DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 691—F

ANTICLINES IN A PART OF THE MUSSELSHELL VALLEY

MUSSELSHELL, MEAGHER, AND SWEETGRASS COUNTIES, MONTANA

BY

C. F. BOWEN

Contributions to economic geology, 1918, Part II
(Pages 185-209)
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CONTENTS.

ILLUSTRATION.

ANTICLINES IN A PART OF THE MUSSELSHELL VALLEY, MUSSELSHELL, MEAGHER, AND SWEETGRASS COUNTIES, MONTANA.

By C. F. Bowen.

INTRODUCTION.

Previous investigations had shown that the Musselshell Valley, Mont., is an area in which the rocks have undergone considerable folding. On the basis of this information work was begun in June, 1916, to determine the nature and extent of the folds and to make examination as to the possible occurrence of accumulations of oil and gas in them. The work has demonstrated the existence within the area studied of several well-developed anticlines and domes, which seem to offer structurally favorable places for the accumulation of oil and gas. The demonstration of the presence or absence of commercial accumulations of these fluids in the folds has been less conclusive, owing largely to the undeveloped condition of the area.

No direct surface indications of oil were observed, but hydrogen sulphide gas escapes from several water seeps in one part of the area. It is also reported that gas was encountered in several wells dug for water. None of these reports could be verified. At the time of the examination drilling operations within the area were confined to two wells. One of these wells, on the Big Elk dome, had reached the Kootenai formation; the other, in the Woman's Pocket anticline, was probably somewhat more than halfway through the Colorado shale. In neither place had oil been discovered. Two other wells, one about 15 miles east of the area and the other about 12 miles south of the central portion of it, had previously been drilled through the Colorado shale without any discovery of oil. Although these results are not altogether encouraging, it is believed that the field has not yet been thoroughly tested.

Sandstones that would serve as suitable reservoirs for the accumulation of oil occur at several horizons. (1) Near the top of the

Colorado shale there is a transition zone of thin sandstones and sandy shale beds. (2) About 1,200 feet below the top of the Colorado a thick porous sandstone, slightly conglomeratic at the top, is well developed in the western part of the field but seems to be nearly or quite absent in the eastern part. This sandstone has approximately the same stratigraphic position as some of the sandstones in the Frontier formation. (3) About 250 to 300 feet lower in the section is another sandstone of similar character but much thinner and more distinctly conglomeratic. (4) Associated with and underlying the Mowry shale member, in the eastern part of the field, are several thin, finely conglomeratic sandstones. (5) At the top of the Kootenai there is 40 to 50 feet of platy, rather fine grained sandstone in approximately the same position as the Greybull sand of the Big Horn Basin, Wyo. (6) Near the base of the Kootenai there is another coarse, porous sandstone of undetermined thickness. The positions of these sandstones and their approximate relations to the productive sandstones of the Elk and Big Horn basins are shown in the columnar sections A, B, C, Plate XXV (in pocket).

The Eagle sandstone is not a likely source of oil or gas in most of this area, for it has been removed from the crests of most of the anticlines, and thus any oil or gas that may have originally been stored in it has had an opportunity to escape.

It is the purpose of this report to discuss the geology of the region as a whole, and also to suggest the most favorable places for future development.

LOCATION AND SURFACE FEATURES.

The area herein described includes about 1,200 square miles lying chiefly in Tps. 7 to 9 N., Rs. 12 to 23 E. Montana principal meridian. It extends from the town of Martinsdale on the west to a point within about 10 miles of Roundup on the east, and lies for the most part north of Musselshell River but in the western portion also extends south of that stream.

Being situated on the western border of the Great Plains, the area exhibits characteristics common to both plains and mountains. To the north are the Big Snowy and Little Belt mountains, and on the west and southwest are the rugged, snow-clad Crazy Mountains. Within the area described, however, the surface features are chiefly those of a plain dissected by erosion and further modified by folding and upheaval. For the most part the highest surfaces of the plain are covered by terrace gravels which rise gradually and likewise become more continuous toward the mountains.

This absence of abrupt and extreme surface irregularity renders the establishment of routes of travel comparatively easy. The Chi-

cago, Milwaukee & St. Paul Railway traverses the area from east to west along the valley of Musselshell River, and the Great Northern line between Billings and Great Falls crosses the area from southeast to northwest. These two railways, together with the numerous wagon roads and trails, bring every part of the area within easy access.

PREVIOUS WORK.

The geology and coal resources of the Musselshell Valley were briefly described by Lindgren[1] in 1886. The western part of the area, lying west of Twodot, was described by Weed[2] in 1899. Later Stone,[3] Woolsey,[4] and Richards,[5] who were engaged in a more detailed survey of the coal fields of this general region, mapped and described that portion of the area lying south of Musselshell River. Several other papers that deal with the stratigraphy of the western part of the area have been published, of which the most important are by Douglass,[6] Stanton and Hatcher,[7] and Stone and Calvert.[8]

FIELD METHODS.

The field work on which this report is based was done by the plane-table method. Horizontal control was obtained by a system of triangulation expanded from base lines 1 mile or more long. Partly for convenience and partly for the purpose of eliminating errors that may have crept in, three such base lines were measured during the progress of the work. Land corners were located wherever practicable, and these furnished a basis for adjusting the triangulation system to the land net compiled from the plats of the General Land Office. Vertical control was carried throughout the field by means of vertical angles read to all the triangulation stations and to numerous other prominent points. The initial elevation was taken from a point on the Chicago, Milwaukee & St. Paul Railway near Roundup.

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[1] Lindgren, Waldemar, Montana coal fields: Tenth Census U. S., vol. 15, Mining industries, pp. 743–746, 1886.

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

[3] Stone, R. W., Coal near the Crazy Mountains, Mont.: U. S. Geol. Survey Bull. 341, pp. 78–91, 1909.

[4] Woolsey, L. H., The Bull Mountain coal field: U. S. Geol. Survey Bull. 341, pp. 62–77, 1909.

[5] Richards, R. W., The central part of the Bull Mountain coal field, Mont.: U. S. Geol. Survey Bull. 381, pp. 60–81, 1910.

[6] Douglass, Earl, A Cretaceous and lower Tertiary section in south-central Montana: Am. Philos. Soc. Proc., vol. 1, pp. 207–224, 1902.

[7] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, pp. 59–60, 1905. Stanton, T. W., The age and stratigraphic relations of the "*Ceratops* beds" of Wyoming and Montana: Washington Acad. Sci. Proc., vol. 11, pp. 251–265, 1909.

[8] Stone, R. W., and Calvert, W. R., Stratigraphic relations of the Livingston formation of Montana: Econ. Geology, vol. 5, pp. 551–557, 652–669, 741–764, 1910.

This control was checked by "tying in" to points on the railway twice during the season. From the field sheets thus constructed and the township plats obtained from the General Land Office the map accompanying this report was compiled with such adjustments as were necessary to bring the two sets of data into harmony.

Scientific assistance in the field was rendered by W. P. Woodring and George E. Dorsey, whose efficiency and general interest in the work have contributed largely to the results obtained.

GEOLOGY.

SEDIMENTARY ROCKS.

GENERAL SECTION.

With the exception of the alluvium and terrace gravel the sedimentary rocks within the area described range from the Kootenai to the Lance. Igneous rocks are also present in small amounts in the vicinity of the Big Elk and Little Elk domes. The sedimentary formations recognized are, in ascending order, the Kootenai, Colorado, Eagle, Claggett, Judith River, Bearpaw, and Lance. In the eastern part of the area these formations are well defined and easily recognized. In the western part, as a result of a marked development of andesitic material and an increasing amount of sandstone in the Claggett, the Eagle, Claggett, and Judith River merge into one another, and so far as lithologic character is concerned are difficult to separate. The areal distribution of the formations is shown on Plate XXV. Their sequence and character are set forth in the following generalized table:

Generalized section of geologic formations in a part of the Musselshell Valley, Mont.

System and series.	Group and formation.	Average thickness (feet).	Characteristics.
Quaternary.	Alluvium.		Unconsolidated deposits along stream courses.
	—Unconformity—		
Tertiary (Miocene?).	Terrace gravels.	0–80	Terrace gravel consisting of well-rounded pebbles, in some places firmly cemented into a well-defined conglomerate. The pebbles consist of limestone, chert, sandstone, and various types of igneous rocks. The igneous pebbles are most abundant in the western part of the field.
	—Unconformity—		
Tertiary? (Eocene?).	Lance formation.	Not determined.	Yellowish-brown sandstones and buff to gray shales with a thick, massive, ledge-making sandstone at base. This basal sandstone may locally be in part marine and represents the Lennep sandstone.

Generalized section of geologic formations in a part of the Musselshell Valley, Mont.—Con.

System and series.	Group and formation.	Average thickness (feet).	Characteristics.
Upper Cretaceous	Montana group. Bearpaw shale.	1,000±	Dark-gray to black marine clay shale containing large calcareous concretions. An especially heavy band of sandy concretions near the base seems to develop in places into a rather well defined sandstone.
	Judith River formation.	550±	As here mapped consists of (1) an upper part composed chiefly of alternate beds of sandstone and shale forming a more or less well-defined ridge or series of ridges; (2) a middle part consisting chiefly of light-buff to gray or white clay shale with some interbedded sandstone which in places of low dip weathers into badlands; (3) a lower part, here included in the Judith River for convenience in mapping and because of lithologic similarity, which seems to be the approximate equivalent of the sandstone assigned to the upper part of the Claggett in its type area and also in the eastern part of the Big Horn Basin. This lower part consists chiefly of sandstone with a thick bed of massive ledge-making sandstone at the base. All the sandstones, especially those in the middle and upper divisions, become markedly andesitic in the western part of the field.
	Claggett formation.	350–490	In the eastern part of the field the Claggett is a dark-drab concretionary shale similar to the Bearpaw. It becomes increasingly more sandy toward the west until it consists entirely of sandstone and sandy shale.
	Eagle sandstone.	300±	Consists of three members. The upper member is composed of moderately thick sandstones interbedded with shale, forming a ridge generally marked by several parallel ribs. The middle member consists of shale and thin-bedded sandstones that erode easily and form an area of depression. The lower member (Virgelle sandstone) is a thick massive white sandstone that forms a pronounced scarp or hogback. In the western part of the field, however, this member becomes more thinly bedded and loses its ridge-making character. The sandstones of this formation also become more or less andesitic toward the west.
	Colorado shale.	2,200±	In the eastern part of the field the lower 400 to 500 feet contains at least three slightly conglomeratic sandstones 5 to 20 feet thick, above which is 10 to 30 feet of sandy, fissile indurated shale which weathers white and contains numerous scales and other fragmentary fish remains. This represents the Mowry shale. The probable representative of the Frontier formation is a zone of thin shaly sandstones about 30 feet thick, with a calcareous sandstone at the top. Farther west, in the Shawmut anticline, the Mowry shale can not be recognized. The lower 700 or 800 feet of the formation consists of alternating black, fissile, somewhat sandy shale and thin quartzitic sandstones, one of which, about 500 feet from the base, is conglomeratic. Above this zone is the Big Elk sandstone member, 200 feet or more thick, consisting chiefly of sandstone slightly conglomeratic at the top. The remainder of the formation is chiefly shale.
Lower Cretaceous.	Kootenai formation.	250 +	Consists mainly of alternating beds of maroon and white sandy shale, containing some beds of more or less concretionary sandstone in the upper part. At the top is about 50 feet of thin-bedded, platy, rusty sandstone in which are numerous markings resembling worm trails: at the base of the exposed section is a coarse gray sandstone of unknown thickness.

QUATERNARY SYSTEM.

Alluvium.—All the larger drainage channels in this area contain alluvial flats of greater or less width. The material consists of an unconsolidated aggregate of gravel, sand, and clay derived from the underlying formations. On the map the alluvium is shown only along Musselshell River and a few of its larger tributaries. The boundaries were merely sketched and are therefore only approximate.

TERTIARY SYSTEM.

Terrace gravel.—Terrace gravels, consisting chiefly of waterworn pebbles of limestone, chert, sandstone, and igneous rock of several types, in places well consolidated by calcareous cements into a true conglomerate, are widespread in this area. The gravel occurs at two or more levels, but the most prominent deposits are at the top of the highest buttes and ridges. These detached areas rise to about the same elevation, so that if the surface represented by them were restored it would form a plain rising gradually toward the mountains. The thickness of the gravel ranges from a few feet far out on the plain to at least 80 feet nearer the mountains, where wells have penetrated it to that depth. Below these highest terraces there is at least one other level at which the gravel occurs. No especial study was made of the relation of these two terrace levels, so that it is not known whether those at the lower level represent a reworking and redistribution of those at the higher level or whether they are simply residual products that have settled to their present position during the process of erosion. The age of the gravels has not been determined. Those at the higher level truncate all formations from the Fort Union (exposed in adjoining areas) to the Kootenai. They are therefore younger than the Fort Union and are probably to be correlated with the Flaxville gravel of Miocene or early Pliocene age, north of Missouri River, described by Collier and Thom.[1] It is possible, however, that they correspond to the Oligocene gravels of White River age occurring in the Cypress Hills of Canada, described by McConnell and Cope.[2]

TERTIARY SYSTEM (?).

Lance formation.—No particular attention was given to the Lance formation. Its lower boundary was mapped in the east end of the area and also in a small outlier on the south side of the Woman's Pocket. The lower part of the formation consists of rusty-brown and

[1] Collier, A. J., and Thom, W. T., jr., The Flaxville gravel and its relation to other terrace gravels of the northern Great Plains: U. S. Geol. Survey Prof. Paper 108, pp. 179–184, 1917 (Prof. Paper 108–J).

[2] McConnell, R. G., The Cypress Hills, Wood Mountain, and adjacent country: Canada Geol. and Nat. Hist. Survey Ann. Rept., new ser., vol. 1, pp. 68c–70c, 1886. Cope, E. D., idem, pp. 79c–85c.

gray sandstones, buff and drab shales, and thin carbonaceous beds. The formation is more fully described in the publications of Stone, Woolsey, and Richards, previously cited.

CRETACEOUS SYSTEM.

UPPER CRETACEOUS SERIES.

Bearpaw shale.—The Bearpaw shale has about the same characteristics in the Musselshell Valley that it has over the greater part of the area in Montana where it has been recognized. It consists chiefly of dark-gray to black clay shale containing numerous large calcareous concretions. There is a more or less sandy transition zone to both underlying and overlying formations. That at the base consists in many places of an unusually large amount of sandy concretions. In other places this concretionary zone seems to form a true sandstone. In this field the Bearpaw shows perhaps less variation in lithologic character than any other formation above the Kootenai.

Judith River formation.—The Judith River formation, as here considered, consists of three more or less well-defined divisions having an aggregate thickness of 400 to 600 feet, the thickness increasing from east to west. The lower division, here included in this formation because of lithologic similarity and for convenience in mapping, is probably the same as the sandstone included in the upper part of the Claggett by some other writers.[1] This lower division is a ledge-making, heavy-bedded to massive, cross-bedded, medium-grained gray to brown sandstone 50 to 150 feet thick. Microscopic examination shows that the sandstone consists of grains of quartz, feldspar, chert, limestone, and mica with other minor constituents. These are embedded as a rule in a calcareous cement, but in some places the cementing material is chiefly ferruginous. The grains are chiefly angular to subangular, but some of them are fairly well rounded. Their average diameter is about 0.15 millimeter, and few of them exceed 0.5 millimeter. In the eastern part of the area this sandstone is, in part at least, of marine origin, as marine fossils have been found in its lower part. Farther west it contains at least one bed of coal and also brackish-water fossils, which extend 200 feet or more below the sandstone.

The middle division of the formation is of fresh-water origin and consists chiefly of gray to buff clay shale, in which several beds of sandstone are intercalated. Petrified wood and dinosaur bones are common in this division. It is less resistant than the overlying and underlying parts of the formation and gives rise to areas of depression or of badland erosion.

[1] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, pp. 13, 36, 1905. Hares, C. J., The Elk Basin anticline: U. S. Geol. Survey Bull. — (in preparation).

The upper division consists mainly of alternate beds of sandstone and clay shale but contains also thin beds of carbonaceous shale and coal. The most persistent and best-developed coal bed is very near the top of the formation and is overlain by an oyster-bearing sandstone in which the most common fossil is *Ostrea subtrigonalis*, though other forms are also present. This division commonly forms a more or less distinct ridge or series of parallel ridges.

Lithologically the sandstones in the upper division are similar to those in the lower division. In all three divisions there is a notable change in character across the area from east to west. This consists both in an increase of sandy material, especially in the middle division, and in the appearance of andesitic material in the sandstones. To the unaided eye the andesitic character is recognized chiefly by the greenish cast of the unweathered rock. Under the microscope some specimens are seen to consist almost entirely of fragments of andesitic groundmass; crystals of feldspar, many of which are perfectly fresh and beautifully striated; and a small amount of quartz. These are embedded in a calcareous matrix, which in some specimens amounts to 50 or 75 per cent of the rock.

Claggett formation.—The Claggett shows perhaps greater lithologic variety within the area described than any of the other formations considered. In the eastern part of the area it consists chiefly of clay shale similar in character to that of the Bearpaw, with a transition zone of sandy shale and thin-bedded sandstone to the Judith River formation. In the east end of the Shawmut anticline, northwest of Franklin, two thin sandy zones appear, making low ridges in the middle part of the Claggett area. A section of the formation at that locality is as follows:

Section of Claggett formation measured in sec. 11, T. 7 N., R. 19 E. Montana principal meridian.

	Feet.
Base of Judith River formation	
Claggett formation:	
Sandstone, platy	7
Shale, mostly concealed	146
Shale, sandy, and sandstone, thin bedded	55
Concealed, probably concretionary shale	90
Sandstone, thin bedded	6
Shale, sandy	5
Sandstone	3
Shale, concretionary, drab	155
Eagle sandstone.	
	467

From this place westward the proportion of sandstone in the formation increases to approximately 50 per cent in a distance of about 20 miles, as shown by the following section:

Section of Claggett formation measured north of Fish Creek, near the line between Rs. 15 and 16 E. Montana principal meridian.

	Feet.
Base of Judith River formation.	
Claggett formation:	
Concealed	75
Shale, sandy	37
Sandstone, thin bedded, somewhat shaly	30
Shale, sandy, with thin sandstone members	40
Sandstone, somewhat shaly in lower part	18
Shale, sandy	20
Interval, concealed, probably sandy shale	70
Shale, sandy, partly concretionary, with thin-bedded sandstone forming rib at top	95
Sandstone, white	18
Interval, concealed	7
Sandstone, white	22
Interval, concealed	8
Sandstone, ledge maker	5
Shale, mostly concealed	45
Eagle sandstone.	
	490

Still farther west the formation becomes sandy throughout, so that none of the typical concretionary marine shale that characterizes the formation in the eastern part of the area is present. Under these conditions any line drawn separating the Claggett from the Eagle below and the Judith River above is more or less arbitrary. The difficulty is increased by an intermingling in the Claggett of marine fossils common to the Eagle and brackish-water fossils common to the Judith River.

Eagle sandstone.—The Eagle sandstone consists of three more or less well-defined members. At the base is the massive white Virgelle sandstone, which is commonly a ledge maker. In the eastern part of the area it is a massive to heavy-bedded, cross-bedded medium-grained gray sandstone. In the western part of the area the lower part of this sandstone is thinner bedded and less resistant and the upper part is more or less andesitic and weathers to a deep brown. This andesitic portion is very resistant to erosion and disintegration and therefore forms a conspicuous ridge. It is commonly the only part of the lower member that is exposed, the less resistant underlying portion being commonly concealed by wash and talus.

A microscopic examination shows that the Virgelle sandstone of the eastern part of the area consists chiefly of quartz, feldspar, and chert, with small amounts of mica, kaolin, and other minor constituents. Calcareous material is almost wholly absent either as grains or as cement. The grains have an average diameter of 0.1 to 0.3 millimeter, and 10 to 15 per cent of them are more or less well rounded, the remainder being angular to subangular.

Specimens from the andesitic portion in the western part of the area show about the same granular constituents as those just mentioned, with more or less fine material that may be andesitic, all embedded in a ferruginous cement to which the color of the rock is due. The grains are less well sorted and more angular than in the specimen just described, and their diameter ranges from 0.4 to 0.09 millimeter, with a common range of 0.2 to 0.1 millimeter. Very few of them show a tendency to rounding.

The middle member of the Eagle consists of soft shales and sandstones that are easily eroded and form a conspicuous depression between the ridges of the lower and upper members.

The upper member, which forms a somewhat conspicuous ridge, is made up largely of sandstone with some intervening beds of shale. In some places the sandstone seems to constitute nearly all of the member, which assumes the appearance of the lower member. In other places the shale beds are more prominent, so that instead of a single ridge there are a series of minor parallel ridges and intervening narrow depressions which together constitute a larger topographic ridge. In many places this upper member contains at its top a highly fossiliferous sandstone in which *Cardium speciosum* is the most abundant fossil.

The threefold division of the Eagle sandstone outlined above is most evident in the eastern half of the area. The gradual increase of sandy material in the western part of the area affects the Eagle as well as the overlying formations and renders this threefold division more or less artificial. For comparison two sections of the Eagle are given—one measured in the Woman's Pocket anticline and the other on the south side of the Big Elk dome.

Section of Eagle sandstone on south side of Woman's Pocket, in the SE. ¼ sec. 33, T. 8 N., R. 21 E. Montana principal meridian.

	Feet.
Claggett formation.	
Eagle sandstone:	
Sandstone, brown, thin bedded, full of *Cardium speciosum*	18
Shale, partly concealed	118
Sandstone, thin bedded, with some interbedded shale	40
Shale, sandy	26
Sandstone, white, massive to thick bedded, cross-bedded	101
Colorado shale.	
	303

Section of Eagle sandstone on south side of Big Elk dome, in the SE. ¼ sec. 3, T. 6 N., R. 13 E. Montana principal meridian.

	Ft.	in.
Claggett formation.		
Eagle sandstone:		
Sandstone, light gray, coarse, somewhat thin bedded, with scattering *Cardium speciosum;* mapped provisionally as top of Eagle	28	6

Section of Eagle sandstone on south side of Big Elk dome, in the SE. ¼ sec. 3, T. 6 N., R. 13 E. Montana principal meridian—Continued.

	Ft.	in.
Eagle sandstone—Continued.		
Shale, drab, slightly carbonaceous	19	0
Sandstone, yellowish brown	9	6
Concealed, probably shale	51	6
Sandstone, light brown, somewhat rusty looking, andesitic in upper part, ledge maker	73	0
Colorado shale.		
	181	6

Colorado shale.—Chief interest in the present connection attaches to the Colorado shale of this area, because the sands in its lower part are the principal source of oil in the Wyoming fields to the south. These sands are well developed in the western part of the Musselshell Valley but are nearly absent in the eastern part. On the other hand, the Mowry shale, also prominent in Wyoming, is present, though in diminished thickness, in the Devil's Basin and Devil's Pocket, in the eastern part of the Musselshell Valley, but can not be recognized as such in the Shawmut anticline or farther west. It was therefore deemed inadvisable to attempt to subdivide the Colorado deposits, as is done farther south. For this reason they are here mapped as a single formation (the Colorado shale), and in those areas where sands of sufficient thickness are present they were mapped as members.

The Colorado shale, as its name implies, is chiefly a shale formation. In the eastern part of the area this shale is for the most part black and fissile, somewhat sandy in the lower part of the section, more concretionary and argillaceous in the upper part. Beginning about 250 feet above the base is a zone about 300 feet thick, in which there are at least three sandstones 5 to 20 feet thick. Each of these sandstones contains small pebbles of black chert at the top, and fragments of fish remains. This zone is overlain by 10 to 30 feet of fissile indurated sandy shale, which contains an abundance of fish scales and bones, weathers white on exposure, and has all the characteristics of the Mowry shale. About 250 to 300 feet above this is another sandy zone, 30 or 40 feet thick, with a calcareous sandstone at the top. This sandy zone forms a very low, inconspicuous ridge, and may represent the top of the Frontier formation of Wyoming. The remainder of the section is chiefly shale, with about 75 feet of thin-bedded sandstones and sandy shales about 100 feet below the top of the formation.

In the western part of the area the lower 500 feet of the formation consists of black fissile shales, for the most part sandy, in which there are numerous thin quartzitic sandstones. This is followed by a thin but prominent conglomeratic sandstone, above which are 300 feet of shales and thin quartzitic sandstones. Next comes a sandy

division about 200 feet thick in which there is a coarse sandstone at least 100 feet thick, and at the top a conglomeratic bed 4 or 5 feet thick. This division is here named the Big Elk sandstone member of the Colorado, from its exposures in the Big Elk dome. It is about 1,200 feet below the top of the formation and in the approximate position of the Frontier formation, though the two can not be directly correlated. The remainder of the formation consists chiefly of shale with a sandy transition zone near the top. This transition zone seems to become increasingly sandy toward the west, till at the Big Elk dome it consists of about 100 feet of white friable, somewhat concretionary bedded sandstone. Fossils obtained at the top of this sandstone on the south side of the Big Elk dome are said by T. W. Stanton to indicate Colorado age.

The two detailed sections given below and columnar sections A and B on Plate XXV bring out more distinctly the differences in the Colorado shale in the eastern and western parts of this area.

Section of Colorado shale in the eastern part of the area, compiled from measurements in the Devil's Basin, in the SE. ¼ T. 11 N., R. 24 E., and in the Devil's Pocket, sec. 12, T. 10 N., R. 21 E.

	Ft.	in.
Eagle sandstone.		
Colorado shale:		
Sandstone, friable	46	
Shale	100	
Sandstone, thin bedded, and sandy shale	90	
Shale, mostly black, fissile, concretionary, containing some sandy layers	1,270	
Shale, sandy; large calcareous concretions	6	
Sandstone, shaly	3	
Clay shale, light gray (gumbo)	5	
Sandstone, conglomeratic; pebbles mostly black chert, size of a pea or smaller	2	6
Sandstone, thin bedded, and sandy shale	27	
Shale, black, fissile, with thin sandy partings	17	
Shale, black (gumbo), with calcareous and ferruginous concretions	33	
Shale, black, fissile, somewhat sandy in upper half	13	6
Shale, somewhat sandy, fissile; weathers white, contains numerous fish scales (Mowry shale member)	12	
Shale, grayish; contains gypsum	8	
Sandstone, conglomeratic at top, small chert pebbles; contains an abundance of fish remains	85	
Shale, black	140	
Sandstone, slightly conglomeratic; contains fish remains	16	
Shale, probably containing at least one thin bed of sandstone	330+	
Kootenai formation.		
	2,204+	

Section of Colorado shale in western part of area, compiled from measurements on the south side of the Shawmut anticline and Big Elk dome.

	Feet.
Eagle sandstone.	
Colorado shale:	
Shale	120
Sandstone, friable	117
Shale, drab	284
Shale, black, with band of large calcareous concretions at top in which fossil collection 9997 was obtained	127
Shale, sandy at top and base; weathers white	182
Shale, black, fissile, with black calcareous zone at top in which fossil collection 9998 was obtained	252
Sandstone, quartzitic, with interbedded shale	23
Big Elk sandstone member:	
Sandstone, coarse, slightly conglomeratic; contains bone fragments, fish teeth, and *Halymenites major*	5
Concealed, probably shale or sandy shale	45
Sandstone, quartzitic, in thin beds alternating with shale	41
Sandstone, coarse, somewhat massive; contains bone fragments	157
Sandstone, quartzitic, in thin beds alternating with shale	37
Shale, black, with thin bands of quartzitic sandstone as much as 15 inches thick	271
Sandstone, platy, with 2 feet of cherty conglomerate at top	23
Shale, black, sandy, with thin sandstone at middle	150
Sandstone, shaly at base, quartzitic at top, ledge maker	15
Shale, black fissile	40
Sandstone, quartzitic at top	15
Shale, black, fissile, somewhat sandy in streaks; contains bone fragments	100
Sandstone, quartzitic at top	3
Shale, sandy at base	120
Sandstone, thin bedded; contains *Inoceramus labiatus* Schlotheim	5
Shale, black, sandy, somewhat concretionary	75
Kootenai formation.	
	2,207

LOWER CRETACEOUS SERIES.

Kootenai formation.—Below the Colorado is the Kootenai formation, a part of which is exposed in two places within this area—the middle and west domes of the Shawmut anticline. As here considered the Kootenai includes at the top about 50 feet of thin-bedded fine-grained platy sandstone of somewhat rusty appearance. The surfaces of the thin platy masses are thickly strewn with small cylindrical elevations that may be worm markings but have more the appearance of casts of sand filling tubular bodies, some of which are branching, resembling vegetable growths. Below this sandstone is

45 or 50 feet of drab to greenish-gray shale, which is succeeded by alternate beds of maroon and white shale containing some interbedded sandstone. The lowest member exposed is a coarse gray sandstone that roofs over the centers of the middle and west domes of the Shawmut anticline. This may be the sandstone member which, according to Fisher,[1] occurs near the base of the formation.

No fossils were collected from this formation by the writer. Fragments of saurian bones were observed in the maroon shales, but a few hours was spent in looking for plants and shells without success. It may be that the upper sandstone here included in the Kootenai belongs in the Colorado.

IGNEOUS ROCKS.

Igneous rocks occur as dikes and sills and possibly in other forms in East Coffin Butte, the Little Elk dome, and Gordon Butte. The rocks are chiefly of basic composition and coarse-grained texture and belong to the type known as theralite, described by Weed.[2] There is also an acidic light-colored variety which was described by Weed as andesite porphyry.

The theralite is dark colored and contains large crystals of augite and biotite in a finer-grained groundmass. In some phases the augite is the predominant phenocryst; in others the biotite is most abundant. This rock occurs in East Coffin Butte, Gordon Butte, and most of the dikes within the area.

The andesite porphyry is a light-gray rock containing crystals of feldspar in a fine-grained groundmass. It occurs as dikes and sills on the southwest slope of the Little Elk dome. According to Weed these intrusives are of Eocene age.

The origin of the larger igneous masses, such as East Coffin Butte and Gordon Butte, is not perfectly clear. At present they occupy synclinal troughs. The relation of these buttes to their surroundings does not seem to admit the hypothesis that they are merely remnants of a more extensive igneous mass derived from some distant source. The material, in the writer's opinion, must have come from vents immediately beneath the buttes. Their synclinal structure is therefore not easily understood, as a laccolith or plug generally implies an upward bulging of the intruded strata. As no detailed work was done around Gordon Butte the description will be limited to East Coffin Butte.

East Coffin Butte is the eastern of two prominent buttes a few miles southwest of Twodot, to one or the other or both of which the

[1] Fisher, C. A., Geology of the Great Falls coal field, Mont.: U. S. Geol. Survey Bull. 356, pl. 4, pp. 32–33, 1909.

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

name Coffin Butte is applied by different individuals. To avoid confusion the writer has adopted the expedient of referring to them as East Coffin and West Coffin buttes. The surface of the east butte rises uniformly toward the south to a height of about 1,200 feet and culminates in a high, sharp rim of sandstone which appears to pass under the theralite to the north. Viewed from a distance, the surface of this butte appears to be formed by a sill or flow. Closer examination shows, however, that many patches of the Claggett formation are included in the igneous mass. The igneous rock appears to reach the surface, especially on the northern slope of the butte, chiefly in the form of dikes that have a southwesterly trend, curving toward the east. On the south and southeast there are larger igneous masses which do not present the form of dikes. The uniform northward surface slope seems to be due to a tilting in that direction and to the large number of igneous talus boulders which strew the surface and protect the softer sedimentary rocks from erosive action. There appear to be no dikes radiating from the butte, and the rim of the butte is, except in a few places, composed of sandstone. Immediately to the east and south is the Big Elk dome, which may be of laccolithic origin, although no intrusives appear in its surface. Its outline seems, however, to have been influenced by the Coffin Butte intrusion.

The tentative conclusion reached by the writer is that East Coffin Butte is a plug or small laccolith from which a few dikes and probably sills also were given off; that the intrusion took place prior to the main folding which gave rise to the Big Elk and Little Elk domes; and that during this subsequent folding the synclinal structure of the butte was developed. The Big Elk dome may be due to a deeper-seated laccolith. The Little Elk dome is even more probably of laccolithic origin, for it is cut by several dikes and one larger irregular mass of theralite.

STRUCTURE.

By structure is meant the attitude or lay of the rock beds. They may be flat, inclined in one direction at various angles, or thrown into folds like the waves on a disturbed surface of water or the wrinkles of a partly dried apple. The upfolds are called anticlines or, if they are nearly equal in width and length, domes; the downfolds are called synclines. Some oil men use the term "structure" in a slightly different sense; they speak of a "structure" in some particular locality when in reality they mean a structural feature of a particular kind, as an anticline or dome or a feature of some other type that is favorable for the accumulation of oil and gas. The term should preferably be confined to its general meaning—that is,

it should be used as an abstract term, like "stratigraphy" or "topography."

The structure of the rocks is one of the major geologic factors controlling the accumulation of oil and gas. By far the greater number of productive wells in the United States occur on the crests or slopes of anticlines or domes. A knowledge of structure is therefore of importance in prospecting for oil. The structure of the rocks may not, and commonly does not, coincide with the surface features. Although some anticlines or domes form surface ridges, others are valleys at the surface, the ridges coinciding with the synclines.

The Musselshell Valley is part of a huge syncline that lies between the Big Snowy and Little Belt mountains on the north and the Crazy, Beartooth, and Pryor mountains on the southwest and south. Within this large syncline there are many secondary synclines and anticlines caused by the compression of the rocks. In some places the folding has also been accompanied by faulting—that is, the rocks have been broken and the fractured ends have slipped past each other.

The secondary anticlines in the Musselshell Valley (see Pl. XXV) have no systematic arrangement; in fact, they seem to be the result of opposing forces acting from several different directions. They possess one feature in common, however, that of being much more highly inclined on one side than on the other. In most of them also the steeper side is the farther from the mountains. Some of them, such as the Pole Creek anticline, are projecting spurs from the main mountain uplifts. The axes of such anticlines plunge in one direction only, and the formations do not completely encircle them but open out fan shaped toward the mountains. Others, such as the Woman's Pocket anticline, are isolated folds whose axes plunge in two directions and which are completely encircled by the inclosing formations. The anticlines of this type are the most favorable for the accumulation of oil, as in them the oil-bearing sands, unless eroded from the crests of the folds, are completely closed in and the oil and gas are prevented from escaping. Still other folds, such as the Big Elk and Little Elk domes, are more or less circular in outline and may be of laccolithic origin—that is, they may have been pushed up by an intrusion of igneous magma which did not reach the surface.

On the accompanying map the structure is indicated by contour lines drawn on the base of the Eagle sandstone. All points along the course represented by one of these lines are in the same horizontal plane, like all points on the "water line" of a standing body of water. These lines are close together for areas in which the dips are steep and far apart for areas in which the beds lie nearly flat, just as when a reservoir is filled to successive levels the water spreads out

horizontally only very little against steep shores but flows over wide areas where the land adjoining the shore is nearly flat.

The contours are marked to indicate altitude above sea level, in feet. By knowing the interval between any other sand and the base of the Eagle sandstone, which may be ascertained from the columnar section, the altitude of that sand at any particular point can be determined by adding to or subtracting from the altitude of the contour that passes through that point an amount equal to this interval.

The base of the Eagle was chosen for contouring because it is the lowest exposed horizon that can be recognized throughout the field. By carefully measured sections its relation to underlying and overlying beds was determined, so that these beds could be used in determining the position of the Eagle where that formation is eroded or passes beneath overlying formations. The positions of the contour lines as shown on the map were plotted by means of numerous surface determinations of altitude on the Eagle sandstone or other recognizable beds, dip and strike readings, and the known stratigraphic intervals between the Eagle and other sandstones. Where these kinds of evidence seemed to conflict, greatest weight was given to the determined stratigraphic thicknesses.

In some places the structure contour lines and strike symbols, which should be parallel, do not closely coincide. This means either that because of lack of data the contour line is incorrectly drawn or that because of poor exposures or for some other reason the strike has been incorrectly determined. The contour lines for some areas, particularly areas of low dip, are farther apart than the dips indicate they should be. This may be due to any one or any combination of the following causes: (1) Because of poor exposures, cross-bedding, or other factors the dips as recorded may be in error. (2) The inclination of the beds may be greater at the surface than underground. (3) The inclination of the beds may not be uniform, resulting in flats or terraces in which the contours should be more widely spaced than in the intervening steeper parts. (4) The formations may be considerably thicker in some places than in others.

Because of these uncertainties and irregularities and the lack of drill records to check surface observations the contour lines do not have the same degree of accuracy in all parts of the field. The degree of accuracy which the writer attributes to them is shown in part by different symbols. Contour lines that are believed to be accurate within one contour interval (250 feet) are shown in solid lines. Those regarding which there is less certainty and in which the error may be as much as 500 feet, are represented by short dashes. Those that are projected into the air—that is, for areas where the Eagle sandstone has been eroded—are indicated by long dashes.

ANTICLINES.

POLE CREEK ANTICLINE.

The Pole Creek anticline is the most eastern one shown on the map. It has an extent from northwest to southeast of about 16 miles, occupying the area from the north side of T. 8 N., R. 24 E., to the southwest quarter of T. 10 N., R. 22 E., where it loses its identity in the south limb of the Devil's Pocket anticline. It is thus a plunging anticline whose axis inclines to the southeast and whose limbs diverge and open out toward the Big Snowy Mountains on the northwest. As is common in the Musselshell Valley, the steepest dips are on the southwest limb and range from 8° to 43° in T. 9 N., Rs. 22 and 23 E., growing progressively steeper from the axis outward to the base of the Lance formation. Farther northwest the dips of the corresponding beds are considerably less than those mentioned. On the northeast slope the dips range from 2° to 8°. In the southeast quarter of T. 9 N., R. 22 E., the Pole Creek anticline is separated by a sharp, narrow southeastward-plunging syncline from the Devil's Pocket anticline. The axis of this syncline dies out to the northwest, probably within the township, though its exact extent and position west of the northwest corner of sec. 27 can not be determined on account of the cover of terrace gravel. It is therefore not known whether the axis of the Pole Creek anticline merges with the south limb of the Devil's Pocket anticline or whether the two folds are more or less distinctly separated by the syncline just described. This relation is critical, for on it may depend the possible accumulation of oil in the Pole Creek anticline. The structural features enumerated above are shown in section E–F, Plate XXV (in pocket).

The oldest formation exposed within the Pole Creek anticline proper is the Eagle sandstone. As no important sands are believed to be present in the Colorado above the Mowry shale, the depth of the highest known sand from the base of the Eagle is estimated to be about 1,800 feet and from the top of the Bearpaw about 4,000 feet.

There are no known surface indications of oil or gas in the anticline. Some wells dug in the Bearpaw shale for water are reported to have found showings of oil, but none of these reports could be confirmed. It is not likely that any formations above the Colorado would be oil bearing, because they are either exposed in or eroded from the axis of the fold, and any oil or gas that may have originally been present in them has had a chance to escape. If oil was originally present in the Colorado its collection and retention in the Pole Creek anticline would depend largely on the structural relations existing between the Pole Creek and Devil's Pocket anticlines. If in the area between them the beds at the depth of the Colorado sands, approximately 1,800 feet, lie in such an attitude as to prevent the

migration of oil from the one to the other, then the oil would be retained in the Pole Creek anticline and would be within reach from almost any point along its crest. It would be nearest the surface in the area where the Eagle sandstone is exposed, and this area would therefore be the most favorable in which to drill.

So far as its relation to other structural features is concerned the Pole Creek anticline is well situated. It has a large collecting ground to the northeast, east, and south. To the southwest the area is small because of the close proximity of a synclinal axis in that direction. The most unfavorable factor which the oil prospector must weigh in considering this anticline, therefore, is the possibility that the oil may have escaped in the direction of the Devil's Pocket anticline. In the opinion of the writer, the Pole Creek anticline is worth testing.

DEVIL'S POCKET ANTICLINE.

The Devil's Pocket anticline is about 9 miles long from northwest to southeast and about 3 miles wide. It projects from the Big Snowy Mountains and is open in that direction. In other directions its outline is marked by the Eagle sandstone, so that the Colorado shale is the surface formation over the entire basin, successively older beds being exposed toward the northwest. The Mowry shale comes to the surface in the northwest quarter of sec. 7, T. 10 N., R. 22 E. The fold may be cut off on the north by an east-west fault, of which there are some suggestions just north of the boundary between Tps. 10 and 11 N., Rs. 20 and 21 E.

This anticline is not likely to be a source of oil, because the possible oil sands in the Colorado shale are exposed within the basin, affording opportunity for the oil to escape. However, if sands below the Colorado, such as those in the Kootenai or underlying beds, should prove to be productive, this anticline may have served as a collecting ground for oil, provided, as suggested above, it is faulted off on the north side and the productive sands have been sealed along the fault plane. This condition would probably occur where a body of shale like the Colorado overlies the productive beds on the downthrown side of the fault.

WOMAN'S POCKET ANTICLINE.

The Woman's Pocket anticline is about 18 miles long from northwest to southeast and a little less than 4 miles wide. It lies southwest of and parallel to the Pole Creek anticline, but, unlike that fold, it has a "closed structure"—that is, its axis dies out both to the northwest and to the southeast. The fold has dips of 18° to 60° on the southwest limb and of 3° to 5° on the northeast limb. As a result the axis or crest of the fold is much nearer the southwest side, and the width of outcrop of the formations

is much narrower on that side than on the northeast. The steep southwesterly dips affect all the formations from the Eagle to the Lance, inclusive, but decrease very quickly in the underlying Colorado shale, being at one place only 9° at a distance of 1,800 feet from the outcrop of the Eagle sandstone. These features are all brought out by the structure contour lines and by cross section D–E, Plate XXV.

The anticline is outlined by the Eagle sandstone, which encircles it as a prominent rim except at a few places where the sandstone is covered by terrace gravel and at the southeast end, where the rim dies down. Within the Eagle rim is the valley occupied by the Colorado shale, which has been eroded to a depth of 600 or 700 feet in the highest part of the fold. The character and thickness of the sands in the lower part of the Colorado in this anticline are not known, as no well logs are available. It is probable that the Big Elk sandstone, so well developed about 15 miles farther west, is present, though diminished in thickness, in the Woman's Pocket. It should be reached in the crest of the anticline at a depth of about 600 feet. It may be this sandstone which yielded the large flow of water encountered in the Foster No. 1 well, in the NE. ¼ sec. 15, T. 8 N., R. 20 E.

Below the Big Elk sandstone many thinner beds will be encountered to the base of the Colorado shale. The sandstone included in the section as the top of the Kootenai should be reached at about 1,500 to 1,700 feet below the surface, and that in the lower part of the Kootenai probably about 300 feet deeper.

Whether or not this anticline will be a commercial oil producer will probably be demonstrated by the drill before this report appears in print. The Foster No. 1 well was in process of drilling when the field work was done, and it was reported that rigs would shortly be installed for two others. Three properly placed wells should give a fair test of this fold.

Looked at as an isolated anticline it seems a very favorable one for oil accumulation, as the possible productive sands in the Colorado are covered and sealed above. Viewed in relation to its surroundings, however, the anticline does not seem so favorable, because it has no large collecting area. The nearness of the synclinal axis on the southwest, together with the steep dips on that side, practically eliminates any considerable gathering ground in that direction. About 6 miles to the northeast lies the axis of the syncline which separates the Woman's Pocket and Pole Creek anticlines, thus limiting the collecting area in that direction to a width of about 6 miles. The area to the northwest and west would probably be drained chiefly by the Shawmut anticline, which presents a much larger surface in that direction. The Woman's Pocket anticline is

therefore more or less hemmed in on all sides except the east and southeast. In these directions there would be a considerable gathering ground, but from all known facts it does not seem probable that the Big Elk sand extends far if at all east of the easternmost extremity of the Woman's Pocket anticline, so that the only known sands that might serve as passageways for the migration of oil from the east would be the thinner sands within and below the Mowry shale.

SHAWMUT ANTICLINE.

The Shawmut anticline is the largest one in the area under discussion. It has an east-west extent of about 30 miles and a maximum width of more than 8 miles. In distinction from the other anticlines this one trends nearly due east. It is really a compound structural feature in which the main fold is modified by local warpings. The larger of these secondary features are the long, narrow eastern nose, terminating on the west in what is known as Deadman's Basin, and three domes in the western part of the anticline, which, for convenience of description, will be referred to as east, middle, and west domes. The axis of the anticline therefore has a wavy profile, as shown in structure section I–J–K–L, Plate XXV, in which the broken line shows the form the base of the Eagle sandstone would assume if restored over the entire uplift. The south limb has dips ranging from 12° to 60°, but the north limb has very gentle dips, as shown by the section through the west dome (G–H, Pl. XXV). On the east this anticline abuts at nearly a right angle against the Woman's Pocket anticline, and on the west it is separated by a narrow syncline from the Big Elk dome.

The oldest formation exposed in the anticline is the Kootenai, which occupies the inner surface depression in the middle and west domes. It is about 200 feet below the surface at the center of the east dome. The Big Elk sandstone and an underlying thinner sand shown by the outer hachure line on the map encircle these three domes. The thickness and relations of these sands are shown in the geologic section on page 189 and in columnar section B, Plate XXV. This is the easternmost locality at which they are exposed. They are under cover if present in the Woman's Pocket and are not present either in the Devil's Pocket or in the Devil's Basin, 8 or 10 miles east of the Pole Creek anticline. In Deadman's Basin the Big Elk sandstone should be reached at a depth of about 800 feet; on Careless Creek, in the small area in which the Colorado is exposed, it lies at a depth of approximately 1,200 feet. The sandstone at the top of the Kootenai is about 800 feet below the Big Elk sandstone, and that in the lower part of the Kootenai approximately 300 feet deeper. They are all, therefore, within drilling depth in Deadman's Basin and the long nose to the east.

With relation to other folds the Shawmut anticline is hemmed in on the east, southeast, and west. To the north it has a large open territory along its entire length; to the south there is similar open territory in that part lying west of the line between Rs. 17 and 18 E. It is from the north and south, therefore, that any considerable oil supply would presumably be drawn. That part of the anticline lying west of Deadman's Basin can with little doubt be eliminated at once as a source of oil within the Colorado, for any oil originally present would have escaped at the outcrop of the sands around the east, middle, and west domes. The middle and west domes can also be eliminated as likely places for obtaining oil in the Kootenai. The east dome, however, is a possible source of oil in this formation, and all three of the domes present ideal structure if oil is ever discovered in rocks older than the Kootenai. That part of the anticline east of and including Deadman's Basin is the most favorable place for testing and is the only part that is likely to produce oil from the sands in the Colorado.

BIG ELK DOME.

The Big Elk dome lies a few miles due south of the town of Twodot. It is roughly circular in outline but is somewhat longer from east to west than from north to south. It covers an area of approximately one township. On the south side the rocks dip 15° to 30°; elsewhere they are inclined at angles of 6° to 10° from the center of the dome. (See structure sections M–N and O–P, Pl. XXV.)

The Eagle sandstone encircles the dome and, together with the Claggett and Judith River, forms a prominent rim on the east, south, and southwest. On the west is the igneous mass of East Coffin Butte. The Big Elk sandstone forms the surface rock in the center of the dome, and a part of it is well exposed facing Elk Creek on the south side of the dome just west of Mr. Martin's house. The sands in the Colorado below the Big Elk member are probably dense and quartzitic. The Kootenai formation is reported to have been reached at a depth of 1,050 feet in a well drilled in the center of the dome by a company under the management of H. B. Henry. One hole was drilled to a depth of about 1,100 feet but became crooked and was abandoned, and a new one was started near by. When the writer's field work was done this hole had reached a depth of 500 feet and was reported by W. H. Ingersoll, driller, to be all in sandstone. It is said that a small "puff" of gas was obtained at a depth of about 400 feet, but no oil was found in either hole.

The structure of this dome is almost ideal for oil accumulation. The collecting ground, however, is not large and is confined principally to the area on the northeast, east, and south. As the most promising sandstone in the Colorado, the Big Elk member, is exposed

in the center of the dome and the underlying sands are quartzitic and very fine grained, it does not seem likely that oil or gas will be found in this formation. Any further prospecting should test the Kootenai sands. A careful watch should be kept for evidence of igneous rock, and if such rock were encountered, further drilling would not be advisable, for it would probably indicate that the dome is laccolithic.

LITTLE ELK DOME.

The Little Elk Dome lies between Little Elk and Fawn creeks in T. 7 N., Rs. 11 and 12 E. It has an east-west extent of about 8 miles and a north-south extent of 4 miles. On the northeast it connects by a narrow neck with the Haymaker anticline. The dome has dips of 8° to 15° on the north, 10° to 25° on the south, and 25° to 45° on the west.

The sandstones in the lower part of the Colorado form the center of the dome, where the Kootenai is probably not more than a few hundred feet below the surface. The sedimentary rocks are cut by several dikes and masses of igneous rock, and it is possible that the entire dome is of laccolithic origin. Because of this possibility, the occurrence of dikes and other intrusive rocks, and the fact that the most favorable sands in the Colorado are exposed in the center of the dome it is not probable that oil will be obtained there. At least drilling should not be undertaken until more favorable areas have been thoroughly tested.

HAYMAKER ANTICLINE.

The Haymaker anticline lies chiefly north of Twodot and is connected by a narrow neck with the Little Elk Dome, to the southwest. The anticline is traversed by Haymaker Creek. It is roughly triangular in outline, with the base of the triangle toward the north. Its structure is not "closed"; on the southwest it connects with the Little Elk Dome; on the north it opens by a narrow neck to the Little Belt Mountains; and on the west it is connected by a low saddle with another small uplift, the Daisy Dean anticline.

Details of structure in the interior of the anticline are not known because there are almost no exposures of the bedrock. From observations around the margin and on Haymaker Creek it is believed that the anticline is compound, a shallow northeastward-trending syncline dividing it into northern and southern portions, so that the major axis of the northern portion trends east and that of the southern portion trends northeast. The dips are steepest along the east limb, where they range from 12° to 24°. Along the north limb the northward dips of the Eagle sandstone are only about 2°. Within a short distance they are reversed, and the beds rise toward the mountains on

the north. Only small patches of the Eagle remain along the north limb, and if erosion had progressed a little farther this formation would have been entirely removed.

The Colorado shale occupies all the central part of the anticline, and probably not more than a few hundred feet of the formation has been removed by erosion. All the possible oil sands are therefore under cover. The chances for oil in this anticline are small. The principal gathering ground lies to the east and west. On the north the foothills of the Little Belt Mountains are only about 6 miles away, and on the south are the Big and Little Elk domes. The shallow syncline which separates the anticline into two parts is probably sufficient to have prevented the migration of oil from the southern part of the anticline, and if oil ever accumulated in this part of the fold it has probably been retained. The southern part would therefore be the most favorable place for drilling. In the northern part there is a possible chance that the oil might have escaped. At any rate the original chances for collection there were much less, and that part of the fold is less favorable.

DAISY DEAN ANTICLINE.

The Daisy Dean anticline, so named from Daisy Dean Creek, lies 5 or 6 miles northeast of Martinsdale and due west of the northern part of the Haymaker anticline. The main uplift is roughly circular in shape and about 4 miles in diameter. It opens to the north toward the Little Belt Mountains.

Almost no details of structure are known in the interior of the uplift, within the boundary between the Eagle and Claggett. As shown on the map (Pl. XXV), this area is largely covered with terrace gravel. Where gravel is absent grass-covered surfaces prevail, so that there are very few exposures of bedrock. The main fold is evidently a spur projecting southward from the Little Belt Mountains. At its south end, however, it expands by a sort of bulge into a dome-shaped uplift, probably owing to the effect of a secondary cross fold connected with the northern part of the Haymaker anticline. The secondary doming effect thus produced may have been sufficient to prevent the northward migration and escape of any oil that may have accumulated in the south end of the anticline. This fold, however, is not regarded as being favorably situated for oil accumulation.

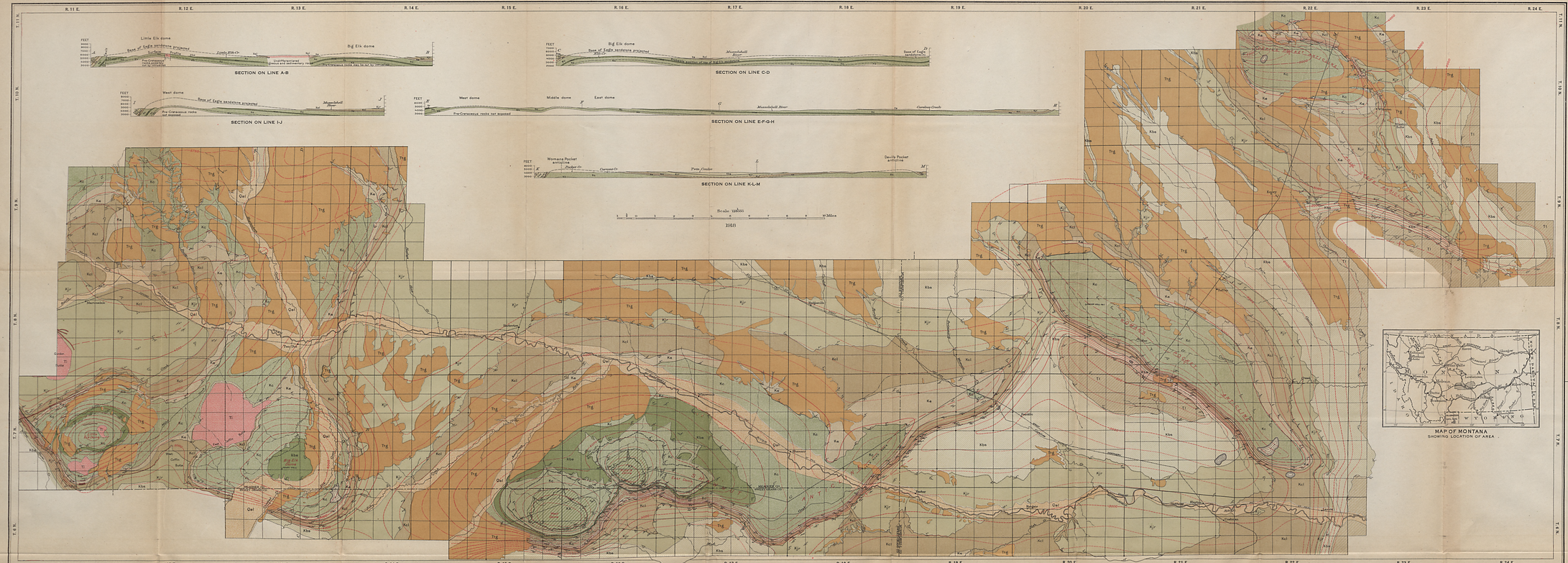
OIL POSSIBILITIES.

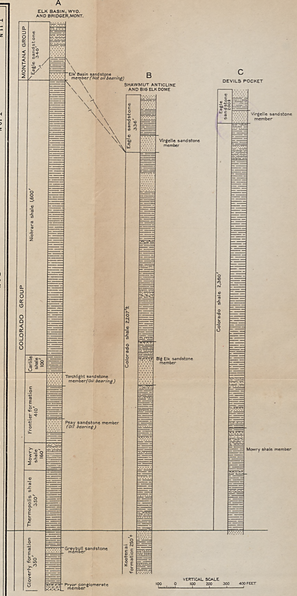
The hopes of obtaining oil in the Musselshell Valley are based mainly on the existence there of the same formations that produce the oil in the Elk Basin and the Big Horn Basin of Wyoming. In those fields the oil comes chiefly from the Mowry and Frontier formations, and at Basin, Wyo., a little oil is obtained from the Grey-

bull sand, the upper member of the Cloverly. The relative positions of these sands compared with the sands in the Colorado in the Musselshell Valley are shown by columnar sections A, B, and C in Plate XXV, in which the top of the Kootenai is used as a datum plane and the Kootenai and Cloverly are assumed to be equivalent. Although in the present state of knowledge the correlation of individual sands is not justified, the sections indicate that the sands in the Colorado shale in the Musselshell Valley occupy, in a general way, the same stratigraphic position as the productive sands in the Elk and Big Horn basins. It is reasonable to expect, therefore, that oil will be found in some of these sands in some places in Montana. But as in the Big Horn Basin only a small proportion of the anticlines are productive, so in Montana the majority of them will probably be barren.

The writer has endeavored to point out in the detailed descriptions of the anticlines their favorable and unfavorable features. The most favorable areas, which, in the opinion of the writer, should be tested first, are the eastern portion of the Shawmut anticline, including Deadman's Basin, the Woman's Pocket anticline, and the Pole Creek anticline.

In the foregoing discussion it has been assumed that the Colorado and Kootenai are the only possible sources of oil. Recent observations have shown, however, that oil shale occurs in the upper part of the Paleozoic rocks in Beaverhead County and possibly in other places in Montana. In the Lander field of Wyoming a small quantity of oil is obtained from rocks of about the same age. Should these older formations prove productive in other localities, as at Dillon, where they are now being tested, a new field for development will be available. These older rocks would be most easily reached in this area in the middle and west domes of the Shawmut anticline.





COLUMNAR SECTIONS SHOWING RELATIONS OF SANDS IN COLORADO GROUP

Section A from unpublished report on Elk Basin by C. J. Hares

GEOLOGIC MAP AND SECTIONS OF A PART OF MUSSELSHELL VALLEY, MONTANA

By C. F. Bowen

Based compiled from General Land Office plats and geologist's field sheets

Geology north of Musselshell River by C. F. Bowen; south of Musselshell River and west of Shawmut by C. F. Bowen and R. W. Stone; south of Musselshell River and east of Shawmut by C. F. Bowen and L. H. Woolsey

SEDIMENTARY ROCKS

QUATERNARY
- Qal — Alluvium

TERTIARY — Miocene ? and Eocene ?
- Tg — Terrace gravel

TERTIARY (?) — Eocene ?
- Tl — Lance formation

CRETACEOUS — Upper Cretaceous — Montana group
- Kbs — Bearpaw shale
- Kjr — Judith River formation (Including at base, for convenience of mapping, a sandstone which seems to be the stratigraphic equivalent of the sandstone included in the Horse Creek member of the Claggett in the eastern part of the Big Horn Basin)
- Kcl — Claggett formation
- Ke — Eagle sandstone
- Kbe — Colorado shale with Big Elk sandstone member (Kbe) in lower part
- Kk — Kootenai formation — Lower Cretaceous

IGNEOUS ROCKS

TERTIARY — Eocene
- Ti — Intrusive andesite porphyry and therallite with some included sediments
- Dike

Structure contours on base of Eagle sandstone
a. Error probably less than 50'
b. Inferred position where nearly horizontal
c. Inferred position where moderately dipping
(Interval 50'. Figures indicate elevation above sea level)

Geologic boundaries
Solid line, accurately located; dashed line, approximately located; dotted line, probably concealed; dashed line, inferred

Fault

Escarpment at edge of hard beds

Strike and dip of sedimentary beds

Axis of anticline

Axis of syncline

Government land corner found