DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 641—J

ANTICLINES IN THE BLACKFEET INDIAN RESERVATION, MONTANA

BY

EUGENE STEBINGER

Contributions to economic geology, 1916, Part II
(Pages 281–305)

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ANTICLINES IN THE BLACKFEET INDIAN RESERVATION, MONTANA.

By EUGENE STEBINGER.

INTRODUCTION.

The discovery of small quantities of oil and gas in several anticlines along the eastern front of the Rocky Mountains west of Calgary, Alberta, has aroused interest in the possible oil and gas resources of the formations in this general region, especially of the southern extensions of the folded and faulted beds that were productive in Canada. This interest has led to drilling for oil and gas at places within a few miles of the northern boundary of the Blackfeet Indian Reservation, on the west edge of the plains. A similar interest, in 1900–1902, led to drilling in the Cretaceous rocks at several places a few miles west of the west boundary of the reservation, close to the mountain front.

A report on the possibilities of finding oil and gas in a large area in north-central Montana east of the Blackfeet Indian Reservation has recently been issued,[1] and the Blackfeet Reservation itself, shown in figure 35, has now become the center of similar inquiries. The purpose of this paper is to give a brief account of the geologic formations in the reservation and of their lay or geologic structure, and a more detailed description of the anticlines and of the formations that appear to contain oil or gas in southern Alberta and northern Montana. An intelligent search for oil or gas in the reservation must be based on a knowledge of these geologic facts. Reports that describe coal[2] and low-grade iron ore[3] and the general features of the geology of the reservation have already been published, and it is now considered desirable to summarize the facts bearing on the oil and gas prospects.

The general conditions in this region suggest that drilling in the Blackfeet Indian Reservation would have about the same chance of

[1] Stebinger, Eugene, Possibilities of oil and gas in north-central Montana: U. S. Geol. Survey Bull. 641, pp. 49–91, 1916 (Bull. 641–C).

[2] Stebinger, Eugene, Geology and coal resources of northern Teton County, Mont.: U. S. Geol. Survey Bull. 621, pp. 117–156, 1916.

[3] Stebinger, Eugence, Titaniferous magnetite beds on the Blackfeet Indian Reservation, Mont.: U. S. Geol. Survey Bull. 540, pp. 338–342, 1913.

success as in the adjacent region in southern Alberta, extending from the international boundary northward to Calgary—a region in which drilling by over 40 companies during the last three years has been slightly successful. The similarity of the geologic features in these two regions may be summarized as follows:

1. The Colorado shale and the Kootenai formation, which yield most of the oil and gas so far found in southern Alberta and northern Montana, underlie the greater part of both regions.

2. The belt of folded and faulted strata along the front of the Rocky Mountains is continuous from one to the other of these regions, and in this belt the productive anticlines near Calgary and the folds in the Blackfeet Indian Reservation are both in places somewhat compressed and in others are associated with faults.

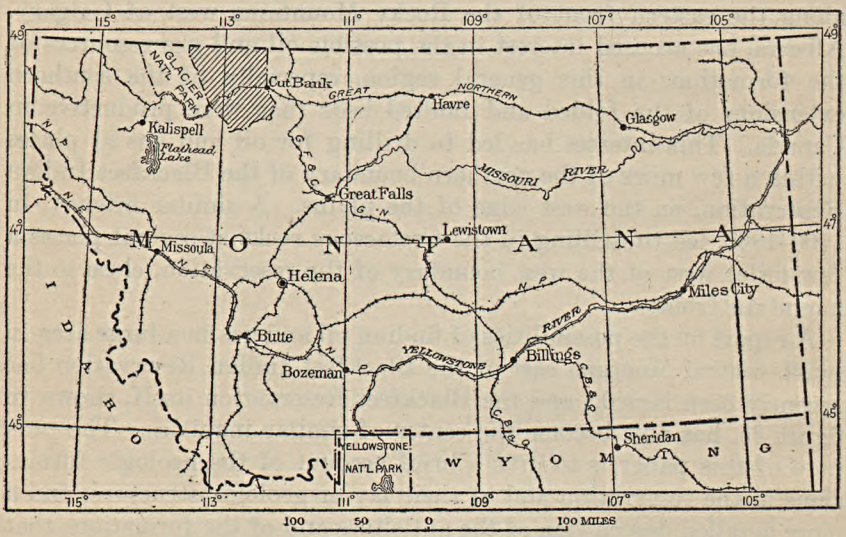


FIGURE 35.—Index map showing location of Blackfeet Reservation, Mont.

3. In the area east of the disturbed belt in both regions great thicknesses of nearly horizontal strata that have no strongly marked structural features, such as anticlines and synclines, overlie the possible productive formations.

LOCATION AND SURFACE FEATURES.

The location and area of the Blackfeet Indian Reservation are shown on the index map (fig. 35). The reservation lies wholly in Teton County, occupying nearly all its northern half, and contains about 2,425 square miles. The international boundary between Alberta and Montana forms its northern limit. The country is a gently sloping, nearly treeless plains region, which is everywhere easily accessible, presenting few obstacles to the construction of

railways or roads. The plains slope gently upward to the west to the base of the mountains, which rise abruptly without marked foothills. The average elevation of the plains districts ranges from 3,800 feet on the east edge of the reservation to about 5,000 feet near the base of the mountains. The mountains rise with wall-like abruptness from 4,000 to 5,000 feet above the general level of the plains.

The main line of the Great Northern Railway crosses the reservation from east to west. Cut Bank, Browning, and Glacier Park are the principal stations. Browning is the seat of the Indian agency for the reservation. Settlement on the Indian reservation has so far been limited almost entirely to its west half, where Indian ranches along the principal streams are devoted to the raising of horses and cattle. The extensive interstream stretches remain an open range, without fences or other improvements.

In the western part of the reservation, near the mountains, there are high, level plains, which comprise numerous isolated tracts, from a fraction of a square mile to 40 square miles or more in extent, and which are doubtless remnants of an older, almost perfectly formed plain. They are covered with a veneer of gravel, made up of kinds of rock found in the adjacent mountains, and have remarkably smooth surfaces and slope very regularly to the northeast, away from the mountains. Milk River Ridge and St. Mary Ridge are typical of the larger of these areas. Below these higher plains there are much more extensive lower plains, which, where best developed, also carry a veneer of gravel and slope evenly eastward, away from the mountains, to merge into the Great Plains. The best examples of the lower plains are Carlow Flat, an extensive and very evenly graded surface crossed by the Great Northern Railway west of Cut Bank, and the equally well developed plain between Cut Bank and Greasewood creeks, a few miles northwest of Browning.

FIELD WORK.

The field work on which this report is based was done by the writer alone, during a part of each of the field seasons of 1911, 1912, and 1913. The main object of the work was to classify the lands in the reservation with respect to their mineral value, and it was therefore necessary to make a regional examination of the geology and a close inspection of all possibly mineral-bearing tracts.

Good topographic maps were available for all the area examined and were used in the field as base maps on which to plot the geologic data. The land corners in all parts of the region are well marked and easily found. Iron pipes marking the boundaries of the lands allotted to the Indians have been placed at many of the corners.

GEOLOGY.

STRATIGRAPHY.

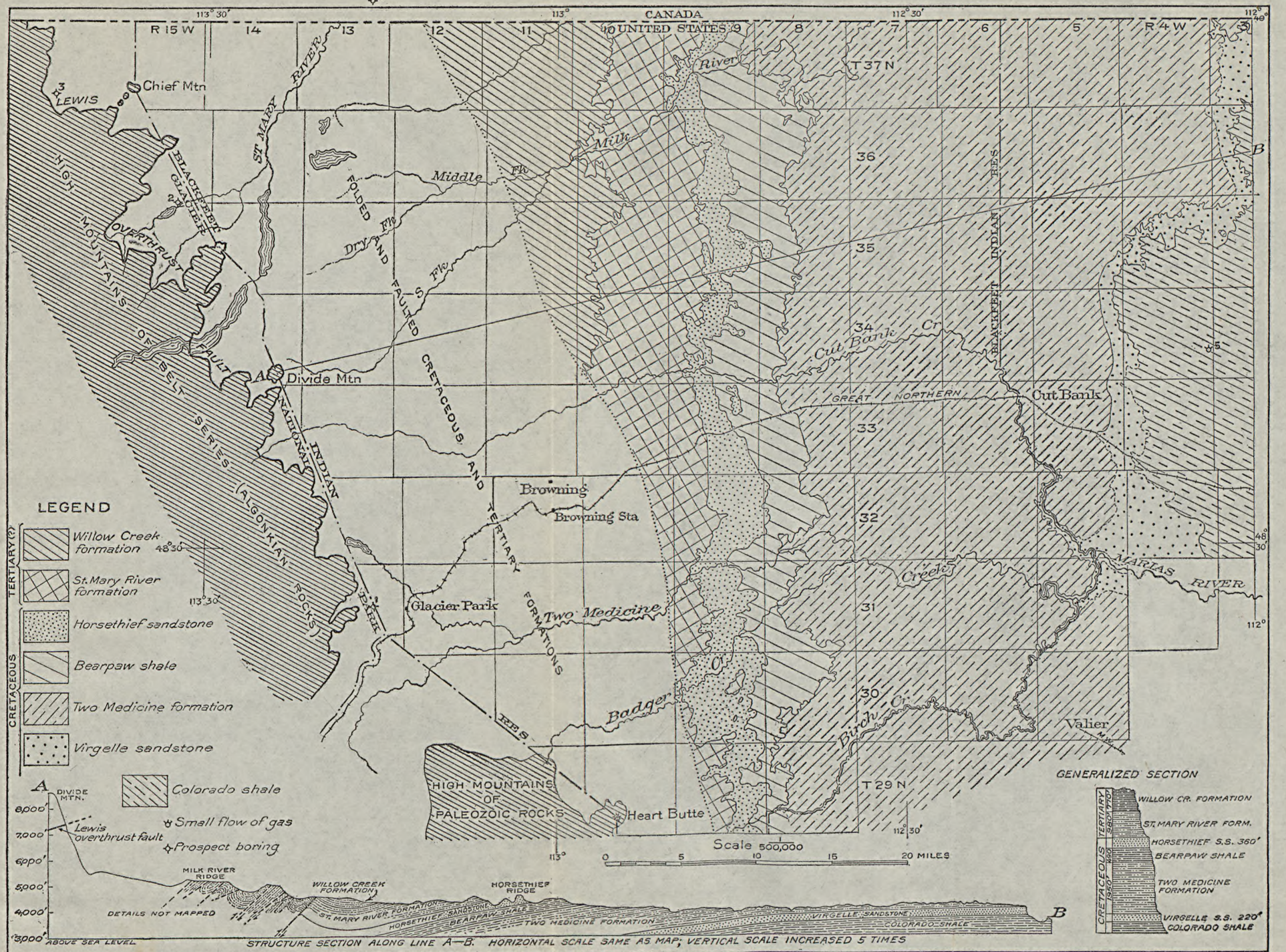
GENERAL FEATURES.

The geologic formations east of the mountains in the Blackfeet Indian Reservation are all sedimentary in origin and range in age from Lower Cretaceous to probably basal Tertiary. (See Pl. XXIV.) All the beds are apparently conformable and afford no evidence of break or disturbance between any of them or any indication of an interval of erosion. The sequence of the formations in the Upper Cretaceous part of the section is different from that so far described for any other locality in Montana, owing to the fact that in this region the marine invasion which is represented by the Claggett shale did not extend so far west as the present position of the Rocky Mountain front between latitudes 48° and 49° N. An account of these relations has already been published.[1]

Two of the formations, the Colorado and Bearpaw shales, are unquestionably of marine origin and were laid down in separate epochs, during which a comparatively shallow sea covered the entire region. The remaining formations are mainly of continental origin—that is, they are irregularly bedded rocks that were for the most part deposited by streams and winds on land areas that were only slightly above sea level.

The succession of formations and the principal features of the rocks are outlined in the table on page 285.

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



GEOLOGIC SKETCH MAP OF BLACKFEET INDIAN RESERVATION, MONT., AND VICINITY, SHOWING SECTIONS AND WELLS DRILLED FOR OIL OR GAS.

Formations occurring east of the mountains on the Blackfeet Indian Reservation, Mont.

System.	Series.	Group and formation.	Thickness in feet.	Character of the rocks.
Quaternary.	Recent.	Alluvium.		Deposits of small extent found along flood plains of the larger streams.
	Pleistocene.	Glacial drift.		Bowlder clay, gravel, and lake silt and clay. Contains bowlders and cobbles of granite, gneiss, quartzite, etc., transported from other regions. Deposits are of several stages not distinguished in this report.
Tertiary (?).	Eocene (?).	Willow Creek formation.	720+	Variegated clay and soft sandstone, chiefly maroon to chocolate-brown with subordinate gray, yellow, and greenish-gray beds. Fragments of fossil bones common. Clay in places contains thin lenticular beds of purplish-gray limestone. Forms a red soil over large areas. Top not seen.
		St. Mary River formation (coal bearing).	980	Alternating clay, clay shale, and soft sandstone; sandstone much cross-bedded and ripple marked. Colors gray to greenish gray; a few layers of clay are red. Contains a few thin lenticular limestones, many fragments of dinosaur bones, and fossil shells.
Cretaceous.	Upper Cretaceous.	Montana group. — Horsethief sandstone.	225–375	Gray to greenish-gray sandstone, weathering buff. Thin bedded and somewhat shaly in lower half. In upper half generally massive and concretionary, weathering in castellated forms. In places near the top contains titaniferous magnetite. Has many shell beds, mainly of oysters.
		Montana group. — Bearpaw shale.	490	Dark-gray clay shale with a few limestone concretions. Contains abundant marine shells. Forms subdued, rounded topography.
		Montana group. — Two Medicine formation (coal bearing).	1,950	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. Coal beds near base and at top.
		Montana group. — Virgelle sandstone.	220	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. Contains gas in the Havre field and at Medicine Hat.
		Colorado shale.	1,500±	Bluish-gray shale with a few limestone concretions. Contains an abundance of marine shells. Forms a subdued and rounded topography. Complete undisturbed section not present. May contain oil and gas in areas of favorable structure.
	Lower Cretaceous.	Kootenai formation.	2,000±	Gray sandstone and shale, alternating with maroon clay shale. Some of the sandstone massive. Conglomerate 6 to 50 feet thick near center. Carries a few leaves and fresh-water shells. Complete undisturbed section not found. May contain oil and gas in areas of favorable structure.

FORMATIONS THAT MAY IN PLACES CONTAIN OIL OR GAS.

Kootenai formation.—The Kootenai formation is the oldest formation seen in the plains portion of the Blackfeet Indian Reservation. It is exposed only in the belt of disturbed rocks adjacent to the mountains but underlies all the plains region. In this disturbed belt folding and especially thrust faulting have so greatly deformed the rocks that their exact sequence and thickness can not be determined, but the exposures are good and the general character of the formation is well known. A few miles beyond the west border of the area the Kootenai overlies a dark marine shale carrying Jurassic fossils. This relation, together with the fact that the Kootenai immediately underlies the Colorado shale, gives the formation approximately the stratigraphic position of the Kootenai of the Great Falls region, 150 miles to the southeast, which has in turn been correlated with the Kootenai formation of British Columbia and Alberta by means of the characteristic fossil plant remains, mainly leaves, found at both localities.

The Kootenai is composed essentially of alternating dark greenish-gray, black, and maroon shales and of gray sandstones that are in many places gritty and conglomeratic. A few beds of black carbonaceous shale and some thin streaks of coal are the only indications of coal found in the area, although to the north, in Alberta, and to the south, in the vicinity of Great Falls, the formation contains a large quantity of coal. An irregular bed of conglomerate, which is at some places as much as 50 feet thick, crops out at a horizon believed to be near the middle of the formation. Beds of sandstone, conglomerate, and grit, which must be considered the more likely reservoirs for oil or gas in the Kootenai, are distributed through it, generally in beds that range in thickness from 20 to 70 feet. Limestone in concretions and thin lenticular beds occurs sparingly in the shale.

The thickness of the Kootenai is not determinable at any point along its outcrop in the Blackfeet Indian Reservation because of its frequent duplication by faulting and because neither its base nor its top is anywhere visible. However, its minimum thickness can be determined by examining faulted blocks of the formation in which no duplication appears. Near Badger Creek (sec. 34, T. 30 N., R. 11 W.) 1,200 feet of beds that clearly belong to the Kootenai were measured in a single block of the formation that shows no repetition by faulting. On comparing this thickness with the measurement obtained in a well bored about 15 miles west of the reservation (see well log cited on p. 305), showing about 580 feet of beds that have been assigned to the Kootenai, it is evident that the formation becomes thinner toward the east in this region. At Great

Falls, where the Kootenai is best known in Montana, it is between 400 and 500 feet thick.

No escaping gas or residues or seepages of oil were noted at any point in the Kootenai formation in the area here described. Small quantities of oil and considerable flows of gas are reported from beds in Alberta that are believed to be equivalent to the Kootenai of this region. A small flow of gas was also obtained from sands in this formation in a well in the Sweetgrass district.

Colorado shale.—The next unit in the strata overlying the Kootenai formation in this region is the Colorado shale, a great body of bluish-gray to black shale containing sandstone beds in its lower half. This formation is about 1,600 feet thick in the eastern part of the Blackfeet Indian Reservation and underlies nearly all the area. It is of marine origin—that is, it was laid down on a sea bottom—and contains fossil sea shells in great variety. The rock deposited during this marine submergence continues northward into Canada and southward into Wyoming and beyond.

The Colorado shale seems to be the most probable source of oil and gas in this region. The only surface showings of oil so far found on the plains of northern Montana seep from the lower part of this formation, and pay sands that are either in the formation or are associated with it are found in adjoining areas both north and south of the State. The principal production from the Salt Creek field in northern Wyoming, and of all the fields in the Bighorn Basin comes mainly from the sands in the lower half of this group of rocks. The production of the important gas field at Bow Island, east of Lethbridge, in the province of Alberta, comes from the top of a sand that is supposed to lie immediately under this formation. This sand, however, is probably in the lower part of the Colorado shale. Likewise, as reported by Dowling,[1] a small production of high-grade oil 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.

There are many exposures of the Colorado shale in the western part of the Blackfeet Indian Reservation, especially from Two Medicine Creek southward, in the belt of disturbed rocks, but the beds are invariably much crushed and crumpled. These crumpled beds of bluish-gray to black shale, which contain limestone in concretions and thin irregular beds, can not be measured, because they are at many places repeated by faulting, and therefore no accurate estimate of the thickness of this formation in the western part of the reservation can be made. The most extensive exposures appear along Two Medicine Creek from its junction with the South Fork in sec. 29, T.

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

31 N., R. 11 W., westward for 8 miles, to the vicinity of Glacier Park station. In this stretch continuous exposures show the shale crumpled and repeated by faults in a remarkable manner. The upper beds of the Colorado shale are exposed at the head of Marias River, on the eastern edge of the reservation in sec. 35, T. 32 N., R. 5 W., and from this point extensive exposures of the upper beds of the formation, which lie nearly horizontal, extend for many miles downstream. The log of a well (p. 305) which was drilled through these horizontal rocks near Kevin, about 15 miles east of the Indian reservation, shows 1,060 feet of shale which doubtless belongs to the Colorado. In addition to this thickness, about 580 feet of shale is exposed between the site of this well and the base of the overlying Virgelle sandstone, in the escarpment lying to the west, making about 1,640 feet in all. This is the only available estimate of the thickness of the formation in this region. According to the well record mentioned, three sandstones containing gas and water are reported from the lower part of the Colorado shale. As these sandstones are overlain by great thicknesses of shale they seem to be favorable receptacles for the accumulation and retention of oil and gas, which may have accumulated in them in commercial quantities in places where anticlines have permitted their concentration.

Additional evidence of the presence of petroleum in the lower part of the Colorado shale in this region was obtained by the writer during the summer of 1916 in the course of field work in the area adjoining the Blackfeet Indian Reservation on the south, extending across Teton County and into the northern part of Lewis and Clark County. The disturbed belt adjacent to the mountains in the Blackfeet Indian Reservation (see Pl. XXIV) continues southward across this area and, as in the reservation, affords many exposures of the Colorado shale, for the most part much folded and faulted. The lower part of this shale formation was found to be petroliferous in every extensive exposure for a distance of about 35 miles, extending from Dupuyer Creek to Sun River.

All the "showings" seem to occur at a single horizon in the lower part of the formation and are in the form of impregnations of a soft tarry bitumen along fracture planes in thin beds of impure limestone occupying a zone about 12 feet thick, in bituminous shale. The limestone is in beds as much as 8 inches in thickness. It has been irregularly fractured by the intense deformation in the disturbed belt, and the fractures are wholly or partly filled with calcite. The openings in the calcite veinlets thus formed are generally filled with a black tarry substance of high luster, readily soluble in carbon disulphide, and soft enough to flow when the thicker accumulations are tilted. A thin film of the bitumen is transparent, and it has a

deep brownish-red color. It is clearly an impregnation from a source outside the limestone, the distance the bitumen was able to travel along individual veinlets being readily determinable in many hand specimens. The shale inclosing these fractured limestone beds is a dark compact bituminous rock giving a distinct though transient odor of kerosene, especially after being gently heated. Hand specimens of this material yielded on distillation between 1 and 2 gallons of petroleum to the ton, and this shale is doubtless the source of the tarry material found in the limestone. The total thickness of this low-grade oil shale averages about 50 feet.

The horizon at which these bituminous limestones and shales occur is near the base of the thick body of shale making up the upper two-thirds of the Colorado shale in this region and just above its lower sandy portion, which contains as many as six sandstone beds from 10 to 50 feet thick intercalated with the shale and carrying Inoceramus and other marine fossils. The principal localities at which these bituminous rocks were noted are as follows: On the south bank of the Middle Fork of Dupuyer Creek, in the SW. ¼ SW. ¼ sec. 18, T. 27 N., R. 8 W.; on the South Fork of Dupuyer Creek, in the NW. ¼ sec. 36, T. 27 N., R. 9 W.; on the North Fork of Willow Creek, in the NW. ¼ sec. 9, T. 24 N., R. 8 W.; on Deep Creek, in the NW. ¼ sec. 28 and in sec. 16, T. 23 N., R. 8 W.; and on Sun River, in the SW. ¼ sec. 29, T. 22 N., R. 8 W.

No seeps or other indications of oil were found on the outcrops of the Colorado shale in the Blackfeet Indian Reservation. However, the only noteworthy showings of oil so far reported from northern Montana occur in the lower half of the Colorado shale. W. A. English,[1] of the United States Geological Survey, reports an occurrence on the north side of West Butte in the Sweetgrass Hills, a short distance south of the Canadian boundary. At this locality, 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 a light-greenish oil, which collects to the extent of about a teaspoonful in every 24 hours. Mr. English also reports that extraction tests made on samples from outcrops of the sandstone in the lower part of the Colorado on West Butte give a good show of oil. That the lower part of the Colorado shale in this part of Montana carries petroleum seems to be clearly proved by this occurrence.

Virgelle sandstone.—The Virgelle sandstone overlies the Colorado shale conformably. The transition from one to the other is marked by alternating beds of shale and sandstone lying between the characteristic rocks of the two formations. The principal member of the Virgelle formation is a thick bed of rather coarse-grained, massive

[1] English, W. A., personal communication.

sandstone which forms its upper half. In places it is much cross-bedded and contains large ferruginous concretions. At the mouth of Cut Bank Creek this formation is 220 feet thick. Near the center of T. 35 N., R. 4 W., it is 225 feet thick. Both these measurements were made on the eastern edge of the Blackfeet Indian Reservation and therefore do not apply throughout the reservation. The Virgelle was not measured along the outcrops in the disturbed belt of rocks, but in the west half of the area its thickness apparently does not differ greatly from that measured to the east.

The Virgelle sandstone contains large amounts of gas at Havre, Mont., along the axis of a folded and faulted uplift.[1] This formation is also gas bearing at Medicine Hat and other places in southeastern Alberta and may therefore contain oil and gas in this general region.

FORMATIONS ABOVE THE VIRGELLE SANDSTONE.

The succession of formations above the beds that may contain oil and gas in this region includes the Two Medicine formation, Bearpaw shale, Horsethief sandstone, St. Mary River formation, and the Willow Creek formation, presenting an aggregate thickness of about 4,400 feet of strata, composed of clay, shale, and sandstone. None of these beds has yet yielded favorable showings of oil or gas in southern Alberta and northern Montana. They have been drilled through in many places in southern Alberta with uniformly negative results except for small puffs of gas in rocks that are equivalent to the Two Medicine formation. The Bearpaw is a marine shale that is roughly equivalent to the upper part of the Pierre shale, which in Wyoming and Colorado, notably in the Florence oil field of Colorado, has yielded oil in commercial quantities.

The prospects for oil and gas in the formations above the Virgelle sandstone are meager, so the oil prospector is mainly interested in their thickness, the best available estimates of which are given in the table on page 285.

COMPARISON WITH CANADIAN CLASSIFICATION OF FORMATIONS IN SOUTHERN ALBERTA.

The general series of formations that occur in northern Montana extends northward into Canada. The changes in the Montana group and the thinning out and disappearance of the Claggett shale from east to west, which became apparent in the section of Montana, persist into southern Alberta, where they have been recognized by Dowling and are in every way similar. The differences in the for-

[1] Stebinger, Eugene, Possibilities of oil and gas in north-central Montana: U. S. Geol. Survey Bull. 641, pp. 49–91, 1916.

mation names used in Canada for the probable oil and gas bearing formations relate chiefly to the Colorado shale and the Virgelle sandstone, which the Canadian geologists have classified into three units, the Dakota sandstone, Benton shale, and Niobrara sands. The "Niobrara sands" are identical with the rocks described as Virgelle sandstone in this report. The fact that all the evidence afforded by fossils is adverse to the use of the name Niobrara for these sandstones was long ago emphasized by Stanton.[1]

The Dakota has not been recognized in northwestern Montana at any point where the strata in which it should be present have been examined, and it is believed that its existence is equally uncertain in southern Alberta, where geologists have been inclined to assign to the Dakota any sandy beds that occur at its horizon. The sandstone beds at Bow Island, elsewhere referred to as Dakota, are probably the sandstones in the lower part of the Colorado shale, as stated in this report. It is very suggestive that well logs at Bow Island show dark shale beneath the pay sands called the Dakota. Marine fossils found in the basal sandstones of the Colorado shale in the section in central Fergus County in Montana seem to indicate the marine origin of all these sandstones, which are very similar to the productive sands in the Colorado shale in the oil fields of Bighorn Basin, Wyo. The use of the name Benton shale for shale overlying the supposed Dakota in southern Alberta is also inadvisable, for no evidence afforded either by fossils or lithology is important enough to warrant the recognition of the Benton and Niobrara divisions of the Colorado. The simple expedient of applying the term Colorado shale to strata in northern Montana, which include both Benton and Niobrara, has long been in use.

The Two Medicine formation, as well as the underlying Virgelle sandstone, when traced northward appears to be identical with the rocks known to the Canadian geologists as the Belly River series. In western Montana, however, the Virgelle sandstone is easily distinguished from the overlying rocks and has been mapped over considerable areas as a distinct unit, so that the term Belly River can not be conveniently used as a formation name in the area here described.

STRUCTURE.

EFFECT OF STRUCTURE ON THE ACCUMULATION OF OIL OR GAS.

It is generally conceded that the accumulation of oil in pools is due to some irregularity in the rock bed. If the beds lie flat or if they dip slightly but regularly in a certain direction, the oil that circulates through the pores of the rock will not tend to accumulate in any par-

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

ticular place, but if the beds have been disturbed—that is, bent into folds or broken—the oil may find a resting place and form a pool.

The structural form that is most favorable to the accumulation of oil is an upwarp or bulge, a feature that is generally known as an anticline, but if the anticline has about the same width as length it is generally called a dome. Other structural forms that are less favorable to the accumulation of oil are terraces, monoclines, synclines, or tilted blocks of rock that have been separated from the adjacent strata by faults. The degree of deformation of rock beds, however, varies greatly. In some places, as in the Kansas, Oklahoma, and Texas fields, it is so slight as to be imperceptible to casual inspection and requires close instrumental work for its detection; in others, as in the California and Wyoming fields, the tilting may be strongly developed, and 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 concerning the presence of water have been verified again and again in developed fields:

1. If the pay sands are saturated with water, the gas and oil, which are lighter than the water, will be found above it in the crests of domes or anticlines or on the flats or terraces of monoclinal structures.

2. If only parts of the sands are saturated with water, the gas and oil will be found at the upper level of saturation, and this level may be on the crest of the anticline or may be part way down its sides.

3. If the sands are dry, the oil will have migrated downward either to the troughs of the synclines or to a point where further shifting has been prevented by the closeness of the sand.

4. If oil and gas occur in the same stratum, gas, which is the lighter substance, will generally, though not invariably, be found above the oil.

GENERAL FEATURES OF STRUCTURE IN THE BLACKFEET INDIAN RESERVATION.

The area described in this report can be divided into two large structural units, which differ greatly in the degree to which the strata have been deformed. A slightly curving line (shown on the geologic sketch map, Pl. XXIV), extending northward from a point on Birch Creek in T. 37 N., R. 9 W., to a point on the Canadian boundary in T. 37 N., R. 12 W., would mark a sharp transition from an area on the east in which the beds are nearly horizontal and undisturbed to an area on the west, adjacent to the mountain front, in which the rocks have been extensively faulted and folded. The eastern part of the area shown on the map is characterized by simple broad belts of out-

crop that trend regularly northward and the western area by a relatively complex arrangement of formations.

In the area where the beds are nearly horizontal they dip in general slightly westward at angles ranging from nearly 0° to 5° in gentle undulating folds whose average dip is not over 2°. As a result of this average westward dip of the bedrock formations the youngest or the highest stratigraphically, the Willow Creek formation, lies farthest west in these nearly horizontal beds, and the oldest, the Colorado shale, lies farthest east on the eastern edge of the tract. Thus one who is traveling westward up any of the principal valleys, as, for instance, from Marias River up Cut Bank Creek or Two Medicine Creek, would cross all the formations in sequence from older to younger in a distance of 35 to 50 miles. Between the south slopes of Milk River Ridge and the international boundary a broad, open syncline, whose steeper limb is on the west, lies on the west border of the area of nearly horizontal rocks. The axis of this syncline is between 1 and 2 miles east of the line that marks the transition to the disturbed belt of rocks and closely parallels that line. Farther north, in Alberta, this syncline broadens into a much more extensive feature, which reaches to Calgary and beyond. On the south it is practically coextensive with the outcrop of the Willow Creek formation and does not reach beyond Cut Bank Creek.

Minor undulations of the strata in the area of nearly horizontal rocks can be seen in detail only along the principal stream valleys. In places these undulations have produced structural terraces—that is, the general westward dip of the beds is interrupted locally by flats or benches. Elsewhere dips to the east in this area of generally westward-tilted strata indicate slight anticlinal folds. Both these types of structure may or may not have acted as reservoirs or traps for oil and gas if these substances were once in any of the underlying rocks. The areas occupied by these structures seem to be most favorable for obtaining oil and gas in the eastern part of the reservation. The detailed descriptions which follow treat of twelve structural terraces and anticlines that were noted in the course of the field work in the area of horizontal rocks. (See map, Pl. XXV.) The change in structure from the nearly horizontal beds in the eastern half of the reservation to the steeply dipping disturbed beds in the other half is very abrupt. Where exposures are good, especially along the major stream valleys, this change can be seen to occur within a few feet, there being no intermediate zone of gentle folds.

The belt of disturbed beds adjacent to the mountains that occupy the western third of the region here described is a small part of a structural area from 15 to 20 miles wide, which extends at least 80 miles southeast along the east front of the Rocky Mountains to and

beyond Sun River and a much greater distance northwest across Alberta. Throughout this belt the rocks have been intensely folded and faulted by thrust stresses that acted from the southwest. In many places the individual formations are so much crushed and broken that it is impossible to identify them with certainty. The only constant feature in this whole disturbed area is the general northwesterly strike of the rocks. Because of this parallelism of strike the more resistant sandstones of the several formations appear as numerous strike ridges, and in many places the same hard beds are repeated by faulting within short distances. In the Blackfeet Indian Reservation the deformation of the disturbed belt accompanied the overthrusting that produced the Lewis overthrust, a great fault which can be traced along the eastern face of the mountains in the Glacier National Park, just off the west edge of the reservation.[1]

The folds and faults in the belt of disturbed rocks along three well-exposed lines transverse to the general trend of the belt are shown graphically in the structural sections given on Plates XXIV and XXV. The only part of this area where large folds were formed lies along its eastern edge, which was farthest removed from the center of disturbance in the mountains. In the western two-thirds of this disturbed belt the beds are so much faulted and crushed that they could hardly serve as reservoirs for oil or gas. Large anticlines, which are described below, occur at seven localities along the east side of the disturbed belt.

DETAILS OF ANTICLINES AND STRUCTURAL TERRACES.

ANTICLINES IN BELT OF DISTURBED ROCKS.

Milk River anticline.—An anticline, here called the Milk River anticline, whose axis can be traced for more than 12 miles in the disturbed belt, extends northwestward across the south, middle, and north forks of Milk River. (See Pl. XXV.) This is the largest and apparently the most promising anticline in the reservation for prospecting for oil and gas in the belt of disturbed rocks. The Two Medicine is the lowest formation exposed in this anticline, and on its crest in each of the river valleys crossed all but about 300 to 500 feet of these beds have been removed by erosion, so that it is possible to explore the underlying Colorado shale and the upper part of the Kootenai formation by drilling to depths of not more than 2,500 feet. The best exposures in this large fold appear in the valleys of the forks of Milk River.

The northernmost outcrops of the Milk River anticline are in the valley of North Fork of Milk River, in the southwestern part of

[1] Willis, Bailey, Stratigraphy and structure of Lewis and Livingston ranges, Mont.: Geol. Soc. America Bull., vol. 13, p. 331, 1902.

T. 37 N., R. 12 W. The axis of the anticline at this locality is fairly well defined and extends through secs. 31 and 32, cutting the section line between these two sections about 1,500 feet north of the quarter corner. The dips on the east limb of the fold are best exposed in the N. ½ sec. 32, where there are a series of outcrops of sandstone and shale whose structure can be accurately determined. The dips in this tract range from 30° to 51° NE. The west limb of this fold is less steeply tilted than the east limb, so the anticline is somewhat unsymmetric. About 1,500 feet west of the east quarter corner of sec. 31 the beds exposed dip to the southwest at an angle of not over 4°. Farther west on North Fork of Milk River the Two Medicine beds are continuous for about 1½ miles upstream, the westward dip apparently continuing through all this stretch to the W. ½ sec. 36, where the overlying Bearpaw shale enters in normal sequence and it in turn is overlain by the Horsethief sandstone, with its characteristic oyster beds. The stratigraphic sequence here shown seems to prove conclusively that the beds exposed along the crest of the Milk River anticline at this point belong to the Two Medicine formation. In sec. 6, T. 36 N., R. 12 W., numerous exposures in a tributary coulee to Milk River also show the westward-dipping rocks on this fold. The low dips on the west limb of this anticline near the axis of the fold again appear at this point, where they are only 7° to 8°, but farther west the beds are inclined at angles as great as 51°.

The northward extension of the Milk River anticline is apparently interrupted by a cross fault, which trends about N. 80° E., cutting through the S. ½ secs. 29 and 30, T. 37 N., R. 12 W., and extending westward into the adjoining township. In the W. ½ sec. 29 the dips, instead of being to the east, as they would be if the east limb of the Milk River anticline continued through this locality, are to the west, the maximum angle being 60°. From this locality westward the dips are all to the west, but instead of the low dips of 4° seen on the west limb of the Milk River anticline—the dips that would appear normally in this position on the fold—the dips are as great as 60°. The lack of accordance of dip in this tract with that in the area to the southeast, along the anticline, seems to prove that the anticline does not continue through this area but has been interrupted by faulting. About 6 miles farther northwest, however, on St. Mary River in Canada, a broad anticline occurs almost exactly on the prolongation of the axis of the Milk River anticline. This is doubtless an extension of the same fold.

The rocks south of the exposures on North Fork of Milk River are very poorly exposed for about 5 miles, but in the valley of Middle Fork of Milk River, in the south half of T. 36 N., R. 12 W., the anticline is again exposed and its axis, which is fairly well

defined, passes through secs. 22, 27, and 34 with a slight curve. Here, as on North Fork of Milk River, the fold is not symmetric, the steeper limb being on the east. Near the center of sec. 22, about 1,500 feet east of the crest of the fold, a dip of 56° NE. was noted. About 2,000 feet southwest of this locality the dip is 4° SW. A quarter of a mile farther southwest it has increased to 18°, and it gradually becomes steeper until in the N. ½ sec. 29 the strata are tilted at an angle of about 40°, and again the dark marine shale of the Bearpaw is overlain by the Horsethief sandstone in normal succession. In this area on the whole the succession of the strata and the character of the folds are identical with those in the area to the northwest and seem to prove conclusively that the Milk River anticline is continuous through the intervening area.

On the south side of the valley of Middle Fork of Milk River the dips outline a fold that is also in harmony with the structure to the north. In secs. 33 and 34 southwestward dips of 24° to 34° are noted, and the Bearpaw shale and Horsethief sandstone enter in normal succession above the Two Medicine formation. The crest of the fold, however, is more compressed than it is to the north, the dips near the north line of sec. 34 being in opposite directions, those on the west having an angle of 58° and those on the east an angle of 65°. Throughout the W. ½ sec. 34 and in the E. ½ sec. 35 dips of 27° to 44° were measured at a number of points, indicating that in this locality the east limb remains much as it is farther north. In the SE. ¼ sec. 26, however, there are several small cross faults, which are indicated by westward dips of about 25° throughout about 50 acres. This is the only cross fault noted on this anticline. Others are probably present and must be considered in prospecting for oil or gas.

In T. 35 N., R. 12 W., the axis of the Milk River anticline is still well outlined by opposite dips in the Two Medicine formation. The anticline continues southward beyond South Fork of Milk River through secs. 2, 11, and 14, and probably as far as the south side of sec. 25. In secs. 3 and 4 the westward dips are much the same as those farther north on Middle Fork. Near the center of sec. 15 of the same township the Horsethief sandstone, which lies on the continuation of its exposures to the north and dips about 30° W., indicates that the fold still continues in this locality. South of Milk River a few exposures of the same sandstone in sec. 26 show that the anticline is continuous for at least a mile south of South Fork. This fold, however, if extended farther south meets the extensive gravel-covered area that forms Milk River Ridge. On the south slope of this ridge, in secs. 8, 16, 17, and 18, T. 34 N., R. 11 W., on the line of the trend of the Milk River anticline, the exposures are fairly good and indicate no anticlinal structure, the beds all dipping westward. At this place, therefore, there is probably a cross fault

like the one that limits the Milk River anticline on the northwest, as already described. The southern limit of this fold must consequently remain indefinite, as the surface indications do not prove its existence for a distance greater than a mile southwest of Middle Fork of Milk River. All told, this anticline can be followed for about 12 miles, and is the largest single fold found in the Blackfeet Reservation. The lowest stratigraphic horizon reached along its crest, and therefore the position that is nearest to the underlying, possibly productive sands in the Colorado shale and Kootenai formation, is in the bottoms of the valleys of the major streams crossed by the axis of the fold. These localities include parts of secs. 31 and 32, T. 37 N., R. 12 W.; secs. 27, 34, and 35, T. 36 N., R. 12 W.; and secs. 2, 3, 11, 13, and 14, T. 35 N., R. 12 W. The most favorable locations for drilling appear to be in these sections. Because of the high dips in the east limb of the fold it seems best to drill on the west limb, near the axis of the anticline.

South Fork anticline.—A large fold, the second in size and probably in value as a possible reservoir of oil or gas, lies east of and parallel to the Milk River anticline and can be traced for about 6 miles across the principal branches of South Fork of Milk River in T. 36 N., Rs. 11 and 12 W., and in T. 35 N., R. 11 W. For convenience of description in this report this fold is described as the South Fork anticline.

This anticline is the only extensive one in the belt of disturbed rocks on the reservation which is not bounded on both sides by faults. It is bounded on the west by a fault along its entire length, but the beds on the east extend into the area of nearly horizontal rocks without a break. The desirability of prospecting in this anticline, however, is somewhat uncertain because of the great thickness of rocks that overlies the possible oil and gas sands. At least 400 feet of the beds of the St. Mary River formation occur at the lowest stratigraphic point on the crest of the fold, so that the depth to the Virgelle sandstone is over 3,000 feet and the depth to the base of the Colorado shale is nearly 5,000 feet. However, if other anticlines in this region should prove productive drilling might be done on this fold. On Middle Fork of Milk River the South Fork anticline is best exposed along the south side of the valley in sec. 36, T. 36 N., R. 12 W., and sec. 31, T. 36 N., R. 11 W. The crest can be located only approximately between the eastward dips along the west line of sec. 31 and the westward dips, which occur about 2,000 feet to the west in sec. 36. The exposures on the north side of the valley are very poor, and the continuation of this anticline northward can not be proved from the surface indications.

Between South Fork and Middle Fork of Milk River the area in a line prolonged from this fold affords only a few exposures, but

on South Fork of Milk River the anticline is again indicated by opposite dips in the cut bank along the south side of that stream. Near the center of sec. 8 the dip in the Willow Creek formation is 16° NE., which accords very well with the dip of 18° along the same line of strike on the Middle Fork. In the NW. ¼ sec. 17, close to the west line of the section, the rocks are tilted 30° SW., the anticlinal axis cutting through the W. ½ sec. 8 apparently in close alignment with the trend of the fold as outlined on Middle Fork of Milk River.

The southward continuation of the South Fork anticline is very indefinite, the area south of the river affording few exposures from which its position can be determined. On the south side of Milk River Ridge, along the line of *C–D* on Plate XXV, the crest of a fold lying close to the fault block that bounds the Blackfeet coal field on the east probably represents a southeastern extension of this anticline, but if so its axis in this area has shifted westward to a point nearer the fault just mentioned than it is in the area farther north. The lower part of the Willow Creek formation outcrops on the axis of the fold at this locality.

Blackfeet anticlines.—A fault block lying between the Milk River and South Fork anticlines and extending southward beyond the limits of those folds contains rocks that are closely folded, for the most part in two parallel anticlines. Coal is exposed on the flanks of these folds for about 12 miles along the fault block, and the area has been described in a previous report as the Blackfeet coal field.[1] Sections *A–B* and *C–D* (Pl. XXV) intersect these folds and give a general idea of their relations to the surrounding structural features. They seem to offer little chance of finding oil or gas, because the faults on both sides probably limit the area which could serve as collecting ground for oil or gas. Wells drilled at the lowest stratigraphic points on these folds to the highest possibly productive sand would have to extend through nearly all the Bearpaw shale in addition to the full thickness of the Two Medicine formation, a depth of nearly 2,500 feet, and would reach the base of the Colorado shale at a depth not much less than 4,000 feet.

Anticlines on Cut Bank Creek.—On Cut Bank Creek, about 2 miles west of Cut Bank School, in secs. 10, 11, 14, and 15, T. 33 N., R. 11 W., there are two parallel anticlines whose axes trend about N. 18° W. The western of these two folds is closely compressed, the dips on the west limb being as high as 70° and those on the east about 60°, the axis intersecting a point very close to the southwest corner of sec. 11. The axis of the east fold crosses the creek in the southwest quarter of the same section. The anticline there is much more open than the one

[1] Stebinger, Eugene, Geology and coal resources of northeastern Teton County, Mont.: U. S. Geol. Survey Bull. 621, pp. 148–153, 1916.

to the west and exposes the Bearpaw shale along its crest, as indicated by the cut-bank exposures on either side of the creek. The east limb of this fold near the axis, on the south side of the creek, has a dip of about 20°. The west limb, on the north side of the creek, has a dip of about 37°, and the St. Mary River formation appears in normal succession above the Horsethief sandstone, which in turn lies above the Bearpaw shale. The rocks exposed in the west fold at this point are identical with those of the St. Mary River formation and apparently belong to that formation, as is shown by the sequence just cited and by the absence of indications of faults between these two folds.

Anticline on Two Medicine Creek.—In the valley of Two Medicine Creek, near the mouth of Little Badger Creek, in secs. 22 and 27, T. 31 N., R. 10 W., there is an anticline which lies between steeply dipping faulted beds on either flank. The axis of this fold can be located approximately by opposite dips on the north side of the valley, in the NE. ¼ sec. 22. Near the center of this section the strata dip 30° SW., whereas about 2,000 feet to the east similar beds are tilted 64° NE., this steep dip continuing to the faulted ground in the W. ½ sec. 23. The exposures clearly indicate a moderately compressed fold, as shown on cross section *E–F* (Pl. XXV), but it was impossible to determine the formation to which the beds belong. Their lithologic appearance indicates that they can be assigned either to the St. Mary River or the Two Medicine formation, but as the rocks are not in normal sequence and the fossil shells and dinosaur bones found in them are indeterminate, it is not yet possible to decide this question.

Anticline on Badger Creek.—On Badger Creek, in the east half of T. 30 N., R. 10 W., there is a fairly open fold which exposes the St. Mary River formation along its axis. The axis trends about N. 15° W. and is fairly well defined on both sides of the creek. Its northwest and southeast limits, however, are indefinite because of the cover of glacial drift, which conceals the rocks in the upland areas on both sides of the valley. The dips on the east limb of this fold range from 15° to 30° and those on the west limb from 30° to 60°. Beds of sandstone in the St. Mary River formation arch over the crest of the anticline and are strikingly shown on the north side of the valley. The small size of this fold and the great depth to the underlying sands that may contain oil or gas seem to offer comparatively little inducement for prospecting.

ANTICLINES AND STRUCTURAL TERRACES IN THE AREA OF NEARLY HORIZONTAL ROCKS.

Anticline on North Fork of Milk River.—In T. 37 N., R. 11 W., there is an anticline in very gently folded rocks whose axis passes through secs. 17, 20, and 21, but can not be more definitely located.

The dips that outline this fold are exposed only along the sides of the valley of North Fork of Milk River. Near the center of sec. 16, on the northwest side of the valley, the beds dip 1½° NW. The strata southwest of this point lie horizontal, as is shown by exposures on both the north and the south side of the river. The west limb of the fold is indicated in the SW. ¼ sec. 20 by dips of about 2° SW. The strata southwest of this point lie horizontal, as is shown by exposures on both the north and the south sides of the river. The west limb of the fold is indicated in the SW. ¼ sec. 20 by dips of about 2° SW.

The strata exposed in the vicinity of this anticline belong to the Willow Creek formation, and a well drilled to the nearest productive sand yet found in this region would necessarily penetrate all the intervening strata between the Virgelle sandstone and the Willow Creek rocks, which would include all of the St. Mary River formation, Horsethief sandstone, Bearpaw shale, and Two Medicine formation—a total of nearly 4,000 feet, in addition to an undetermined thickness of Willow Creek beds—probably about 500 feet. The extension of this fold can not be certainly determined from the surface exposures, as the outcrops of the bedrock formations away from the river valley are very meager. In the valley of South Fork of Milk River, in secs. 27 and 28 of the township adjoining to the south, and nearly on the line of strike, there is no anticline, as the beds dip continuously westward.

Anticline on Cut Bank Creek.—On the south side of the valley of Cut Bank Creek, in sec. 34, T. 34 N., R. 9 W., exposures indicate a gentle anticline whose axis extends north-northwestward, the axis lying approximately along the center of the valley of Willow Creek, which at this point enters Cut Bank Creek from the south. The Bearpaw shale is the surface formation on the fold. In the W. ½ sec. 34, in a steep bank on the south side of the creek, the clay shale beds belonging to this formation dip westward at an angle of about 2°. On the east side of the same section beds of similar shale dip eastward at an angle somewhat under 1°. This fold does not reach as far north as the south edge of Rimrock Butte, near the center of this township, as is indicated by excellent exposures of the rocks, which show a uniform westward dip. The southward extension is indefinite because of the poor exposures along the lower part of the valley of Willow Creek. Nearly the full thickness of the Bearpaw shale is exposed along the crest of this fold on Cut Bank Creek, and the overlying Horsethief sandstone lies above the shale less than 1 mile to the west. The depth here to the top of the Virgelle sandstone is about 2,400 feet.

Anticline on Willow Creek.—On Willow Creek, in secs. 8, 16, and 17, T. 33 N., R. 9 W., there are excellent exposures of the crest of a

broad, gentle anticline outlined by dips for several miles along the valley of the creek. The east limb of the fold shows dips as great as 4° on the south bank of the creek, near the north line of the section, in the NW. ¼ sec. 16. A few hundred yards to the west the beds have flattened to a dip of only ½°, and where the creek crosses the line between secs. 16 and 17 the beds are horizontal. The next exposures to the southwest, along the valley of the creek, show rocks that are tilted uniformly at an angle of about 2° SW. for about 1,500 feet, as far as the exposures continue. The dips indicate that an anticline extends in a northwestward direction across the creek near the line between secs. 16 and 17. Nearly the full thickness of the Horsethief sandstone is exposed along the crest of this anticline, so that in order to reach the underlying Virgelle sandstone the drill would have to penetrate about 2,700 feet of rocks.

Small structural terraces on Two Medicine Creek.—On the lower part of Two Medicine Creek there are four localities where a flattening of the dip in beds that are generally inclined westward produces small structural terraces. At each locality these features can be seen only in the badland exposures along the sides of the valley of the creek, the north and south extent of the structural terraces being indeterminate because of the lack of exposures. In the N. ½ sec. 4, T. 31 N., R. 6 W., the rocks of the Two Medicine formation lie horizontal, and the flat or terrace structure apparently continues northward through the center of sec. 33. Near the east line of the section the beds dip about 2° W., and near the center of sec. 3 they again lie practically flat over an area of several hundred acres. Still farther east, in sec. 2, these beds dip westward, and this dip continues for several miles downstream. The dips therefore seem to show the presence of two small structural terraces, which are indicated on the map (Pl. XXV). Three miles to the southwest, in secs. 11 and 12, T. 31 N., R. 7 W., there is another structural terrace. In the W. ½ sec. 12 the beds lie nearly horizontal. In the E. ½ sec. 12 they dip about 1½° W. and then flatten in the E. ½ SW. ¼ sec. 11, west of which they again assume the uniform westward dip which continues for many miles up the valley of the creek. These four structural terraces on the lower part of Two Medicine Creek are all in the lower half of the Two Medicine formation. The eastern pair of terraces is probably not more than 400 or 500 feet above the top of the Virgelle sandstone, whereas the two farther west lie nearly 1,000 feet above the Virgelle.

Structural terraces in Tps. 29, 30, and 31 N., R. 9 W.—Between Badger Creek and Two Medicine Creek, in secs. 29 and 32, T. 31 N., R. 9 W., and secs. 5 and 8, T. 30 N., R. 9 W., there is a structural terrace that occupies about 3 square miles. In secs. 21, 22, and 28

the Horsethief sandstone and St. Mary River formation are fairly well exposed and dip uniformly 2° SW. Toward the southwest these inclined beds flatten first to a dip of about ½° in the NE. ¼ sec. 29 and then to practical horizontality near the center of the section. The flat-lying beds, as indicated by exposures of rocks in the coulees, extend southeastward in a belt that reaches nearly to Badger Creek. The southward extent of this structural terrace could not be definitely ascertained, because the exposures along Badger Creek, on what appears to be its trend, are very poor. In secs. 7 and 8, T. 30 N., R. 9 W., on the north side of Badger Creek valley, the Horsethief sandstone dips 1° W., and this dip is probably the continuation of the general westward dip on the west side of the structural terraces referred to. Farther north, in sec. 19, T. 31 N., R. 9 W., in the line of strike of the inclined strata last mentioned, the rocks dip as much as 3° NE., and this dip suggests that the horizontal strata near the center of sec. 29 occupies the basin of a shallow syncline. Farther south the dips, however, clearly indicate the presence of the structural terrace. Nearly the full thickness of the Horsethief sandstone and a few feet of St. Mary River beds appear at the surface in this terrace.

In an area of about 3 square miles that lies at the south edge of T. 30 N., R. 9 W., and extends southwestward into the adjoining township, there seems to be a second structural terrace. The beds lie flat throughout all of sec. 34 and parts of the adjoining sections, and exposures in the N. ½ sec. 10, T. 29 N., R. 9 W., indicate that this area of horizontal rocks extends at least that far south. To the west, as indicated by the numerous dip symbols shown on the map (Pl. XXV), the rocks dip uniformly to the west. Dips of 4° to 5° in sec. 9 of the same township, together with those of 2° to 3° in sec. 32, T. 30 N., R. 9 W., indicate that the beds are uniformly tilted to the west on the west side of this structural terrace. In the SW. ¼ sec. 26 a dip of 7° NE. was noted, which suggests that there is at that locality a sharp reversal of the normal southwestward dip.

Anticlines on Blacktail Creek.—In the valley of Blacktail Creek, in the southeast quarter of T. 30 N., R. 8 W., a gentle fold is clearly outlined in the upper part of the Two Medicine formation. The dip of the beds on the west side of this fold is in places as great as 8°, and many exposures show that the beds are uniformly tilted to the west for a distance of about 4 miles along the side. The dip of the beds on the east side of the fold is lower but equally persistent. Flat beds were noted in the W. ½ NW. ¼ sec. 28, and the axis of the fold that extends in a northwest direction crosses near this locality. In order to reach the base of the Colorado shale on the crest of this fold the drill would have to penetrate about 3,800 feet of rocks. The

MAP SHOWING ANTICLINES ON THE BLACKFEET INDIAN RESERVATION, MONTANA

By Eugene Stebinger

EXPLANATION

Features in area of nearly horizontal rocks

- *Anticline, location of axis not known. North and south extent indefinite*
- *Structural terrace, area in which the beds that generally dip westward are horizontal*

Features in belt of disturbed rocks

- *Anticline and anticlinal axis. North and south extent of fold indefinite*
- *Area in which no large folds are known. Dips are generally westward and faults numerous*
- *Bedrock generally concealed*

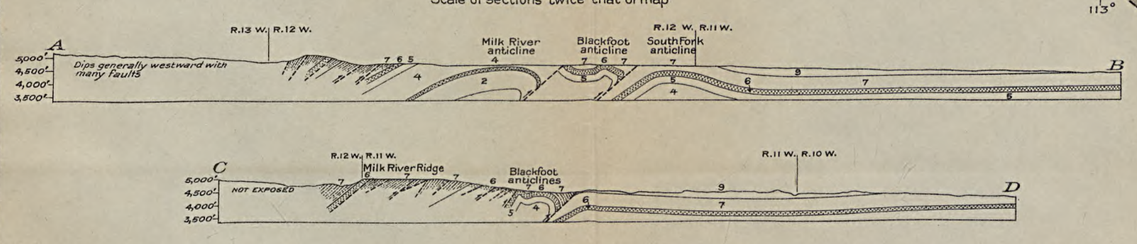
General

- *Dip and strike*
- *Horizontal rocks*
- *Prospect boring*
- *Road*

Scale 1/250,000

0 1 5 10 15 20 MILES

Scale of sections twice that of map



Key to formations: 1, Kootenai formation; 2, Colorado shale; 3, Virgelle sandstone; 4, Two Medicine formation; 5, Bearpaw shale; 6, Horsethief sandstone; 7, St. Mary River formation; 8, either Two Medicine or St. Mary River formation; 9, Willow Creek formation.

Base from U.S.G.S. topographic maps, General Land Office plats and author's field sheets

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southeast extension of the anticline just described can not be accurately determined because of the lack of exposures in the level areas southeast of Blacktail Creek. Where the extension of this fold should cross Birch Creek the exposures are also very poor, and no definite indications of an anticline were noted.

Rocks dipping in opposite directions on Blacktail Creek, near the north quarter corner of sec. 13, T. 29 N., R. 9 W., indicate a narrow-crested fold extending in a direction about N. 15° W. The dips on the east flank are about 1° and those on the west flank about 2°. Bearpaw shale outcrops along the cre , of this fold.

Anticlines on Birch Creek.—There is a small, narrow-crested anticline on the west edge of the area of nearly horizontal rocks on Birch Creek, in secs. 4 and 9, T. 28 N., R. 9 W. This fold is exposed only along the sides of the creek in outcrops near water level. The beds on the west limb of the anticline dip between 8° and 10° and to the southwest are cut off sharply by a fault within half a mile of the axis of the fold. The beds on the east limb dip about 1°, thus showing a decidedly unsymmetric fold with a steep flank on the southwest. The St. Mary River formation is exposed on the crest of the anticline and at water level along the creek there are a few feet of the Horsethief sandstone.

Two miles farther up Birch Creek fairly good exposures indicate a second anticline, whose axis, which trends N. 12° W., crosses the creek about 900 feet west of the line between secs. 17 and 18, T. 28 N., R. 9 W. The Bearpaw shale and Horsethief sandstone are exposed along the crest of the fold, and on the west flank a considerable thickness of the St. Mary River formation overlies the Horsethief. This anticline is also unsymmetric, but the steeper flank is on the northeast, the dips approaching the vertical. On the southwest side for a mile from the axis the dips do not exceed 30°, and for nearly half this distance the beds dip gently at angles not much over 8°.

RESULTS OF DRILLING.

No drilling had been done on the Blackfeet Indian Reservation up to the time of the preparation of this report. Borings, however, have been made on the east, north, and west sides of the reservation, all of them with negative results. These borings suggest that in this region it is useless to drill either in highly faulted rocks, such as those in the west half of the disturbed belt near the mountain front, or in areas where the rocks lie very flat.

The only well so far drilled on an anticline near the reservation was located near the crest of a large fold on the line of the Milk River anticline, on St. Mary River about 1½ miles north of the boundary (locality 4, Pl. XXIV). Information concerning this boring,

which was drilled since the writer examined the region, was kindly furnished by Dr. James S. Stewart, of the Geological Survey of Canada. Only a few hundred feet of the upper part of the Colorado shale were penetrated according to latest reports, and therefore the boring can not be considered a fair test of the possibility of obtaining oil along this fold. The boring was made with a diamond drill and reached the Colorado shale at a depth of about 300 feet, after passing through the sandy beds of the lower part of the Two Medicine formation and the Virgelle sandstone. By September, 1915, the drill had reached a depth of 560 feet, and operations were suspended. The shale at the bottom of the hole, as shown by the drill core, is crumpled and dips at a high angle, although the overlying sandstones on the crest of the anticline are practically flat. Although the soft shale of the upper part of the Colorado has been thus crushed and crumpled, the more rigid sandstones in the lower part of the formation and in the Kootenai, like those that are exposed at the surface of the anticline, may have been strong enough to withstand the stresses that caused the deformation without crumpling and breaking. It is therefore probably in general true that the presence of crumpled shale in the larger anticlines in the belt of disturbed rocks in this region does not necessarily condemn these folds for oil prospecting.

About 15 miles off the east edge of the Blackfeet Reservation, near Kevin, Toole County, on the James Miller ranch, a boring 1,755 feet deep, sunk in search of oil, passed through the lower two-thirds of the Colorado shale and all of the Kootenai formation, and probably entered the Jurassic. This well is in the midst of a large area whose rocks lie horizontal, as shown by exposures in the vicinity and also by the Virgelle sandstone in the prominent escarpment west and north of the locality. The boring was therefore made at a place where the structure was unfavorable to the accumulation of gas or oil. Small flows of gas, however, were encountered at three horizons. The log of this well, furnished by H. C. Price, of Great Falls, Mont., was 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.	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	95	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.	Limerock	50	1,730
	Black shale	25	1,755

Borings were also made just off the west edge of the reservation in three places at the base of the mountain front in the Glacier National Park (localities 1, 2, and 3, Pl. XXIV). All these borings seem to have been dry or to have struck only very small amounts of gas. The Colorado shale is the surface rock at each of these places and the greater part of the beds penetrated belong to that formation. At locality 2, near Sherburne Lake, several holes were drilled to a depth of about 1,600 feet entirely in the Colorado shale. These three places are only a few miles from the trace of the Lewis overthrust, and the whole of the Colorado shale is tilted to the west and has been much thickened by crumpling and repeated faulting. The negative results obtained at these widely scattered places along the base of the mountain front and the geologic evidence that the formations on the west edge of the reservation are much disturbed indicate that this part of the region is unfavorable for oil and gas prospecting.