of the Eagle sandstone. The estimated stratigraphic position of the first rocks encountered below the glacial drift is about 400 feet above the base of the Judith River formation. If the thickness of the Claggett shale is taken as 285 feet and that of the Eagle sandstone as 390 feet, the bottom of the hole is about 100 feet from the base of the Eagle sandstone and hence is probably in the Virgelle sandstone member of the Eagle.

An analysis of the gas from this "gusher" well was kindly furnished by the Havre Natural Gas Co. and is given below, together with one of gas from Alberta for comparison.

*Analyses of natural gas from Havre, Mont., and Medicine Hat, Alberta.*

[Analysts not known.]

| | Havre. | Medicine Hat.[a] |
|---|---|---|
| Carbon monoxide (CO) | 0.20 | |
| Methane ($CH_4$) | 94.80 | 99.49 |
| Nitrogen (N) | 5.00 | |
| Hydrogen sulphide ($H_2S$) | | .51 |
| | 100.00 | 100.00 |
| Heating value per cubic foot (British thermal units) | 897 | |

[a] Clapp, F. G., and others, op. cit., vol. 1, Table 12.

The analysis in the first column is that of a "dry" gas from which little or no gasoline could be extracted by freezing tests and which is very similar to that obtained at Medicine Hat, being composed chiefly of methane and not containing any of the higher series of hydrocarbons. The heating value given is too low for that of a natural gas containing 95 per cent of methane, and therefore there may be an error either in the determination of heating value or in the analysis. A recent analysis of this gas by G. A. Burrell, of the Bureau of Mines, gave the following: Heating value, 1,036 British thermal units; methane, 97.3 per cent; nitrogen, 2.7 per cent.

A comparison of the results of this large gas well with those of the wells drilled at Medicine Hat is of interest because the gas obtained at the two localities comes from the same geologic formation. At Medicine Hat, in December, 1913, there were 16 municipal wells between 1,000 and 1,300 feet deep, having an open-flow capacity of 43,200,000 cubic feet a day, according to a statement by the city engineer. The production of the largest of these wells from a 10-inch aperture was 6,000,000 feet a day, but the average yield is between 2,000,000 and 3,000,000 feet. There are also in this field several wells, owned by manufacturing companies, concerning which data are not available. The development of these gas resources has led to a rapid industrial expansion at Medicine Hat.

### PROBABLE EXTENSION OF THE FIELD.

The gas pool in the district about Havre will probably have its greatest extension in a direction S. 70°–75° E. This statement can be made with considerable certainty, because (1) the single dominant uplift in the district has this trend, and (2) the strong flow of gas encountered is with little doubt located on or near this uplift. If this strong flow should prove to be short-lived the location is probably too far down the flank of the inclined strata present. The territory along the axes of the two Boxelder anticlines and along the probable extension of these axes, especially northwestward toward

Havre, seems to offer the best chance for further extension of the field. On the north side of the Meili fault the area of tilted beds occupying parts of secs. 27, 28, and 34, T. 33 N., R. 15 E., seems to be favorable, with a chance of getting gas at comparatively shallow depths. There is also a probability of getting oil and gas in these areas by drilling for sands in the lower part of the Colorado shale at depths of 2,000 to 3,000 feet, the depth depending on the location on the folds.

### EXTENT TO WHICH FAULTS HAVE PERMITTED THE ESCAPE OF GAS OR OIL.

The extent to which faults have unsealed any deep-seated sands containing gas or oil and have therefore allowed much of their contents to waste is an important problem in the Havre district and in all of the area surrounding the Bearpaw Mountains where faults are generally prevalent. All the evidence at hand seems to indicate that in the soft Cretaceous formations of the Rocky Mountains and the Great Plains faulting can at the most only slightly unseal the underlying sands. This seems to be especially true of the sands in a thick mass of soft marine shale, such as the Colorado shale. In Wyoming this is shown by the fact that many of the producing anticlines are faulted, some of them to a considerable extent. In the Calgary region, Alberta, a 2,000,000-foot flow of gas obtained from an area of much faulted rocks in the disturbed belt[1] adjacent to the Rocky Mountains is further proof that gas can accumulate in faulted rocks, if the formations are composed of soft materials. The well at the west end of Havre, at location No. 2, seems to offer proof of this also, for although it is situated close to two faults of considerable throw, it contains gas which had an initial closed pressure of 540 pounds to the square inch.

### CHANCES OF SUCCESS BY RANDOM DRILLING IN THE MILK RIVER VALLEY.

A successful oil or gas well invariably leads to a popular belief that the hydrocarbons are to be found under all lands in the district in which it is situated, and that drilling at random locations in that district is certain to be successful. In the Milk River valley, throughout which the geologic features remain much the same, five deep borings have been put down at random locations—three at Havre, one at Chinook, and one at Fort Assinniboine. Only one of the five was successful, and there is no reason to believe that drilling at haphazard locations will be any more successful over the remainder of the area. The only possibility of decreasing this percentage of dry holes outside of the proved territory is by a better understanding of

[1] Clapp, F. G., and others, op. cit., vol. 2, p. 283.

the lay of the rock strata and its influence on the accumulation of oil and gas.

### OTHER AREAS OF TILTED AND FOLDED ROCKS NORTH OF THE BEARPAW MOUNTAINS.

Areas of tilted and folded rocks in the region north of the Bearpaw Mountains are shown on Plate VI. Structure similar to that at Havre has been noted in at least 11 widely scattered localities. In much of the area lying between these faulted tracts the hard rocks are covered by glacial till and their structure is therefore not known, but it is possible that other anticlines or tilted blocks as extensive as those represented on the map are present in the region. However, large areas are certainly underlain by rocks that are nearly or quite horizontal. Outside of the Havre district no developments of oil or gas or even indications of these substances have been found in the area shown on Plate VI. In the following pages the principal features of these areas of tilted beds will be described, beginning with the northernmost tier of townships and progressing southward.

#### T. 37 N., R. 15 E.

On Signal Butte, in the west half of T. 37 N., R. 15 E., an anticline, broken along its crest by faulting, extends in a direction approximately N. 25° W. This anticline can be traced very clearly for about 2 miles, and there is a possibility that it extends for several miles more under the glacial drift. The exposures on the east side of Signal Butte are excellent. They show the Judith River formation with its coal zone lying near the top, together with 200 feet of the underlying beds. The Bearpaw shale appears normally above the Judith River formation on either flank of the broken fold. The structure is clearly anticlinal—that is, the beds dip away on both sides from a middle axial line, although there is some displacement by faulting along this axis. On the northeast side of the anticline the dips close to the fault line range from 10° to 32°. Toward the east they flatten rapidly, and about a mile from the fault the strata lie nearly horizontal. On the west side the beds do not dip so steeply, the average dip being not over 12°, except in a few irregularly disturbed tracts. In the S. ½ sec. 20, on the fault cutting the crest of the anticline, there is a spring whose surface is covered with a thick film of reddish-brown ferric hydroxide. This material should not be mistaken for oil. No signs of oil or gas were found in the vicinity. A cross fault in the S. ½ secs. 19 and 20, nearly at right angles to the trend of the broken anticline, forms the south boundary of a block of Judith River beds which are tilted to the northeast at angles of 6° to 13°. This tilted block lies in anomalous relations to the faulted anticline just described and covers an area of nearly 4 square miles.

T. 36 N., R. 14 E.

In the east half of T. 36 N., R. 14 E., mainly in secs. 11, 14, 22, and 23, there is a tilted block of rocks having an average dip of about 8°, bounded on the northwest side by a fault. On the whole the exposures in this vicinity are not good, the limits of the tilting being hidden either by glacial drift or alluvium. The best exposures appear on the northward-facing slope in the N. $\frac{1}{2}$ sec. 23. Practically all of the Judith River formation is exposed along this slope, and there is probably a little Claggett shale at its west end. The dips for the greater part of the distance average between 7° and 8°. Near the top of the Judith River there is a local dip of 28°, but this flattens to about 9° a short distance farther southeast. The Bearpaw shale appears on this slope in normal relations above the Judith River beds and is exposed to the southeast across almost all of sec. 24. The actual extent of this tilted block can not be determined, but to judge from the area of the exposed portion it seems safe to say that, as indicated on the map, it extends at least 2 miles in a northeasterly direction.

T. 35 N., R. 12 E.

In the west half of T. 35 N., R. 12 E., the rocks are uplifted and tilted to the southeast by a fault that has a general trend of N. 25° W., and extends from Milk River near the southeast corner of sec. 14 northwestward for at least 4 miles, crossing secs. 6 and 7 of the township adjoining on the east. On the northwest side of the fault the area is occupied by the Judith River formation, which lies approximately horizontal for many miles to the northwest, and the beds are undisturbed, even in close proximity to the fault plane. On the southeast side the beds are tilted to the southeast in an area occupying 4 to 5 square miles. The Claggett shale is the lowest formation exposed in this area and crops out in a belt that averages a quarter of a mile in width adjacent to the fault and is traceable as far as the fault is exposed. Southeast of the Claggett outcrop is the lower part of the Judith River formation, with a persistent thin coal bed at the base in normal relations to the Claggett shale. The highest dip (60°) in this tilted block was observed in the Claggett shale in sec. 14. The average dip is not over 40°. Northeast of this area, in secs. 12, 6, and 7, the dips in the Claggett shale at the same position with reference to the fault do not average more than 20° to 25°. In sec. 14 the beds are approximately horizontal within three-fourths of a mile of the fault. Farther north the distance from the fault to practically horizontal beds is somewhat greater, but nowhere is it more than 1 mile.

T. 35 N., R. 14 E.

On the upper end of Red Rock Coulee, in T. 35 N., R. 14 E., there is a tilted block of strata between two parallel faults extending for 4 miles in a northeasterly direction. The areas northwest and southeast of the two faults bounding this block are underlain by the Bearpaw and Judith River formations, for the most part nearly horizontal. Between the faults the rocks are considerably tilted, and the steepest dips are on the southeast edge of the block, where dips in the Bearpaw shale and in the coal zone in the upper part of the Judith River formation range from 35° to 70°. On the northwest edge of the block the dips are much less, the observed readings varying from 6° to 14°. The lowest rocks (the upper part of the Claggett shale) are exposed in sec. 30. Southeast of this point the full thickness of the Judith River beds is present, followed in the SW. ¼ sec. 29 by a small amount of the Bearpaw shale.

T. 35 N., R. 16 E.

In T. 35 N., R. 16 E., near the head of a small coulee tributary to Red Rock Coulee, there is an area of tilted beds that strike about N. 65° E. These beds dip to the southeast at an average angle of about 20°, although readings as high as 37° were observed. The lowest beds exposed are those of the Claggett shale, which are followed in normal sequence by the Judith River formation with its coal zone at the top, which is well exposed. Southeast of the coal outcrops, near the south side of sec. 14, the Judith River beds are folded into a shallow syncline that lies on the south edge of the tilted block. Beyond this syncline the area is entirely covered with glacial drift. The extent of this tilted block in the direction of the strike is very uncertain because of the general cover of glacial drift, which makes it impossible to follow the exposures beyond the sides of the coulee.

T. 34 N., R. 12 E.

In the northeastern part of T. 34 N., R. 12 E., on Milk River, there is a fault trending about N. 55° E., which is exposed on both sides of the river valley and extends an unknown distance under the drift to the northeast and southwest. Northwest of this fault, up Milk River, the only formation outcropping for many miles is the Judith River, which lies nearly horizontal even in close proximity to the fault plane. Southeast of the fault for a distance of over a mile the strata are tilted to the southeast. The Claggett shale is the oldest formation exposed on this side, and overlying it are the Judith River beds in normal sequence, with a thin coal bed near their base. Within 1,500 feet of the fault the observed dips range from 35° to

60°. Farther away the dips flatten rapidly to 10° and then gradually lessen until the strata are nearly horizontal. The exposed rocks involved in this tilting occupy an area of about 3 square miles, but the total area may be much greater, including extensions under the cover of glacial drift.

#### T. 34 N., R. 13 E.

In T. 34 N., R. 13 E., there are three tilted blocks identical in form and nearly parallel to those in the adjoining townships to the west and the northwest, already described. Each block is separated by a fault trending northeast from a considerable area of nearly horizontal rocks on the northwest. The northernmost of these tilted blocks cuts across Saddle Butte, extending from secs. 18 and 19 to secs. 4 and 5. Practically all of the Eagle sandstone is brought up by the faulting. This occurrence is noteworthy, as it is the only outcrop of the Eagle formation in this part of the Milk River valley. The Eagle is the lowest geologic formation exposed in the area covered by Plate VI, and the section given on page 69 was measured at this point. The full thickness of the Claggett shale and the lower part of the Judith River formation, with a thin coal bed near the base, are also exposed. The dips in the zone occupied by the Eagle and Claggett in this faulted area in the first quarter of a mile southeast of the fault vary from 45° to 15°. Beyond this they rapidly become less, and a mile from the fault the beds lie nearly horizontal.

About 3½ miles southeast of the fault just described there is a similar fault crossing the Milk River valley and extending from the W. ½ sec. 22 northwestward as far as sec. 1, a distance of a little over 3 miles. The extent of this fault beneath the glacial drift beyond these limits can not be determined. According to Pepperberg,[1] the Claggett shale is the lowest formation brought to the surface in this faulted uplift. The beds on the northwest side of the fault are nearly or quite horizontal for several miles to the northwest. On the southeast side the dips appear to be irregular, varying from 14° to 60°. Farther southeast the beds flatten to a nearly horizontal position within a mile of the fault.

Farther down the Milk River valley the Judith River formation, lying nearly horizontal, is exposed on both sides of the valley as far as the center of sec. 36 and is the only formation exposed in this territory. Half a mile above Brown's ranch there is an anticline, broken to some extent by faulting, here referred to as the Browns Coulee anticline. This anticline trends in a northeasterly direction and extends several miles into the township adjoining on the east. An account of it is given under the next heading.

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[1] Unpublished data.

#### T. 34 N., R. 14 E.

From the west bank of Milk River, in sec. 36, T. 34 N., R. 13 E., the Browns Coulee anticline is well exposed, with minor interruptions, for a distance of about 3 miles, as far as the east side of Browns Coulee, in sec. 32, T. 34 N., R. 14 E. How much farther northeast and southwest it extends under the drift-covered prairies is not known. Beginning on Milk River in the southeast corner of sec. 36, its axis trends N. 65° E., passing a few rods south of the east quarter corner of the section. Continuing northeastward it crosses the north branch of Browns Coulee about 700 feet north of the center of sec. 31. In the main branch of Browns Coulee, in the NW. ¼ sec. 32, the crest of this fold is broken by a fault of relatively small throw, the dark shale of the Claggett abutting against a massive brown sandstone at the base of the Judith River formation, but the essential anticlinal nature of the structure, the strata dipping in opposite directions from a medial line, still prevails. The Claggett shale, according to Pepperberg,[1] is the lowest geologic formation exposed on the Browns Coulee anticline. The observed dips on the north limb of the fold range from 20° to 55° within half a mile of the axis; on the south limb the recorded dips range from 10° to 50°. The north limb is somewhat the more steeply tilted of the two. The total distance in a direction transverse to the axis of this anticline between the beds lying nearly horizontal on the north and those in the same attitude on the south is about 1¾ miles.

### TILTED AND FOLDED ROCKS NORTH OF CHINOOK.

#### T. 34 N., R. 19 E.

On Lodge Creek, in the southwestern part of T. 34 N., R. 19 E., the Claggett and Judith River formations are tilted about 25° S. in an area covering parts of secs. 19, 20, 29, and 30 and probably extending a short distance into the township adjoining on the west. The fault that produced this tilting crosses the river valley near the south quarter corner of sec. 19 and trends N. 17° E. There are no exposures on Battle Creek, where this fault, if extended, would cross the valley. The prevailing cover of till and glacial drift makes it impossible to determine how far the tilting continues.

In the southeastern part of this township there is an anticline whose axis trends northwest. It is very poorly exposed and seems to merge into a fault, which becomes prominent in the township to the south. The most definite indications of this fold are in the vicinity of the southwest corner of sec. 23, where the axis trends N. 30° W. and is outlined by opposite dips appearing on both sides of the valley of Dry Fork Creek. The fold is probably closely compressed. The observed dips on the east limb range from 20° to 75°

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[1] Unpublished data.

and those on the west limb from 4° to 30°. In the S. ½ sec. 35 there is a fault in the position that would be occupied by the anticlinal fold above mentioned if it were extended. This fault, however, trends more nearly north and causes the Judith River beds, dipping 11° W., to abut against the Bearpaw shale.

### T. 33 N., R. 19 E.

On Battle Creek, in the northeastern part of T. 33 N., R. 19 E., there is a fault trending nearly north, which seems to merge into the axes of the small anticlines at each end of it. For the greater part of the distance along this fault the Judith River formation, which is the lowest geologic formation exposed, abuts against the Bearpaw shale, the Judith River beds appearing mainly on the west side of the fault and the Bearpaw shale on the east. The dips within a few hundred feet on either side of the fault appear to be very steep, the observed readings, according to Pepperberg,[1] being as high as 65°, but the dips lessen both east and west of the fault line, and at a distance of one-half to three-fourths of a mile the beds lie approximately horizontal. On the east side of the fault the beds dip to the east at angles between 60° and 3°, according to the distance from the fault line, making the structure in effect anticlinal—that is, the beds dip in opposite directions from a medial line.

The only drilling operation in this part of the Milk River valley whose record is available was undertaken at Chinook in July, 1890. The well was drilled to a depth of 960 feet[2] by the town of Chinook in an attempt to develop artesian water. At the bottom of the bore, in a 6-foot stratum of blue clay, gas and petroleum were reported. Water was encountered at several horizons, of which the lowest, at 540 and 620 feet, yielded salt water. The log of this well is as follows:

*Log of well at Chinook, Mont.*

[Elevation, 2,404 feet.]

| Probable formation. | Driller's description of the rock. | Contents. | Thickness. | Depth. |
|---|---|---|---|---|
| | | | *Feet.* | *Feet.* |
| Glacial drift. | Loam and sand | Water | 112 | 112 |
| | Stone bowlders | | 12 | 124 |
| Claggett shale or Colorado shale (?). | Stiff clay | | 96 | 220 |
| | Sandstone | Water | 2 | 222 |
| | Blue clay | | 318 | 540 |
| | Sandstone | Salt water | 1½ | 541½ |
| | Blue clay | | 78½ | 620 |
| | Blue clay, interspersed with thin strata of lime and sandstone, soft mud. | Salt water | 330 | 950 |
| | Blue clay | Gas and petroleum. | 6 | 956 |

[1] Unpublished data.

[2] Nettleton, E. S., Final report on artesian and underflow investigation to the Secretary of Agriculture: 52d Cong., 1st sess., S. Ex. Doc. 41, pt. 2, pp. 72–73, 1892.

#### T. 33 N., R. 20 E.

On Coal Creek, in the west half of T. 33 N., R. 20 E., there is a fault whose trace makes a curved outline that can be followed, except for several minor interruptions by drift and alluvium, for about 3 miles across secs. 3, 10, and 14. According to Pepperberg,[1] the Bearpaw shale is present over most of the northern part of this township, but the Judith River formation, the lowest exposed, is brought to the surface along the southwest side of the fault. The observed dips in these beds, which are tilted to the southwest, range from 3° to 20°. The exposures are poor, and the distance to which the tilting of the strata extends southwestward was not determined, but it is probably as much as three-fourths of a mile.

## AREA OF TILTED AND FOLDED ROCKS SOUTH OF THE BEARPAW MOUNTAINS.

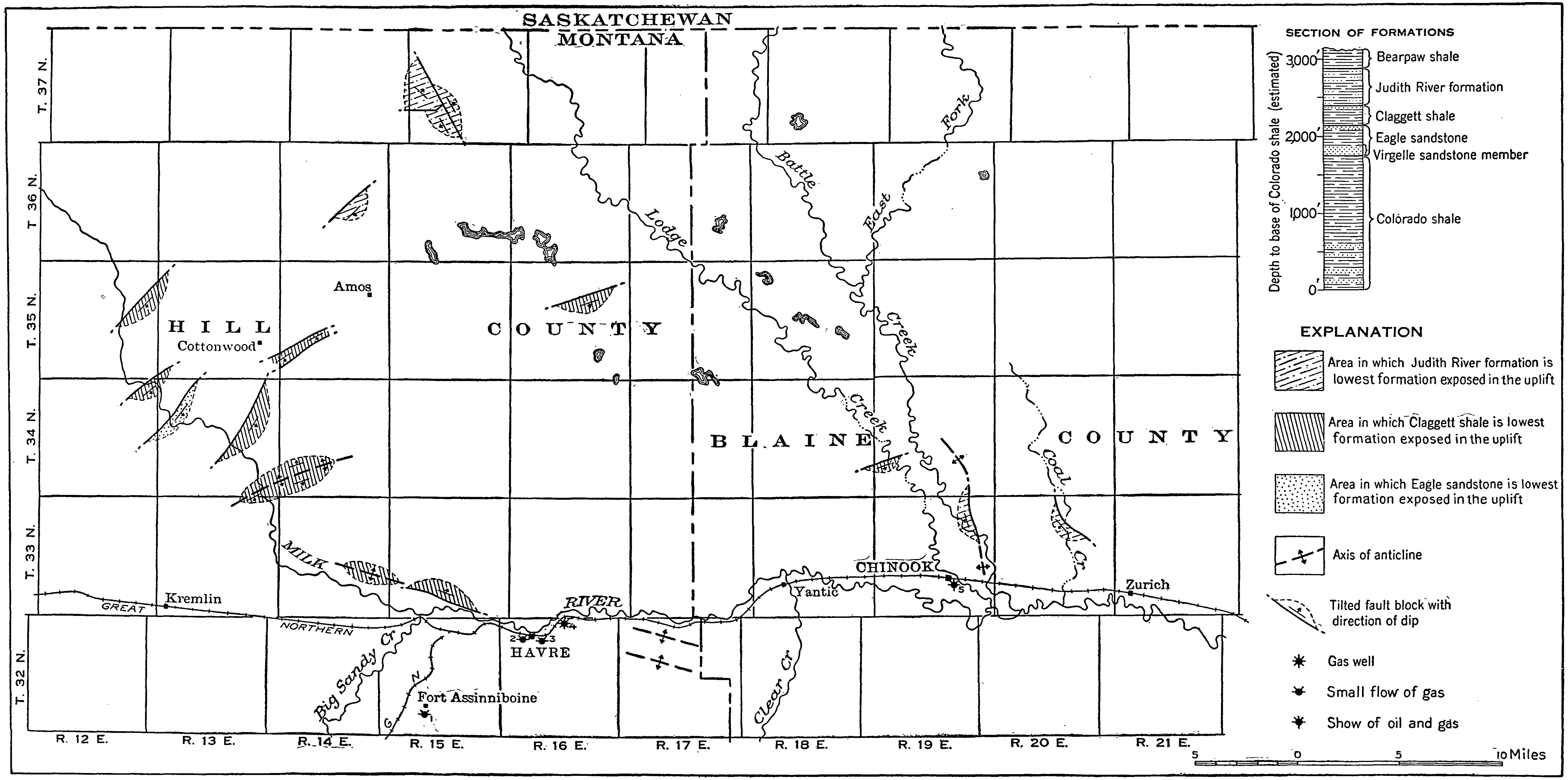
### GENERAL FEATURES.

In the vicinity of Missouri River south of the Bearpaw Mountains there are many areas of tilted and folded rocks similar to those near Havre, already described. On Plate VII the largest and least disturbed of these areas of folded and faulted rocks, comprising 18 separate structural features, each of which may be of importance as a reservoir of oil and gas, are outlined. A considerable portion of the area lying north of Missouri River has not been examined geologically, but there are doubtless similar structural features in these unsurveyed townships. Escapes of gas or seeps of oil have not been recorded in any part of the region along Missouri River, nor are the records of any deep borings available.

### FAULTED AREAS IN THE VICINITY OF VIRGELLE.

In T. 26 N., Rs. 11 to 13 E., in the vicinity of Virgelle, there are four areas of tilted rocks in which the Colorado shale is the lowest formation exposed. The westernmost of these tilted blocks is produced by a fault that crosses secs. 16, 17, and 18, T. 26 N., R. 11 E., extending from the west side of Missouri River along the coulee that enters the river near the center of sec. 16. This fault, according to E. R. Lloyd,[1] trends N. 65° W., and is best exposed along the sides of the coulee in secs. 17 and 18. The Colorado shale is exposed southwest of the fault, where it dips to the southwest at low angles for half a mile to a mile beyond the fault line. On the fault line the lower shales of the Colorado have been carried upward against the Virgelle sandstone and the uppermost beds of the Colorado. The beds on the northeast side of the fault lie for the most part nearly

[1] Unpublished data.




SKETCH MAP SHOWING TILTED AND FOLDED STRUCTURES NORTH OF THE BEARPAW MOUNTAINS, MONT.

horizontal. A second fault, nearly parallel with this one, and the largest of those present in the vicinity of Virgelle, extends from a point near the center of sec. 20, T. 26 N., R. 12 E., northwestward to a point near the south quarter corner of sec. 4, T. 26 N., R. 11 E., a distance of about 6 miles. This fault is well exposed in sec. 24 of the latter township, on the south bank of the Missouri. Here beds of the Colorado shale that dip as much as 43° abut against nearly horizontal beds of the Colorado shale, but the inclined beds flatten to nearly horizontal within about three-fourths of a mile. To the northwest the trend of this fault follows Missouri River very closely, but the fault is covered by the alluvium along that stream as far as the W. ½ sec. 10. From sec. 10 to its northeastern extremity the fault is again well exposed and has a trend identical with that noted in sec. 24. A tilted block on the southwest, composed of Colorado shale, abuts against nearly horizontal Virgelle sandstone and the upper beds of the Colorado shale on the northeast. This fault can be traced for about 2 miles, into the township on the east, to a point where it is concealed under the cover of glacial drift. The trend changes to nearly east, as shown by the exposures near the center of sec. 20, T. 26 N., R. 12 E.

In the north half of T. 26 N., R. 12 E., about 4 miles northwest of Virgelle, tilted rocks lie on the west side of a fault trending N. 40° E., which crosses Missouri River in the W. ½ sec. 3 and extends northeastward beyond the river for a short distance to a point where it is concealed by glacial drift. The dips near this fault are comparatively steep, but they flatten rapidly, and within a mile of the fault plane the beds lie horizontal.

The fourth area of tilted rock in the vicinity of Virgelle occupies a part of the west half of T. 26 N., R. 13 E., near the lower end of Lone Tree Coulee. The fault, which has uptilted the beds in this locality, trends nearly west across secs. 17 and 18 of this township and is cut at several points by dikes of igneous rock. On the north side of the fault the beds are tilted northward at angles ranging from 23° to 60°, the steeper dips being near the fault, and the area of tilted rocks extends about a mile from the fault line. The Colorado shale, the lowest formation exposed, is overlain by the Eagle sandstone and Claggett shale in normal succession. On the south side of the fault the beds lie nearly horizontal, except in the S. ½ sec. 17, where exposures in the Claggett shale on Lone Tree Coulee show a small anticline with dips of 3° on the west limb and 4° on the east and an axial trend approximately due north. This anticlinal axis probably meets the fault mentioned above near the center of sec. 17. Its southward extent is not known because of the prevailing cover of glacial drift.

### FAULTED AREAS ALONG MISSOURI RIVER BETWEEN EAGLE CREEK AND ARROW RIVER.

In the west half of T. 25 N., R. 13 E., and in the township adjoining on the south, there are two nearly parallel faults trending about N. 30° W. The northern fault can be traced continuously, except for several interruptions caused by the cover of glacial drift, from sec. 7 to the west bank of the Missouri in sec. 28. The tilted beds, which occupy an area extending about three-fourths of a mile southeastward from the fault line, show dips that for the whole area may average about 15°. The Colorado shale is the lowest geologic formation exposed and is overlain in normal succession to the southwest by the Eagle sandstone and the Claggett formation. The second of the two faults in this township crosses the NE. ¼ sec. 31 in a direction about N. 50° W. As in the faulted rocks lying immediately to the north, the Colorado shale is the lowest formation exposed in the tilted block southwest of this fault. The fault reaches the west bank of the Missouri in the NE. ¼ sec. 4, T. 24 N., R. 13 E., where it finally disappears under the alluvium on the sides of the river. Its extent southeastward along the opposite side of the river is not known, that area not having been examined, but the trend of the fault is so closely in alignment with that of the extensive fault crossing the west half of T. 23 N., R. 14 E., that they are probably parts of a single fault.

In the west half of T. 25 N., R. 14 E., there is an area of strata tilted to the northeast along a fault mapped by Bowen,[1] trending about N. 50° W. These upturned rocks occur in a large area in which the Claggett shale is the principal formation. The Eagle sandstone, the lowest formation exposed, has been carried upward and lodged against the Claggett shale lying southwest of the fault. This fault is in many places concealed by the usual cover of glacial drift, but the best exposures are on Spring Creek in secs. 19 and 29. Where this fault crosses Eagle Creek, near the southwest corner of sec. 18, it turns to a direction N. 20° W. The area occupied by the tilted strata, so far as the exposures indicate, includes about 4 square miles.

In the west half of T. 23 N., R. 14 E., and the townships adjacent on the northwest, west, and south, there is a fault over 12 miles long. In places this fault produces an anticline, as the dips are in opposite directions on the two sides of the fault line. Most of the tilted beds, however, lie on the southwest side of the fault. The rocks affected by this long and somewhat irregular fault show at a number of points where it crosses the watercourses. The northwest end of the fault is best exposed where it crosses Missouri River, in the

[1] U. S. Geol. Survey Bull. 541, pl. 21, 1914.

S. ½ sec. 25, T. 24 N., R. 13 E. Here an area of tilted Colorado shale overlain by the Eagle and Claggett formations is exposed southwest of the fault, which trends S. 30° E. It next appears, with approximately the same trend, along the watercourses in the W. ½ sec. 1, T. 23 N., R. 13 E., where the Colorado shale dips both to the southeast and the southwest from the fault line. From this locality the beds are covered by glacial drift as far as the crossing of the next coulee, in the W. ½ sec. 7, T. 23 N., R. 14 E. In the coulee at this point the Colorado shale and the entire succession of formations above it are again well exposed. Farther southeast the fault, trending about S. 20° E., is still readily traceable by means of the numerous exposures in the drainage ways to the south side of T. 23 N., R. 14 E., crossing Flat Creek Pass in the N. ½ sec. 33. It continues southwestward as far as sec. 15, T. 22 N., R. 14 E., crossing the main valley of Flat Creek in sec. 10. At this point there is a considerable area of tilted rocks on the southwest side of the fault, and the average dip in the more steeply tilted beds is about 15°, but this gradually flattens and the beds are nearly horizontal about three-fourths of a mile to the southwest. At its southeast extremity, in sec. 15, this fault becomes very irregular, being lost in an area of much broken and disturbed rocks in secs. 13, 14, 23, and 24.

Near the west line of T. 23 N., R. 14 E., there is a well-developed fault that has a slightly curving trend but extends in a general northerly direction. In secs. 13 and 24 this fault appears along the west side of Missouri River, where the Colorado shale abuts against the Virgelle sandstone and the upper members of the Eagle formation. The tilted strata, in which some petroleum or gas may have accumulated, lie east of this fault line, occupying a considerable part of the alluvium-covered areas along Missouri River. To the south the fault is much concealed by glacial drift, but in the N. ½ sec. 36 it is again well exposed, trending in a northeasterly direction across the valley of Flat Creek. The tilted strata here also lie on the east side of the fault, the Colorado shale and Eagle sandstone being carried against the Eagle sandstone and Claggett shale on the west side. The dips are between 15° and 20° in the steeper beds, but they flatten to approximately horizontal a mile or so east of the fault line.

### TILTED ROCKS OF LOWER PART OF JUDITH RIVER.

In the north half of T. 22 N., R. 16 E., there is an extensive fault cutting across the township with a trend about N. 65° W. Southwest of this fault there is a tilted block which is the largest of those in the region along the Missouri River described in this report. The tilted beds are best exposed along Judith River is secs. 10, 11, 14, and 15. At this locality the Colorado shale is the lowest formation exposed and is succeeded to the southwest by the Eagle and Claggett formations, and part of the Judith River, in normal succession. The tilted beds extend southwestward from the fault line for a distance of about 2 miles. In the S. ½ sec. 15 they are cut by a small fault trending in a northeasterly direction, which probably meets the main fault near the west line of sec. 12. Along Missouri River near the north line of secs. 5 and 6, the main fault crosses Missouri River, bringing up the Colorado shale and the overlying formations. At this locality the area of tilted strata extends to the southwest about 1½ miles from the fault line.

From sec. 6, T. 21 N., R. 16 E., a fault whose trace makes a slightly curved line extends eastward for a distance of over 12 miles into the townships adjoining on the east. On the north side of the fault there are tilted beds dipping about 8° N. The best exposures of these tilted rocks are along Judith River in the S. ½ sec. 2, T. 21 N., R. 16 E. Here the upper part of the Colorado shale, overlain by the Eagle sandstone and the Claggett formation, are brought against shale in the lower part of the Colorado. In T. 21 N., R. 17 E., this fault extends in a slightly curved line southeastward through secs. 7, 8, and 16. In the N. ½ sec. 22 it is broken by several cross faults, but its extension continues eastward, makes a sharp curve toward the south, and extends northeastward about 1 mile into T. 21 N., R. 18 E., nearly to the northeast corner of sec. 19. The beds on the north side of this fault dip northward at an average rate of about 7°.

### TILTED ROCKS ON DOG CREEK.

At the mouth of Dog Creek, about 2 miles east of Judith post office, there is a thrust fault extending in a northerly direction, which crosses Dog Creek in the NE. ¼ sec. 6, T. 22 N., R. 17 E. West of this fault, which extends to and probably crosses Missouri River, there is an area of about 2 square miles of tilted beds which dip to the west. In this area the Colorado shale, overlain by the full thickness of the Eagle and a part of the Claggett shale, is carried upward against the lower part of the Claggett formation. The dips near the fault plane vary between 6° and 12°. About half a mile west of the fault they become steeper, averaging between 20° and 30°, and still farther west the beds flatten and approach a horizontal attitude within 1 mile of the trace of the fault.

In the north half of T. 21 N., R. 18 E., is a fault that extends across the township with a trend about N. 60° W. and brings a considerable block of tilted rocks, in which the Claggett shale is the lowest formation exposed, against nearly horizontal Judith River beds. This fault crosses very near the northeast corner of sec. 6 and extends about 4 miles northwestward from this point, into T. 22 N.,

R. 17 E. On the southeast it holds this trend to and beyond Dog Creek, in sec. 10, and is well exposed in the badlands along the creek. The tilted strata lie southwest of this fault and have an average dip of about 15°. Nearly horizontal beds are present within about 1½ miles southwest of the fault line.

A fault that is probably a continuation of the fault last described extends due east from a point near the northwest corner of sec. 18, T. 21 N., R. 19 E., for a distance of nearly 4 miles. On the south side of this fault there is a considerable area of tilted and slightly folded strata, in which the upper half of the Judith River is the lowest formation exposed and is overlain normally by the Bearpaw shale to the south. These tilted beds are carried upward against nearly horizontal Bearpaw shale on the north side of the fault. A well-defined anticline in the tilted area on the south side of the fault was noted in secs. 17 and 18. Its axis passes through the center of sec. 18, with a trend about N. 75° E., and extends into the N. ½ sec. 17, where the trend changes to nearly east. On the north limb of the anticline the rocks dip between 7° and 35°, and the steeper dips occur close to the fault line. On the south limb the dips vary between 6° and 12°. East of this fold, in an area of tilted strata lying south of the fault, the ground is much broken by short faults trending nearly at right angles to the principal break. The strata in this area are irregularly folded or bent but generally lie at low angles, the dips rarely exceeding 10°. In the S. ½ sec. 17 there is a minor fault which can be traced for about a mile in a direction nearly due east and which offsets the coal zone in the upper part of the Judith River formation.

In the northeastern part of T. 21 N., R. 19 E., there are two faults lying nearly at right angles to each other, both of which have brought up the Judith River beds in an area in which the Bearpaw shale is the predominating formation. The longer of these faults crosses secs. 1, 2, and 12 in a direction about N. 60° W. On its northeast side the Judith River beds, overlain by the Bearpaw shale in normal succession, are tilted at angles varying between 40° and 50° within a quarter of a mile of the fault, but farther northeast the dip of the beds is less, and within 1 mile of the trace of the fault they are nearly horizontal. Southwest of the fault the Bearpaw shale, lying practically horizontal, occupies a considerable area. The other fault in the northeastern part of the township crosses sec. 13 in a direction about N. 50° E. and joins the fault just described in the SW. ¼ sec. 7, T. 21 N., R. 20 E. On the southeast side of this fault there is an area of titled upper Judith River and lower Bearpaw beds, which dip at angles ranging from 20° adjacent to the fault to 10° within 2,000 feet. This fault crosses Cutbank Creek about 1,500 feet north of the center of sec. 13 and is there well exposed, but to the southeast it can not be traced more than a few hundred yards and probably dies out before reaching the west line of sec. 13. In the SE. ¼ sec. 13 the strata in the tilted block are folded into a shallow syncline, the south limb of which is near the south line of the section. The axis of this syncline trends northeast, nearly parallel to the fault.

## AREA OF COLORADO SHALE EXTENDING FROM A POINT NEAR GREAT FALLS TO THE SWEETGRASS HILLS.

### GENERAL FEATURES.

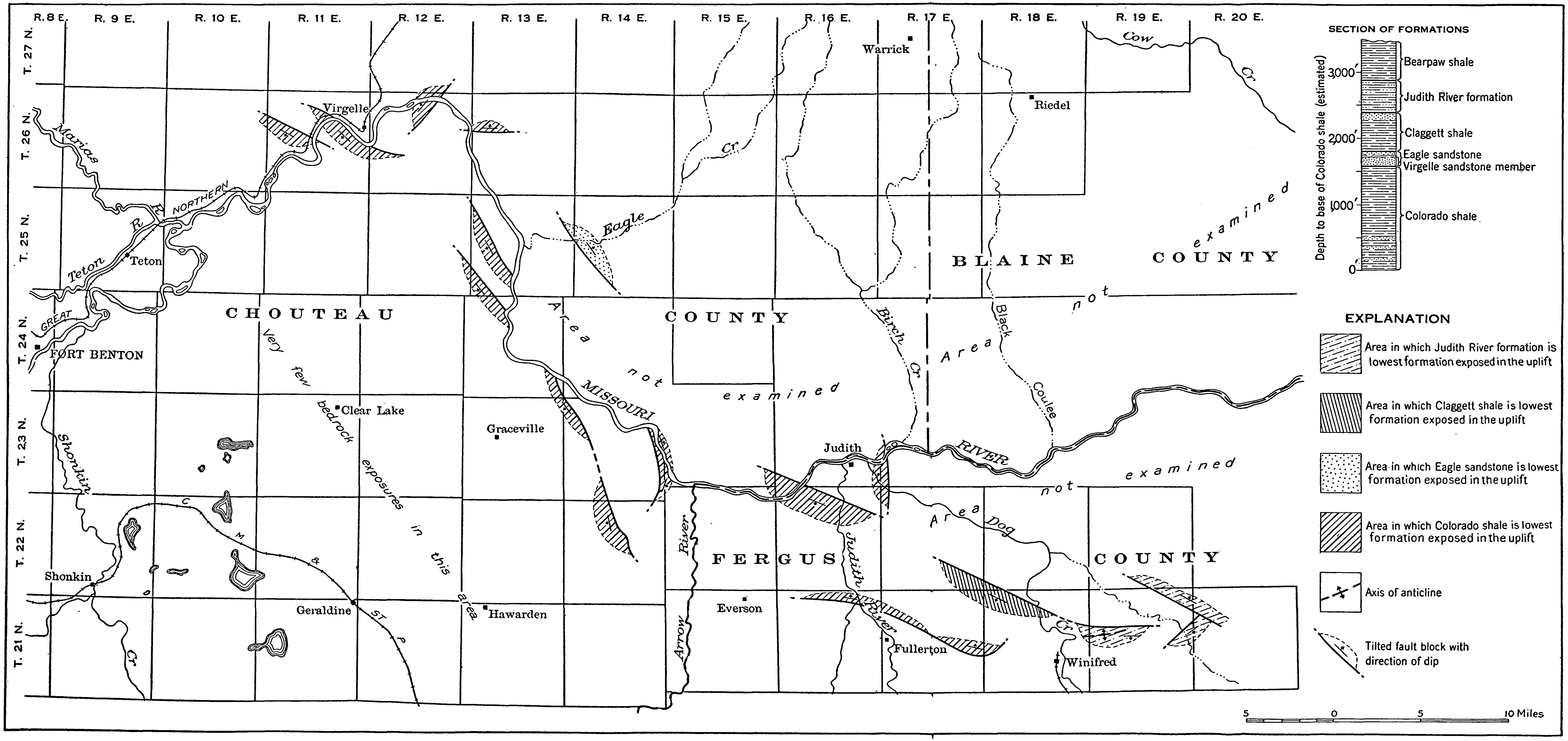
The results of six deep borings (see locations on the map, Pl. IV) are available for the area extending across the outcrop of the Colorado shale from Great Falls to the Sweetgrass Hills. None of these borings were successful, although five report showings of gas or oil, or both. These wells, located regardless of the structure, seem to show that a fair percentage of success can not be obtained by random drilling in the large area occupied by the Sweetgrass arch. Two of the wells are near the center of the arch, and seem to prove that this broad uplift as a whole has not caused the accumulation of oil or gas along its crest. However, if local folds are present within the broader uplift, they may have served as reservoirs for oil or gas.

The Bow Island gas field,[1] 60 miles north of the Canadian boundary, is near the northwestward extension of the Sweetgrass arch, its exact position probably being a little to the east of the crest of the arch. The details of the structure in the vicinity of the Bow Island field have never been published, but it is not improbable that the field is located on a local fold within the arch. The first well in this field was drilled about 1908. By 1914 sixteen wells had been completed, spaced about 1 mile apart over an area of about 15 square miles. The total production from these wells in 1914 was 75,000,000 cubic feet a day, and the gas was distributed from a 16-inch pipe line for 160 miles, supplying Lethbridge, Calgary, and intermediate towns.

### DRILLING NEAR THE SWEETGRASS HILLS.

Several wells have been drilled within the last few years in the vicinity of the West Butte of the Sweetgrass Hills. These wells are about 3 miles northeast of the oil seep in the Colorado shale, described on page —. They were put down in a flat plain, much covered by glacial drift, and are not known to have been located with reference to local structure of any description. The general dip in the vicinity, as shown by a few scattered outcrops of the Virgelle sandstone, is northward at a low angle. The deepest of these wells was

[1] Clapp, F. G., and others, op. cit., pp. 276–277.




SKETCH MAP SHOWING TILTED AND FOLDED STRUCTURES SOUTH OF THE BEARPAW MOUNTAINS, MONT.

drilled to a depth of 2,670 feet, nearly to the base of the Kootenai, and obtained small flows of gas at two horizons. According to W. A. English, of the United States Geological Survey, the seep on West Butte probably comes from the 50-foot member of the sandstone that is reported to contain water, whose base in this well is at a depth of 1,640 feet. A log of the well, furnished by E. C. Galbraith, of the General Land Office, is as follows:

*Log of well in sec. 4, T. 37 N., R. 2 E., a few yards south of the international boundary.*

[Elevation, 3,675 feet (barometric).]

| Probable formation. | Driller's description of the rock. | Contents. | Thickness. | Depth. |
|---|---|---|---|---|
| | | | *Feet.* | *Feet.* |
| Glacial drift. | Glacial drift | | 65 | 65 |
| Virgelle sandstone. | Light-colored sandstone | | 245 | 310 |
| Colorado shale. | Black and dark-colored shale | Water | 970 | 1,280 |
| | Dark-colored shales | | 310 | 1,590 |
| | Gray sandstones | Water | 50 | 1,640 |
| | Black sandy shale | | 20 | 1,665 |
| | Gray sandstone | Gas | 70 | 1,735 |
| | Dark sandy shale | | 25 | 1,760 |
| | Black sandy shale | | 45 | 1,805 |
| | Gray sand | Salt water | 5 | 1,810 |
| | Black sandy shale | | 10 | 1,820 |
| | Conglomerate | | 20 | 1,840 |
| | Gray sandstone | | 40 | 1,880 |
| | Black shales | | 180 | 2,060 |
| Kootenai formation. | Bluish shales | | 70 | 2,130 |
| | Red shale | | 68 | 2,198 |
| | Gray shale | | 132 | 2,330 |
| | Black shale | | 20 | 2,350 |
| | Brown shale | | 150 | 2,500 |
| | Sandstone strata | Gas and water. | 170 | 2,670 |

A second hole was put down about a quarter of a mile southeast of the well just described and passed through the same strata. According to C. H. Jennings, who superintended the drilling of this well, shows of oil were encountered at about 960 and 1,660 feet, and small flows of gas at 1,300, 1,535, and 1,810 feet.

### DRILLING NEAR KEVIN, TOOLE COUNTY.

A boring in search of oil was made about 8 miles southwest of Kevin, Toole County, on the James Miller ranch. It went to a depth of 1,755 feet, passing through part of the Colorado shale and all of the Kootenai formation, and probably entering the Jurassic. This well is in the midst of a large area of horizontal rocks, as shown by exposures in the vicinity and also by the lay of the Virgelle sandstone in the prominent escarpment to the west and north. This well was therefore drilled in an unfavorable structure position. Small flows of gas, however, were encountered at three horizons. The log of the well, furnished by H. C. Price, of Great Falls, Mont., is as follows:

*Log of well at the James Miller ranch, in the NW. ¼ sec. 25, T. 34 N., R. 4 W.*

[Elevation, 3,360 feet.]

| Probable formation. | Driller's description of the rock. | Contents. | Thickness. | Depth. |
|---|---|---|---|---|
| | | | *Feet.* | *Feet.* |
| Glacial drift. | Loam and gravel | | 40 | 40 |
| Colorado shale. | Black shale | | 120 | 160 |
| | Lime shell | | 2 | 162 |
| | Black shale | | 153 | 315 |
| | Sand | Gas and water. | 5 | 320 |
| | Gray-black shale | | 100 | 420 |
| | Sand | Gas | 10 | 430 |
| | Sandy shale | | 30 | 460 |
| | Hard dark shale | | 10 | 470 |
| | Black shale | | 180 | 650 |
| | Gray sandy shale | | 70 | 720 |
| | Black sand | | 10 | 730 |
| | Sandy shale | | 40 | 770 |
| | Light shale | | 80 | 850 |
| | Sandy shale | | 100 | 950 |
| | Black shale | | 90 | 1,045 |
| | Gray sand | | 20 | 1,065 |
| | Sand | Gas, best flow. | 5 | 1,070 |
| | Black shale | | 30 | 1,100 |
| Kootenai formation. | Light shale | | 15 | 1,115 |
| | Red rock | | 35 | 1,150 |
| | Light shale | | 45 | 1,195 |
| | Hard shell | | 5 | 1,200 |
| | Hard sand | | 25 | 1,225 |
| | Shell | | 5 | 1,230 |
| | Sand | | 70 | 1,300 |
| | Light shale | | 60 | 1,360 |
| | Sand | | 30 | 1,390 |
| | Hard shell | | 10 | 1,400 |
| | Light shale | | 60 | 1,460 |
| | Hard sand | | 40 | 1,500 |
| | Hard shell | | 10 | 1,510 |
| | Hard sand | | 40 | 1,550 |
| | Yellow shale | | 50 | 1,600 |
| | Gritty sand | | 50 | 1,650 |
| | Hard shell | | 5 | 1,655 |
| | Black shale | | 20 | 1,675 |
| | Hard shell | | 5 | 1,680 |
| Jurassic. | Lime rock | | 50 | 1,730 |
| | Black shale | | 25 | 1,755 |

## DEEP BORINGS IN CHOUTEAU COUNTY.

About 10 miles southeast of Collins a prospect hole for oil and gas, known as the Banatyne well, was driven to a depth of 1,500 feet and obtained a small flow of gas at one horizon. The log for 1,240 feet of this bore, passing through the Colorado shale and into the Kootenai formation, is given below. This well is near the crest of the Sweetgrass arch, if that structure extends this far south of Teton River. Nothing is known of the local structure, and it is probable that the rocks are much concealed by glacial drift.

*Log of Banatyne well, 10 miles southeast of Collins.*

| Probable formation. | Driller's description of the rock. | Contents. | Thickness. | Depth. |
|---|---|---|---|---|
| | | | *Feet.* | *Feet.* |
| Glacial drift. | Yellow clay | | 74 | 74 |
| Colorado shale. | Shale | | 206 | 280 |
| | Sand | Salt water and gas. | 5 | 285 |
| | Sandy shale | | 73 | 358 |
| | Black sand | | 7 | 365 |
| | Shale | | 135 | 500 |
| | Sand | Salt water | 9 | 509 |
| | Sand and gritty shale | | 96 | 605 |
| | Soft white conglomerate | | 175 | 780 |
| | Hard conglomerate | | 90 | 870 |
| | Fine blue sand | | 10 | 880 |
| | Hard blue shale | | 20 | 900 |
| | Hard shale in thin layers | | 50 | 950 |
| | Dark-blue shale | | 25 | 975 |
| | Black shale | | 65 | 1,040 |
| | Hard bluish sandstone | | 90 | 1,130 |
| | Black shale | | 30 | 1,160 |
| Kootenai formation. | Red limestone | | 40 | 1,200 |
| | Red sandstone | | 40 | 1,240 |

Small flows of gas are also reported from two deep wells in the northeastern part of Chouteau County. One of these, 15 miles northwest of Fort Benton, obtained gas in the Colorado shale at a depth of 300 feet. The other gas well is 10 miles north of Virgelle and was drilled to a depth of 800 feet. Details of the structure in the vicinity of these borings are not known.