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THE GEOLOGY OF THE INGOMAR ANTICLINE TREASURE AND ROSEBUD COUNTIES MONTANA

BY

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THE GEOLOGY OF THE INGOMAR ANTICLINE, TREASURE AND ROSEBUD COUNTIES, MONTANA

By K. C. HEALD

INTRODUCTION

Field work.—The data presented in this report are based on field work by K. C. Heald and W. W. Rubey in October, 1922. Division of mapping by the two observers is indicated on the small diagram on Plate 1. The observers worked singly, determining locations and altitudes by triangulation. Outcrops of certain beds were traced continuously, so far as this was possible.[1] Geologic structure was determined by means of numerous observations of altitude on beds of known stratigraphic position, supplemented by dip and strike observations, which, wherever the method seemed justified, were made by determining relative position and altitude of three points on single beds with outcrops 10 feet or more in extent. Where maximum dips could not be certainly observed components of the dips were recorded and used in determining the structure.

Acknowledgments.—The writer takes pleasure in acknowledging his indebtedness to the Absaroka Oil & Development Co. for information furnished through the company's chief geologist, Mr. A. A. Hammer, and to Mr. Darwin Harbicht, of Ingomar, whose knowledge regarding conditions in the Ingomar region greatly facilitated and expedited the geologic work.

Publications with a bearing on the Ingomar area.—The only publications dealing specifically with the Ingomar area are a short notice issued to the press August 1, 1921, by the United States Geological Survey giving the results obtained in a brief examination of the Ingomar anticline made in June, 1921, by W. T. Thom, jr., and C. E. Dobbin, of the Geological Survey; and University of Montana Bulletin 4, by C. H. Clapp, Arthur Bevan, and G. S. Lambert, dealing with the geology and oil and gas prospects of cen-

[1] The relative stratigraphic position of these beds is indicated on Plate 1 by arbitrarily chosen numbers, No. 1 indicating the lowest bed, and so on.

tral and eastern Montana, published in June, 1921. The press notice was accompanied by the only map showing the geologic structure of the anticline which has, to the writer's knowledge, been published. Neither of the papers mentioned describes in detail the stratigraphy of the area.

C. F. Bowen, in Bulletin 621 of the United States Geological Survey, published in 1916, and also in Professional Paper 125, gave details of stratigraphy observed in the Porcupine dome, a few miles to the east. Certain stratigraphic details mentioned in Geological Survey Bulletin 611, "Guidebook of the western United States, Part A," published in 1915, also relate to this region. The descriptions of the Judith River formation and discussions dealing with its character and correlation may with advantage be read by any geologist who contemplates work in this area, both because the observed details may be of help to him and because he is more likely in turn to observe something that will be a contribution to knowledge regarding the Judith River formation if he is thoroughly acquainted with previous ideas regarding its character, correlation, source, and conditions of deposition. Among works of this nature are those cited below:

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

Stanton, T. W., and Hatcher, J. B., The stratigraphic position of the Judith River beds and their correlation with the Belly River beds: Science, new ser., vol. 18, p. 212, 1903.

Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River Beds: U. S. Geol. Survey Bull. 257, 1905.

Peale, A. C., On the stratigraphic position and age of the Judith River formation: Jour. Geology, vol. 20, pp. 350–549, 640–652, 738–757, 551–557, 652–669, 741–761, 1912.

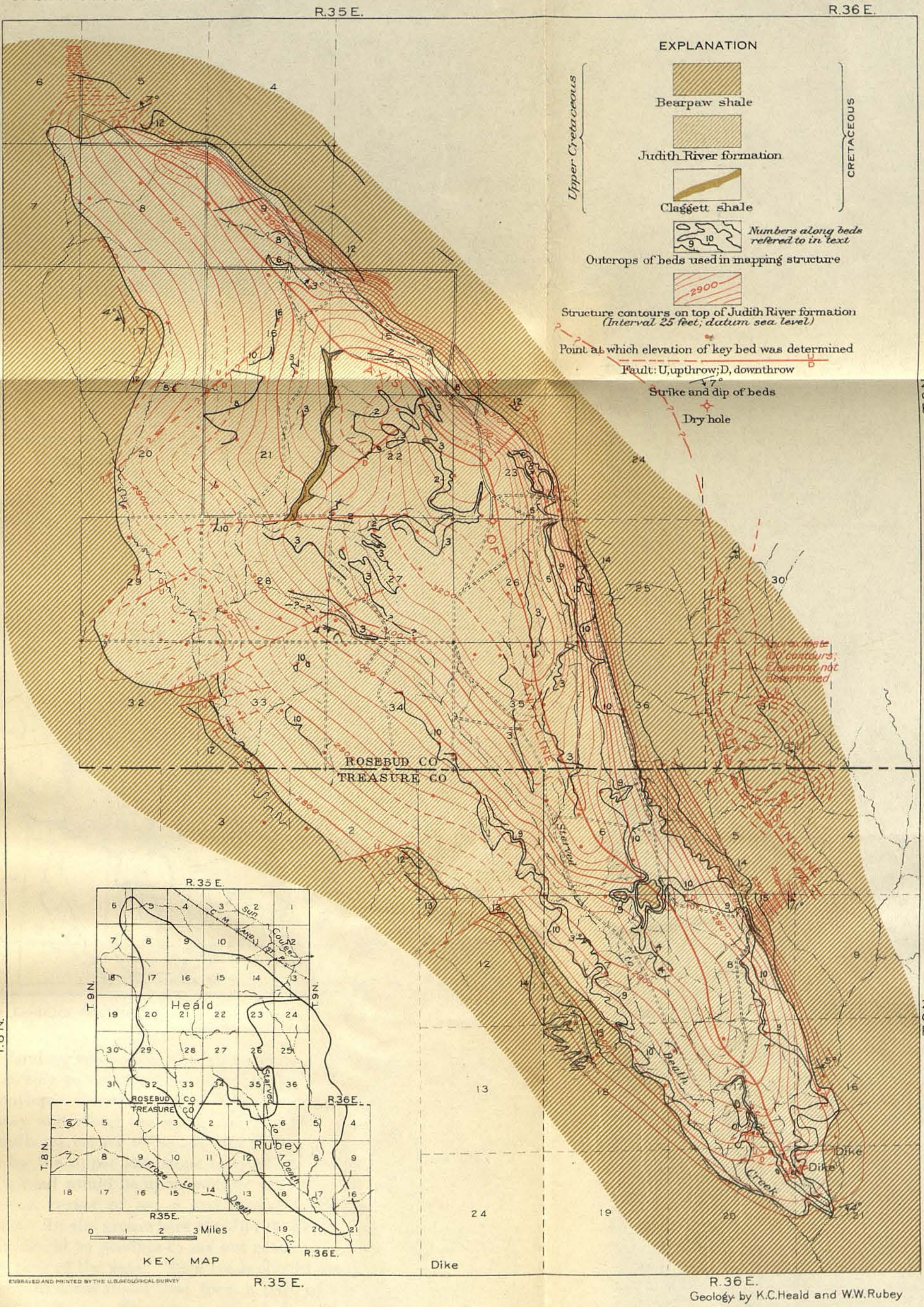
Bowen, C. F., Possibilities of oil in the Porcupine dome, Mont.: U. S. Geol. Survey Bull. 621, pp. 61–70, 1916.

Bowen, C. F., Gradation from continental to marine conditions of deposition in central Montana during the Eagle and Judith River epochs: U. S. Geol. Survey Prof. Paper 125, pp. 11–21, 1919.

Hancock, E. T., Geology and oil and gas prospects of the Huntley field, Mont.: U. S. Geol. Survey Bull. 711, pp. 105–148, 1920.

GEOGRAPHY

Location.—The Ingomar anticline lies in T. 9 N., R. 35 E., and T. 8 N., Rs. 35 and 36 E. Montana principal meridian, Rosebud and Treasure Counties, Mont. (See fig. 1.) The anticlinal fold passes beyond the boundaries of the townships named, but that part which is of interest in connection with the possible occurrence of oil or gas falls within their limits. The nearest town is Ingomar, on the Chicago, Milwaukee & St. Paul Railway, about 1¼ miles northwest



GEOLOGIC MAP OF THE INGOMAR DOME, ROSEBUD AND TREASURE COUNTIES, MONT.

Scale $\frac{1}{63,360}$

1 0 1 2 MILES

of the northwesternmost outcrop of Judith River sandstone brought up by the anticline, and only a little more than half a mile north of the axis of the anticline, which there trends northwestward across an area of Bearpaw shale.

Roads.—Supply points for drilling activities on the anticline are the town of Ingomar and the flag station of Thebes, about 6 miles east of Ingomar. The Electric Highway, which passes through Ingomar and skirts the northwest flank of the anticline for about 3 miles, is an excellent automobile road for dry-weather hauling. During wet weather the Bearpaw shale, over which this highway is in part constructed, forms a very sticky mud on which heavy hauling is almost impossible. Therefore if it becomes desirable to do

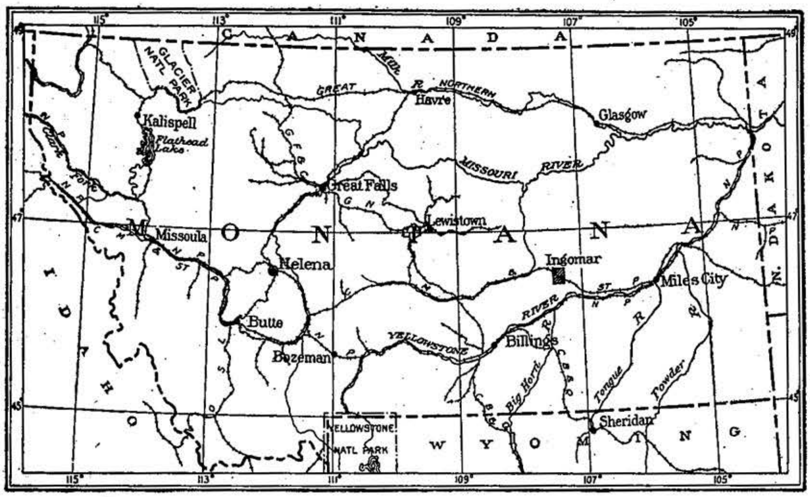


FIGURE 1.—Index map showing location of Ingomar anticline, Treasure and Rosebud Counties, Mont.

much hauling when such weather conditions prevail it will probably be desirable to construct a road diagonally from the northwest to the southeast corner of sec. 8, T. 9 N., R. 35 E., thence follow the highway east along the south line of sec. 9, leave the highway at the southeast corner of sec. 9, and follow the crest of the hogback made by the upper sandstone beds of the Judith River formation. Such a road would be upon sand or sandstone all the way from the northwest corner of sec. 8 and should be passable in almost any weather. In the area where the Judith River is the surface formation it should be possible to lay out roads to reach almost any point at any time of the year. Such roads should detour to avoid outcrops of the bentonitic shales that form a part of the middle member of the Judith River. These bentonitic shales cover small areas in secs. 15, 16, 21, 22, and 27, T. 9 N., R. 35 E., and in the bottoms of some of the deeper valleys, as in sec. 8, T. 8 N., R. 36 E.

The road between the northwest corner of sec. 8, T. 9 N., R. 35 E., and Ingomar runs over Bearpaw shale and must be surfaced if it is to be made passable during wet weather. No alternate route that may be selected will obviate this difficulty, nor is there an easily accessible source of surfacing material. The sandstone beds of the Judith River and Lance formations crumble into incoherent sand under traffic, and there are no limestones or siliceous shales in either the Bearpaw shale or the Judith River formation. Experiments with the heavy limestone concretions of the Bearpaw shale to test their suitability for road surfacing are desirable. There are zones in the Bearpaw shale where these concretions lie almost in contact with one another over wide areas. It has been suggested that if these concretions were crushed they would form a very fair self-binding road metal, but so far as the writer is aware their use has never been attempted.

If oil in quantity is ever found on the Ingomar anticline it will doubtless be to the advantage of the oil companies to construct either a very high crowned road with elaborate provisions for drainage or a hard-surface road between the northwest corner of sec. 8 and Ingomar.

Relief.—The Ingomar anticline is almost encircled by a line of low hills with smooth outer slopes, inclined gently and evenly away from the center of the fold, and steeper inner slopes, roughened in places by craggy ledges of gray sandstone, facing toward the axis of the anticline. Inside this barrier there are flats, low ridges, and a few isolated hills, with a network of intervening small water-courses, dry except during wet weather, that unite to form valleys that break through the encircling wall of hills and connect with the main drainage channels of the region.

Differences in altitude between hill crest and valley bottom in the vicinity of the anticline are probably everywhere less than 200 feet and throughout most of the region are less than 100 feet. In fact, were it not for the gullies with their steep walls, it would be possible to drive a car almost anywhere in the region except up the steep face of the hills that encircle the anticline and over some hills inside this rim where heavy ledges of sandstone have induced the development of steep slopes and low cliffs.

Almost everywhere throughout the Ingomar region the character of the surface indicates accurately the character of the rocks that underlie it. Ridges are without exception due to the presence of the more resistant rocks. Thus the line of hills that encircle the anticline is due to thick beds of sandstone in the upper part of the Judith River formation. Ridges farther from the axis of the fold are due to zones in the Bearpaw shale that contain many concretions of limestone and of siderite. The low conical hills apparently occur only where concretions in the Bearpaw shale are particularly numerous. Broad, smooth slopes are developed on the tops of inclined beds of sandstone or of zones of concretions in the shale. Most of the flats that are not in valley bottoms signify that the underlying rocks are flat-lying or nearly so, although a few miles from the anticline there are remnants of a smooth upland surface that probably extended over the Ingomar region before the vigorous cutting that produced the present topography began.

Figure 3, a sketch profile across the anticline, gives an idea of the way the geologic structure is indicated by the topography.

Drainage.—The Ingomar region is drained by the Yellowstone River system, to the south, through Froze to Death and Starved to Death Creeks and their tributaries. Small valleys and draws that feed the major streams have been formed so extensively both over and around the anticline that, except for a few very small wind-scooped hollows, there are no undrained areas.

Water supply.—There are no permanent streams in or near the Ingomar anticline, although pools of water stand in the beds of Froze to Death Creek and its large tributaries except in very dry years. Water for human consumption and for stock is obtained from a number of never-failing springs supplemented by wells within the rim of hills that encircles the anticline. There are a few springs in the Bearpaw shale outside this line of hills, and a few wells that have yielded water have been dug or bored in this shale, but such springs and wells almost invariably yield water unfit for human consumption, and some of the spring water is also unfit for stock because of its mineral content. The high mineral content renders the Bearpaw water unsuitable for use in boilers.

Springs and wells inside the rim of hills that inclose the anticline obtain their supply from the Judith River and Claggett formations. The best water seems to come from thick sandstones in the upper part of the Judith River formation, but water from silty sandstones near the middle of the formation is also potable, although, to judge from the deposits near springs, it has a greater mineral content than the water higher in the formation. The water in the uppermost sandstone bed of the Claggett formation appears to be both less in amount and poorer in quality than waters from the Judith River beds.

Supplies ample for use in oil-well drilling can be developed at any one of a number of springs or wells. The water for the Absaroka Oil & Development Co.'s test well in sec. 26, T. 9 N., R. 35 E., was pumped from a spring in sec. 23, T. 9 N., R. 36 E.

It seems probable that water suitable for both domestic and industrial purposes could be obtained in the area where the Bearpaw shale crops out by drilling to the Judith River formation, which should lie less than 1,500 feet below the surface anywhere between the Ingomar anticline and the Porcupine dome.

Culture.—The only settlement with more than one of two families near the Ingomar anticline is the town of Ingomar, which has a population of about 200. Although small, it is a shipping center of importance to the sheep industry, which is highly developed in the surrounding region, and of less importance as a shipping point for cattle. Dry-land farming has been attempted with discouraging results wherever the Judith River formation is at the surface. Elsewhere the clays of the Bearpaw formation yield a lean soil that is apparently not suitable for raising crops. Most of the area has been homesteaded and either is or was at one time privately owned, but crop failures, low prices for the produce that was raised, and high costs of machinery and living necessities have combined to drive the owners from the land, so that now abandoned houses are characteristic features of the landscape.

Fuel.—The Ingomar anticline and the region immediately surrounding it are practically bare of trees. Even the sagebrush is stunted on much of the upland area, although in some of the valleys it grows luxuriantly. Wood for fuel must be hauled many miles from the pine-bearing outcrops of the Lance and Fort Union formations. Coal would naturally be used for fuel in any extensive drilling operations. Coal is mined near Roundup, only about 70 miles from the town of Ingomar, so there should be little difficulty in obtaining an adequate and fairly cheap supply. A showing of gas encountered at about 520 feet in the well drilled by the Absaroka Oil & Development Co. encourages a hope that gas enough for drilling may be found somewhere on the anticline.

STRATIGRAPHY

ROCKS EXPOSED

The rocks exposed on and adjacent to the Ingomar anticline are sedimentary shales and sandstones of Cretaceous age and a few dikes of igneous rock. Most of the sediments are of marine origin, but a few were formed where the water was brackish, and others were probably deposited by streams. Three formations are exposed in whole or in part on the anticline—the lower part of the Bearpaw shale, which consists of clay shale with thin streaks of bentonite, limy concretions, and very thin, discontinuous layers of sandstone; the Judith River formation, which comprises sandstone and shale with a little bentonite; and the uppermost part of the Claggett shale, which appears to be represented on the Ingomar anticline by a soft, massive sandstone. The igneous rock in the dikes is a porphyritic lamprophyre. To the southwest of the Ingomar anticline the Bearpaw shale is overlain by the Lance formation, of Tertiary (?) age.

Over most of the area the outcrops of the Judith River and Claggett formations can be easily distinguished from those of the Bearpaw, for the Judith River and Claggett tend to produce hilly surfaces with sandy soil, in contrast to the smooth flats, ridges, and conical hills covered with clay soil that are characteristic of the Bearpaw exposures, but in a few places, notably on the west flank of the Ingomar anticline, where the rocks lie almost flat, the surfaces underlain by the Judith River and Bearpaw formations are so similar that it is difficult to say where one formation stops and the other begins.

BEARPAW SHALE

The Bearpaw shale surrounds the Ingomar anticline and crosses its axis in sec. 21, T. 8 N., R. 36 E., and sec. 6, T. 9 N., R. 35 E. Near the south end of the anticline there are a few small outliers that cap low hills. Elsewhere it has been stripped from the anticline. There is no sharp line of division between the Bearpaw and the underlying Judith River formation—in fact, a collection of brackish-water fossils obtained from a sandstone near the top of the beds mapped as Judith River was considered by Reeside[1] a Bearpaw rather than a Judith River fauna. The boundary mapped between the Bearpaw and Judith River formations is a convenient lithologic dividing line, but it is probably not the precise boundary for the highest mappable sandstone bed (the one containing the Bearpaw fossils) was considered the uppermost bed of the Judith River formation. The contact between the Bearpaw shale and the overlying Lance formation was neither mapped nor studied.

The thickness of the Bearpaw shale was not measured in this field work, although it was determined at more than 600 feet. Bowen[2] states that on the Porcupine dome, to the east, it is 900 to 1,100 feet, while Woolsey, Richards, and Lupton[3] believed it to be more than 1,000 feet in the Bull Mountain coal field to the west. It therefore seems reasonable to ascribe a thickness of about 1,000 feet to the formation in the vicinity of the Ingomar dome.

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[1] Personal communication.

[2] Bowen, C. F., Gradations from continental to marine conditions of deposition in central Montana during the Eagle and Judith River epochs: U. S. Geol. Survey Prof. Paper 125, p. 12, 1920.

[3] Woolsey, L. H., Richards, R. W., and Lupton, C. T., The Bull Mountain coal field, Musselshell and Yellowstone Counties, Mont.: U. S. Geol. Survey Bull. 647, p. 18, 1917.

Probably 95 per cent or more of the entire thickness of the formation is shale, deposited under marine conditions. The remaining 5 per cent consists of limestone and siderite in the form of concretions and bentonite in layers 2 feet or less thick. The concretions occur in bands or zones, some of which may be traced for miles, although most of them are probably much less persistent. Some of these concretions are distinctive in color, size, or shape. For instance, one band of closely spaced reddish-brown concretions, none of which appeared more than 2 feet in diameter, was noted. Another band of concretions near the Judith River-Bearpaw contact contained fragments of fossil plants. Others were notable for the abundance and perfect preservation of the fossils that occurred in them. No characteristics were noted that could be relied upon for positive identification, but there were several that aided continuous tracing of concretion-bearing layers in the shale.

Although generally similar throughout, in detail the shale that makes up the Bearpaw is uniform in neither appearance nor composition. Much of it is massive, without easily detected bedding planes, but there are also layers of brown to dark-gray fissile shale that, at least in places, is carbonaceous. These layers of fissile shale are particularly important in geologic work, because they can be traced without great difficulty, and they exhibit definite bedding planes on which determinations of dip and strike can be made. In spite of the great thickness of the Bearpaw shale in this district there is little doubt that by careful work thin members of it can be traced with sufficient precision to determine the structure of the area in which it forms the surface rock.

The stratigraphic section given below is a composite of several partial sections and probably contains minor inaccuracies, although it is believed that the measurements are fairly accurate.

Section of Bearpaw shale on the flanks of the Ingomar anticline

	Feet
Top, somewhere in Bearpaw shale.	
Shale, light brownish gray, massive, littered with chips of light-gray calcareous concretions that carry many fossils including *Inoceramus* and *Baculites*	12
Brownish-gray massive shale without concretions	34
Dark-gray fissile shale; breaks into thin plates	19
Shale, medium brownish gray, massive. At the top occurs an irregular line of small concretions, about 1½ inches in diameter and three-fourths inch thick, brownish gray on weathered surface, light gray on fresh surface. A fragment of a large cephalopod was found at this horizon. At the base of this shale band is a bed of bentonitic material about 2 feet thick that may be either ocherous or greenish, and contains needles of selenite	18

	Feet
Two lines of concretions with interbedded shale. The concretions are dove-gray on weathered surface, dark gray on fresh surface. They contain fragments of large *Baculites*. The interbedded shale is gray and fissile	6
Shale, massive, light brownish gray on weathered surface	13
Shale, massive, medium brown to dark brown on weathered surface. At the top of this layer is a line of calcareous concretions, dark gray to brownish on weathered surface, about 2 feet in greatest dimension and an inch or less thick	14
Poorly exposed. Contains some fissile dark-gray shale, but most of the interval is occupied by massive brownish-gray shale with a few inconspicuous layers of concretions and some thin bands of bentonite	190
Shale, light to medium brownish gray, massive. At the top is a zone of concretions, light to medium gray on fresh surface, dove gray to grayish brown on weathered surface. Individual concretions average about 2½ feet in diameter and 1 foot thick. No fossils were found	38
Shale, most of thickness massive, but some fissile shale near top. Massive shale is brownish gray; fissile shale light gray. At the top of the shale are concretions, dove-gray on fresh surface, with thin bands of dark aragonite and honey-yellow calcite, from 1 to 2 feet in diameter and about 1 foot thick. Contains a few pelecypods	38
Shale, poorly exposed. Most of it is massive and light brownish gray. Discontinuous line of concretions at top, grayish brown on weathered surface, dark gray on fresh surface; average about 1 foot in diameter	68
Shale, fissile, light gray to purplish brown, with one or more thin beds of bentonite associated. At the top is a zone of concretions that weather grayish brown but are dove gray on fresh surface. Concretions contain veins of honey-colored calcite and also some pelecypods	20
Shale, massive and brownish gray near top, more fissile near bottom. At the top of this shale is a layer of very ferruginous concretions, 1 to 3 feet in diameter and perhaps as much as 1 foot thick. The concretions are cut by veins of yellow calcite and contain a very few small pelecypods	50
Judith River formation. In some places soft gray sandstone, in others brown carbonaceous shale is in contact with the Bearpaw.	

The oil geologist may be interested in the detail of the Bearpaw shale in this region, as there are large areas where it is the only surface formation, and he must have a knowledge of these details to be able to interpret the structural conditions correctly. He may also be interested in the fact that the basal part of the Bearpaw shale was evidently laid down in shallow water near shore, and that this basal part contains some beds of shale that appear rich in organic matter, suggesting that they may be a source of oil or of gas where conditions of cover, water circulation, and structure are favorable.

JUDITH RIVER FORMATION

The Judith River formation in the Ingomar area is exposed only over the crest of the anticline where it occupies an oval area about 10 miles long and 3½ miles wide in T. 9 N., R. 35 E., and T. 8 N., Rs. 35 and 36 E. It is overlain on the flanks of the anticline by the Bearpaw shale. The contact between the two formations is not sharp, and the boundary adopted for mapping is paleontologically doubtful.

The age of the Judith River formation in this region is revealed by its relation to the Bearpaw shale, which immediately overlies it and which can be traced continuously to areas where its age has been established by previous work. Fossil collections gathered from both the Bearpaw and the Judith River formations on and near the Ingomar anticline leave no doubt as to the correctness of the general formation identifications, even if the relations of the Bearpaw and Judith River and the similarity of the Judith River formation in the Ingomar region to the same formation in near-by areas were not in themselves conclusive.

The thickness of the formation on the Ingomar anticline is about 245 feet. The figure was obtained by combining many measurements, each covering a part of the formation. There are undoubtedly local variations in thickness, but the figure given is an average that is believed to be within 20 feet of the thickness on any part of the anticline. It shows that the formation is more than twice as thick as it is on the Porcupine dome, where Bowen[4] measured a section about 20 miles north and a little east of the Ingomar anticline, for he records thicknesses of 115 feet in sec. 8, T. 12 N., R. 38 E., and 125 feet "near head of Big Porcupine Creek," and in both measurements he includes a basal sandstone that probably corresponds to a sandstone that on fossil evidence has been mapped as Claggett in the Ingomar area.

The formation falls naturally into two divisions—an upper sandy member about 85 feet thick, and a lower member that is also sandy but that contains thick beds of shale, in all about 160 feet thick. The underlying Claggett has at its top a sandstone that might be included in the Judith River because of similarity in lithology and absence of any detectable erosional break at its upper surface, but the fossil evidence shows it to be Claggett. Seemingly it corresponds to a sandstone that was included in the Judith River formation in the Lake Basin and Huntley area by Hancock,[5] who says,

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[4] Bowen, C. F., Gradations from continental to marine conditions of deposition in central Montana during the Eagle and Judith River epochs: U. S. Geol. Survey Prof. Paper 125, p. 15, 1920.

[5] Hancock, E. T., Geology and oil and gas prospects of the Huntley field, Mont.: U. S. Geol. Survey Bull. 711, p. 121, 1920.

"The most resistant sandstone * * * is the one that seems to be the approximate equivalent of the upper part of the Claggett formation in its type area, but for convenience of mapping it is here treated as the base of the Judith River formation," and to a similar sandstone included in the Judith River in the Tullock Creek coal field by Rogers and Lee.[6]

Upper member.—The upper member is for the most part sandstone, but there are also some beds of shale, and in some places the upper sandstone beds seem to pinch out and give way to carbonaceous shale with one or more streaks of coal 2 inches or less thick. In other places massive sandstones grade laterally into thin sandstones with interbedded gypseous shales. The conditions are interpreted diagrammatically in Figure 2, and the appearance of

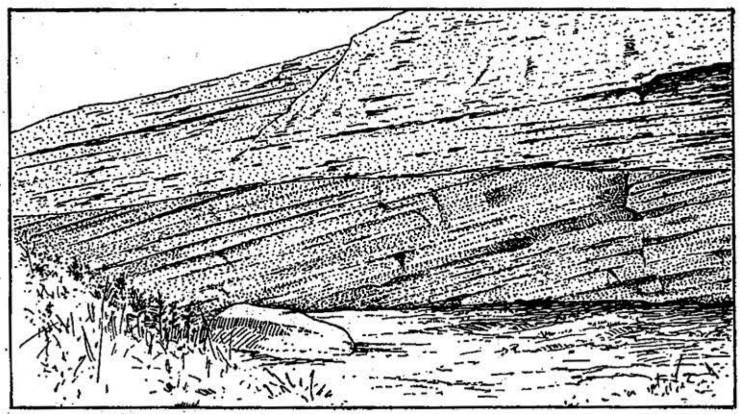


FIGURE 2.—Detail of cross-bedding in the upper part of the Judith River formation

different phases of the upper beds of the Judith River is illustrated in Plate 2.

These upper beds of the Judith River formation in this region appear to be delta deposits that were laid down along the margin of a shallow sea. Presumably the material was transported by sluggishly moving streams or by coastal currents, and part of it was dropped in brackish water, where the salinity of the sea was lessened by the rivers, while elsewhere fresh-water conditions prevailed. In such an environment there would be some swamps bordering lagoons and sounds where flourishing vegetation would result in the accumulation of carbonaceous shale and thin coal beds, but apparently conditions in the shallow sea did not favor the existence, or at least the preservation, of much carbonaceous or bituminous matter in the marine beds. Undoubtedly such accumulations gath-

[6] Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek coal field, Rosebud and Big Horn Counties, Mont.: U. S. Geol. Survey Bull. 749, pp. 13–16, 1923.

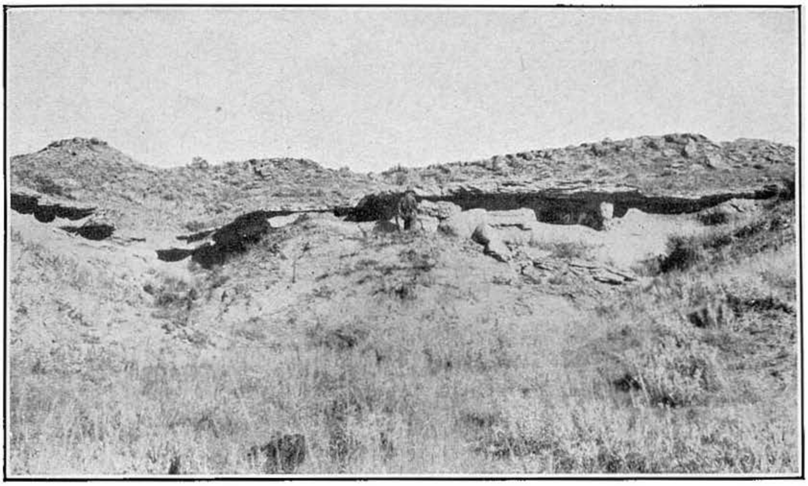
ered in local areas, and there black shales rich in bituminous matter will be now found in the basal part of the Bearpaw shale or in the Judith River formation, but such areas will probably be small.

The sandstones in the upper part of the Judith River formation are brownish gray or white on exposed surfaces and almost everywhere brownish gray on fresh surfaces. They are composed of quartz, feldspar, black chert, mica, and a very few other constituents. In places the feldspar content is so high that the rock might appropriately be classified as an arkose or graywacke. The chert may make up from 2 to 20 per cent of the rock. The micas, muscovite and biotite, although apparently present in every bed, are rarely conspicuous. The grains are small, and, as is common in fine-grained rocks, many of them are angular.

In places certain beds in the upper sandstone member are conspicuously cross-bedded, and some alternating beds of shale and sandstone were also noted to dip as much as 20° in one direction where the true dip was about 3° in the opposite direction. In small exposures cross-bedding of this type may easily be misinterpreted as true dip due to fault drag or sharp folding, and it is therefore important to recognize the presence of steep depositional dips. Casts of *Halymenites major* occur throughout the formation on the Ingomar anticline, and some beds contain great numbers of these nubbly, branching fossils. Other fossils are scarce except in the sandstones near the contact between the top of the sandy zone and the shale that has been considered the base of the Bearpaw, where great numbers of fossil pelecypods, many of them as typical of the Bearpaw as of the Judith River, were found.

The shales in the upper part of the Judith River formation range in color from brown to light gray. In places the gray shales are very sandy; the brown shales owe their color to limonite and to carbonaceous matter. Gypsum, in white powdery crystals, large colorless translucent crystals, and joint and fissure fillings, is common in all the shale beds. Bands of limonitic clay 2 inches or less in thickness are common and in places grade into material so limy that it may be classified as limestone. Near the top of the formation the carbonaceous shales contain a few very thin lenses of coal, which is of interest only in relation to the origin of the beds.

The upper member of the Judith River formation is well exposed in the SE. ¼ sec. 6 and at the southeast corner of sec. 15, T. 9 N., R. 35 E., and from the latter point southeastward along the ridge that marks the east flank of the anticline. The shale phase of the upper part of the Judith River is well exposed along the east section line in the NE. ¼ sec. 32, T. 9 N., R. 35 E. Other exposures of the brown carbonaceous shale near the top of the formation may



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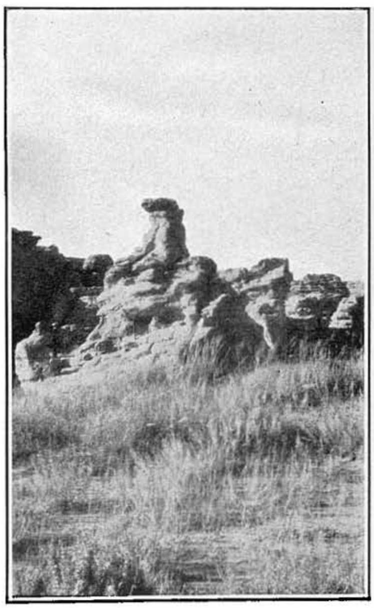

B C

UPPER BEDS OF THE JUDITH RIVER FORMATION

be seen along the west flank of the anticline and at its north end in sec. 5, T. 9 N., R. 35 E.

Lower member.—The lower member of the Judith River formation on the Ingomar anticline comprises beds of limonitic concretionary sandstone, uncemented sand, shale, and bentonite. The most conspicuous beds are the hard brown limonitic sandstones, which yield much more slowly to erosion than the overlying and underlying sands and shales, so that they now cap low steep buttes and ridges. The composition of these hard sandstones seems to be the same as that of the higher sandstones except for a dark-green mineral that was not identified and for the iron content, which is irregularly distributed, so that in places the rock is very hard and dark colored. In other places it is soft and light yellowish gray. Some of the concretionary zones can be traced for more than a mile, but for the most part the concretions are not confined to any definite bedding plane, and what looks like a continuous zone of concretions may transgress across the bedding planes.

The sands are like the concretionary sandstones except that they lack the limonite. The shales range in color from light gray to dark brown, and near the base of the formation there is a highly bentonitic shale about 6 feet thick that weathers light blue. Other shales in the member contain some bentonite, but only the bed mentioned has a percentage large enough to make it conspicuous. The beds of brown shale owe their color to plant débris. All the shales contain much gypsum.

Fossil wood has been found in many parts of the formation, but on the Ingomar anticline it is particularly characteristic of the zone that contains the limonitic concretionary sandstones. One silicified log 40 feet or more in length and with a butt over 2 feet in diameter was seen, but most of the fossil wood is in small fragments. The concretionary sandstones also carry bone fragments. Most of those found were too small to give a clue to the identity of the animal from which they came, but C. W. Gilmore, of the United States National Museum, recognized fragments of the shell of a turtle of the genus *Aspideretes*, and also fragments from the centrum and the tibia of a dinosaur. In these same sandstones there were a few casts of smooth-shelled pelecypods and multitudes of casts of *Halymenites major*.

Particularly good exposures of the lower part of the Judith River formation occur in secs. 21, 22, 27, and 28, T. 9 N., R. 35 E. This part of the formation may be recognized by the driller because of the succession of thin hard sandstones with intervening soft material, the greenish cast of some of the sandstones, and the tendency of the bentonite to swell and cave when it is wet.

Possibilities of oil in the formation.—The Judith River sediments on the Ingomar anticline do not seem promising as possible source beds of oil. However, the formation contains from 20 to 40 feet of shale that is carbonaceous and a little that seems bituminous. Gas has almost certainly been evolved from the organic matter in this shale, and its relations to possible reservoir beds and to thick shales that would hinder extensive migration across the bedding justify the hope that at least small gas pools will be trapped in the Judith River sandstones where these sandstones are under a few hundred feet of shale cover and where the carbonaceous beds are well developed. In the areas of carbonaceous shales water wells in the Judith River formation should also yield small volumes of gas—perhaps enough to be separated for lighting and heating a single house.

It appears that the conditions in central Montana during Judith River time did not favor the formation of black shale, bituminous limestone, or other sediments similar in type to those thought to be the source of oil in the oil fields of the United States. Apparently there was a broad plain bordered by a shallow sea without " deeps " or areas where large bodies of stagnant or " dead " water favored the accumulation and preservation of organisms that under other conditions would be quickly decomposed. This is also indicated by the nature of the shales in the basal part of the Bearpaw. If regional conditions were thus unfavorable it is to be expected that any areas where oil originated in the Judith River formation must be very small. The formation of gas, however, apparently does not require such highly specialized conditions as that of oil, and it is not surprising that volumes of gas have been found in beds that occupy the general position of the Judith River formation in the Glendive-Baker region.

ROCKS NOT EXPOSED

WELL LOG

Below the rocks that crop out on and around the Ingomar anticline lie some 3,000 feet of Cretaceous strata that have been penetrated by the drill, and the presence below them of about 2,500 feet more of sedimentary rocks can be forecast with a fair degree of certainty.

The driller's log of a well drilled in 1920 and 1921 by the Absaroka Oil & Development Co. is given below, with the writer's interpretation as to the formations penetrated:

Log of well of Absaroka Oil & Development Co. on the James Savage lease, in the NW. 1/4 sec. 26, T. 9 N., R. 35 E.

	Feet
Judith River formation:	
Cellar	0–20
Sandrock	20–65
Shale	65–85

	Feet
Claggett shale:	
Sand	85–94
Gray shale	94–520
Eagle (?) sandstone:	
Sandy shale with little gas	520–525
Gray shale	525–560
Sand	560–570
Colorado shale:	
Shale	570–830
Hard shell	830–832
Gray shale, practically no change	832–1, 806
Hard sand	1, 806–1, 810
Dark shale	1, 810–2, 040
Shale, more brown, and thin hard streaks of sandy rock a few inches to a foot and a half thick	2, 040–2, 285
Gray shale, soft and very cavey with pieces of green shale and chunks of soapstone	2, 285–2, 350
Black shale	2, 350–2, 485
Shale	2, 485–2, 675
Lime shell	2, 675–2, 685
Shale	2, 685–2, 690
Shale, some sand	2, 690–2, 745
Limy gray sand	2, 745–2, 800
Dark-gray shale	2, 800–2, 835
Dakota (?) sandstone:	
Fine gray sand, limy	2, 835–2, 843
Black shale	2, 843–2, 850
Dark sandy shale	2, 850–2, 858
Gray sand, lime	2, 858–2, 865
Fine-grained sandy lime	2, 865–2, 873
Fine white sand	2, 873–2, 879
Dark sandy shale; no lime	2, 879–2, 886
Gray sand with dark-red grains	2, 886–2, 894
Fine gray sand; some red particles	2, 894–2, 900
Kootenai formation:	
Red shale	2, 900–2, 907
Soft dark shale	2, 907–2, 925
Red shale	2, 925–2, 932
Soft red and gray shale	2, 932–2, 938
Soft dark-gray shale	2, 938–2, 944
Chiefly gray shale	2, 944–2, 950
Soft red shale	2, 950–2, 957
Mostly red lime; some shale	2, 957–2, 962
Red limy shale	2, 962–2, 976
Red shale	2, 976–2, 992
Gray shale	2, 992–3, 000
Gray and red shale	3, 000–3, 008
Maroon shale	3, 008–3, 016
Gray sandy shale	3, 016–3, 024
Soft sandy maroon and gray shale	3, 024–3, 027
Sand, limy, gray	3, 027–3, 034
Gray sand; some lime	3, 034–3, 038
Fine-grained angular white to gray sand; some iron pyrite	3, 038–3, 040

CLAGGETT SHALE

Area covered in Ingomar anticline.—The top bed of the Claggett shale (a soft massive sandstone about 40 feet thick) is exposed in a small area where streams have cut deeply into the sediments over the axis of the Ingomar anticline. The narrow strip where Claggett rocks are exposed covers less than half a square mile, in secs. 15, 16, 21, and 22, T. 9 N., R. 35 E. So little has been removed by erosion that practically the entire thickness of the Claggett everywhere underlies the Ingomar anticline.

Correlation.—The Claggett shale on the Ingomar anticline was identified by the fossils it contains. The exposed part of the formation consists of sandstone and interbedded shale so similar to the overlying Judith River rocks that until the fossils were identified it was thought that the sandstone represented the basal part of the Judith River and that no Claggett was exposed. However, a good collection of invertebrate fossils was obtained from the sandstone, and J. B. Reeside said of it that "so far as there is a distinctive Claggett fauna this assemblage, with the addition of *Tancredia americana*, would represent it very well." Mr. Reeside's determinations are given below.

Pteria nebrascana (Evans and Shumard).
Pteria linguaeformis (Evans and Shumard).
Ostrea sp. undet.
Pecten (Syncyclonema) rigida Hall and Meek.
Modiola attenuata (Meek and Hayden).
Anatina lineata Stanton.
Liopistha undata Meek and Hayden.
Lucina subundata Hall and Meek?
Sphaeriola? endotrachys Meek and Hayden.
Cardium speciosum Meek and Hayden.
Legumen planulatum Conrad?
Mactra gracilis Meek and Hayden.
Lunatia subcrassa Meek and Hayden.
Cinulia concinna Hall and Meek.

There is no indication of an unconformity between the Claggett and Judith River formations on the Ingomar anticline, and it seems certain that here, as elsewhere in Montana, there is a perfect gradation between them. In western Montana, where the two formations are differentiated on the basis of their respective marine and continental origin, there is much more justification for distinguishing between them than here, where at least a part of the Judith River formation is marine. To the east it becomes practically impossible to draw a line that will mark a definite change in conditions of deposition, and it is quite impossible to pick out the horizon that served as the line of demarcation between the two formations near their type localities in north-central Montana.

Character.—The Claggett shale on the Ingomar anticline is thought to be about 435 feet thick. A positive statement as to its thickness is not justified, for although it seems very probable that sandy shale recorded as occurring at a depth of 520 feet in the Absaroka Oil & Development Co.'s well on the anticline represents the Eagle, there is no proof to establish this beyond question. Figures of thickness must perforce depend on well records, as there are no exposures near by where the entire thickness can be measured. On the McGinnis Creek (Alice) dome, about 24 miles north of Ingomar, the thickness is apparently about 500 feet. Still farther north, in the Cat Creek area, Reeves [7] found an average thickness of about 430 feet. In the Huntley area, east of Billings and about 60 miles southwest of the Ingomar anticline, Hancock [8] found an average thickness of about 550 feet and in the Crow Indian Reservation, still farther south and west, Thom [9] determined the average thickness to be 400 to 500 feet.

The records of wells show the Claggett to consist almost entirely of shale throughout the eastern part of Montana. This is to be expected, as the massive sandstones that are so prominent southwest and west of Billings thin and disappear eastward. The exact nature of the shale penetrated by the wells can not be determined, for practically without exception the drillers have recorded it simply as "shale," with no comment on its variations in color, hardness. or mineral composition.

The sandstone at the top of the Claggett formation on the Ingomar anticline is about 40 feet thick. Like the sandstones of the Judith River formation it is composed chiefly of quartz and colorless feldspar, with very minor amounts of black chert, mica, and a few dark minerals, though it may contain distinctive mineral constitutents.

The upper sandstone bed in the Claggett shale is in places strongly cross bedded. Here and there indurated masses make prominent knobs, towers, or more irregular figures. Lentils of dark-gray shale a few inches to several feet long and a fraction of an inch to 3 inches thick are common. In places there are many casts of the probable seaweed *Halymenites major*, although no place was seen where these are as abundant as they are in some of the Judith River sandstones. The top of the sandstone is limonitic and grades through a series of thin sandstones and interbedded shales into a thick bed of sandy shale with some layers of clean gray shale that are free from sand.

Origin.—The shales and sandstones of Claggett age were probably deposited in a wide-spreading flat-bottomed sea that en-

[7] Reeves, Frank, Oil fields of central Montana: U. S. Geol. Survey Press Bull., 1920.

[8] Hancock, E. T., Geology and oil and gas prospects of the Huntley field, Mont.: U. S. Geol. Survey Bull. 711, p. 110, 1919.

[9] Thom, W. T., jr., Oil and gas prospects in and near the Crow Indian Reservation, Mont.: U. S. Geol. Survey Bull. 736, p. 38, 1922.

croached westward upon the land when the eastern two-thirds of Montana subsided uniformly and with relative rapidity. The change from the conditions under which the Eagle sandstone accumulated to those that gave rise to the Claggett beds shows that the shore line of this sea moved westward more than 100 miles in a very short time. The subsidence was probably a uniform sinking rather than a tilting that would permit the sea to creep gradually over the old land surface. This sea was gradually filled with the muds that formed the Claggett shales by rivers that brought their load from a land mass that was probably located in western Montana, Idaho, Washington, and Oregon.

Possible value as a source of oil.—Apparently the Claggett strata are not to be looked upon as a source of oil. The shales are somber in color and in places black, and this color must be due to a content of organic matter, but apparently this organic matter occurs in amounts so small as to have given rise to few if any accumulations of oil and gas that will prove commercially important. It is, of course, possible that the gas and oil that have been reported from the underlying Eagle sandstone and from the overlying Judith River sandstones have come in part or entirely from the Claggett.

It is not safe to disregard entirely the chance that any marine formation composed dominantly of shales that plainly show an appreciable content of organic matter may give rise to some important accumulations of oil or of gas, and reservoir beds associated with such a formation or fractured and fissured rocks in it should be studied carefully for traces of these substances, but the evidence now available would not justify prospecting in an area where the chances of finding oil appear to depend on its having originated in this formation.

EAGLE SANDSTONE

The Eagle sandstone, named by Weed [10] from exposures on Eagle Creek, in Chouteau County, Mont., is one of the most conspicuous formations of central Montana. In the type section on Missouri River it is considered to be the basal formation of the Montana group, but recent work [11] has shown that in some areas there are underlying shales which are also of Montana age and grade without perceptible break into shales of Colorado age. Bowen,[12] who made a careful study of its easternmost exposures, came to the con-

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

[11] Thom, W. T., jr., Oil and gas prospects in and near the Crow Indian Reservation, Mont.: U. S. Geol. Survey Bull. 736, p. 38, 1922.

[12] Bowen, C. F., Gradations from continental to marine conditions of deposition in central Montana during the Eagle and Judith River epochs: U. S. Geol. Survey Prof. Paper 125, pp 11–21, 1920.

clusion that it thins eastward and disappears west of the latitude of the Ingomar anticline, but the records of wells on this anticline and on the Maginnis Creek (Alice) dome, to the north, show about 40 feet of sandy shale and sandstone that very probably represent this formation. There are neither fossils nor lithologic evidence to check this correlation, but the position of the Eagle between two formations that consist predominantly of shale makes this assignment seem logical. It is believed by the writer that farther east the Eagle sandstone is represented by a sandy shale and that careful work may reveal characteristics other than its sandiness that will serve to identify it.

Showings of gas were yielded by the Eagle sandstone on the Ingomar and Maginnis Creek anticlines. This was to be expected, for the Eagle carries either gas or oil, particularly gas, in many places. In the Lake Basin district, west of Billings, both gas and oil are found in it. To the north, near Havre, wells have been yielding gas from it for many years. Many wells drilled where the Eagle is 300 feet or more beneath the surface have reported gas in this formation, but have made no attempt to exploit the gas, because there is little or no market for it near most of the localities where it has been found. In Wyoming the Shannon sandstone member of the Steele shale, which is probably, in part at least, equivalent to the Eagle sandstone, has yielded considerable volumes of oil in the Shannon, Pilot Butte, and Big Muddy fields. Clearly there is a source of gas and oil associated with this sandstone, either in the basal part of the overlying Claggett shale, in the topmost beds of the underlying Colorado shale, or perhaps in carbonaceous beds in the Eagle itself.

On the Ingomar anticline or east of it the chance of commercially important gas production from the Eagle sandstone seems negligible, but it is quite possible that this sandstone will yield enough gas for lighting and heating single houses or even small groups of houses.

COLORADO SHALE AND DAKOTA (?) SANDSTONE

The deposits of Colorado age, which underlie the Eagle standstone and overlie the Dakota sandstone where that formation is present, are divisible into several formations in most places where they appear at the surface but are rarely differentiated by well drillers and where undifferentiated are usually called Colorado shale, as they consist chiefly of shale. If the Colorado deposits of the Ingomar anticline are lithologically the same as those that occupy the same stratigraphic position in northeastern Wyoming they contain representatives from top to bottom of the Niobrara, Carlile, Greenhorn, and Graneros formations In south-central Montana, however, the Colorado group is divided lithologically into the Niobrara, Carlile, Frontier, Mowry, and Thermopolis formations. It appears that the deposits in the Ingomar region are more like those in northeastern Wyoming than those in south-central Montana, for there is nothing to suggest the sandstones of the Frontier formation in the log of the Ingomar well. They are, however, here treated as a unit and designated Colorado shale.

The Colorado deposits have a sandy base, and below them, in the Black Hills region and to the east, lies the Dakota sandstone. There is no sharp break between the Colorado and Dakota in eastern Wyoming, and it is the writer's belief that the Dakota can logically be considered a basal phase of the Colorado shale and that the overlying sandstones with intervening shales mark recessions and advances of the Colorado sea as it advanced from the south and east.

The well on the Ingomar anticline indicates that the combined thickness of the Colorado shale and the Dakota (?) sandstone is about 2,330 feet.

Thickness and character of Colorado shale.—The record of the well drilled on the Ingomar anticline by the Absaroka Oil & Development Co. shows the Colorado to be about 2,265 feet thick. The record is lamentably lacking in details, and little can be learned about the composition of the Colorado deposits beyond the facts that they are made up of shale, that is gray in the upper half, brown and bluish gray over an interval near the center, and black and gray near the base, with a very few thin beds of sandstone and limestone. One of these thin sandstone beds that is about 1,000 feet above the base of the Colorado may be the equivalent of the Mosby sandstone of the Cat Creek field.[13] Either a sandstone, a lime "shell," or a sandy shale is recorded at this horizon in the logs of most of the wells in this part of Montana that are deep enough to reach it.

The Colorado shale on the Ingomar anticline seems thick when compared to measurements of 1,985 feet or less on the Maginnis Creek (Alice) dome, 1,924 feet in the Cat Creek field,[14] 2,150 feet in the Huntley field,[15] about 2,050 feet in the Crow Indian Reservation,[16] and about 1,975 feet on the Porcupine dome.

The thickness at Vananda, about 20 miles southeast of the Ingomar anticline, is believed by the writer to be about 2,435 feet, or

[13] Lupton, C. T., and Lee, Wallace, Geology of the Cat Creek oil field, Garfield and Fergus Counties, Mont.: Am. Assoc. Petroleum Geologists Bull., vol. 5, No. 2, p. 253, 1921.

[14] Idem, p. 263.

[15] Hancock, E. T., Geology and oil and gas prospects of the Huntley field, Mont. U. S. Geol. Survey Bull. 711, pl. 15, 1920.

[16] Thom, W. T., jr., Oil and gas prospects in and near the Crow Indian Reservation, Mont.: U. S. Geol. Survey Bull. 736, pp. 38–40, 1923.

about 175 feet more than it is at Ingomar, although the well record on which the opinion is based is admittedly an imperfect one. The differences in thickness between the Colorado deposits at the Ingomar and Vananda wells and in the Cat Creek district are more apparent than real, for a part of the shale in the upper part of the Colorado on the Ingomar anticline and at Vananda is probably the homotaxic equivalent of the lower part of the Eagle sandstone farther north and west.[17]

Origin of Colorado shale.—The Colorado shale presumably originated from flocculent mud settling in a comparatively shallow sea. There is no conclusive evidence that the sea was shallow enough to permit occasional emergence of the muddy bottom, but the forms now fossil that lived in that sea are not deep-water types. The sea must have swarmed with life, as many of the beds of shale are black with bituminous or carbonaceous matter, and this makes it one of the most promising of the possible source beds of oil in the stratigraphic section of this region. There is no doubt that most of the light oil that has been produced in Wyoming originated is some member of the Colorado shale, and there is nothing to indicate that it is not quite as well adapted to yield oil in Montana. Unfortunately, however, in the Ingomar region there are no beds of porous sandstone interbedded with the fat black shale like the oil-yielding sandstones of the Frontier, Mowry, and Thermopolis formations of Wyoming, and consequently even if oil has originated in the Colorado shale it has not accumulated under conditions that will permit it to be recovered by wells.

Dakota (?) sandstone and overlying sandy beds.—In the lower 100 or 200 feet of the Colorado shale are widespread sandy beds that for convenience may be discussed with the underlying Dakota (?) sandstone, which in this general region is commonly about 50 feet thick. These basal sandstones in many places yield evidences indicating that they were laid down by fresh-water streams, either on deltas or in river beds, but the shales that alternate with them locally carry marine fossils.

The well on the Ingomar anticline found 210 feet of silty sandstone, sandy shale, and fine-grained sandstone at this horizon. The well at Vananda found a little less than 200 feet, and other wells in this general region have found about 300 feet of these beds.

The main producing sand of the Cat Creek field of Montana is equivalent to the sandstone here called Dakota (?). Sandstone in this general position also carries either gas or oil in a number of

[17] This exceptional thickness of the Colorado shale in the Ingomar region has been pointed out by A. A. Hammer in "A study of some Upper Cretaceous sedimentation and diastrophism in the State of Montana," presented before the American Association of Petroleum Geologists at its meeting at Wichita, Kans., in March, 1925.

fields in Wyoming. It was therefore reasonable that the earlier prospectors should hope to find it productive in the Ingomar-Porcupine region. However, it has not only proved barren of either oil or gas, but in the well drilled on the Ingomar anticline it did not even yield water. This means either that the sand is so fine grained that the intergranular pores are too small to permit water to move out of them unless propelled by great gas pressure, or else that the original pores of the rock have been filled by some cementing material such as calcium carbonate.

Wells have been drilled through this succession of sandstones and shales on the Ingomar anticline, McGinnis Creek (Alice) dome, Porcupine dome, and Vananda anticline. None of these wells have found more than a trace of oil or gas, in spite of their location on the most pronounced anticlinal features of the region. It can not be said that these tests definitely prove that the zone of sandstones and shales is barren in this region, or even on the anticlines tested, for it is a demonstrated fact that one test does not condemn an anticline. Furthermore, there is no proof that the wells mentioned were drilled at the points on the anticlines most likely to prove oil-bearing, although those on the Ingomar anticline and McGinnis Creek dome seem well located. However, the lack of even a pronounced trace of oil or gas is very discouraging, and further drilling to test this zone can not be recommended unless localities that present structural conditions very different from those tested and that seem decidedly promising can be selected for the test.

It may be pointed out that on the Cat Creek anticline, the Elk Basin anticline, the Greybull anticline, and elsewhere within a radius of 200 miles where sandstone in the general position of the Dakota (?) of the Ingomar anticline is productive of oil or gas there are faults of such magnitude that the sand is brought into juxtaposition with the dark shales of the overlying Colorado, so that it might receive oil from those shales without the necessity of downward migration; also that these same faults might well serve as avenues of migration up which oil from a deep source—such as the Phosphoria or the Madison—might move. If similar profound faulting can be found in the Ingomar-McGinnis-Porcupine region the prospect for production adjacent to the faults would, in the opinion of the writer, be much greater than on the unfaulted or slightly faulted folds.

The Dakota (?) sandstone of the Ingomar anticline is apparently present throughout central Montana and is a good key bed or horizon marker to help the driller recognize the exact position of the bottom of his well in the stratigraphic section. Furthermore, it commonly carries water, which, at least in some places, is potable and suitable for boiler use.

KOOTENAI AND MORRISON (?) FORMATIONS

The Kootenai formation, of Lower Cretaceous age, and the Morrison formation, of Lower Cretaceous or Upper Jurassic age, probably underlie the Ingomar anticline and other parts of this general region. The well on the Ingomar anticline penetrated 140 feet of beds believed to belong to these formations. These beds do not reach the surface near the Ingomar anticline, but they or their equivalents crop out in the nearest uplifts that expose this part of the column. Variegated shales of maroon, gray, green, and pink colors, in places sandy; sandstones, locally conglomeratic; and thin lentils of limestone are characteristic of the Kootenai and Morrison (?) formations at the nearest points where they are accessible for examination. These beds may have a thickness of about 300 feet in the Ingomar region, but there is nothing in the character of the sediments, which are of fresh-water origin, nor in the history of oil development in the Rocky Mountain region that offers much basis for hope that oil in important quantity will be found in them.

SUNDANCE OR ELLIS FORMATION

Rocks of Upper Jurassic age, consisting of strata that accumulated in a shallow sea, are very probably present under the Ingomar anticline. Shale predominates, but there are thick beds of sandstone, particularly near the base and near the top, and a few thin limestones that are commonly very fossiliferous. Around the Black Hills and Big Horn uplifts and throughout the larger part of Wyoming these marine Jurassic rocks constitute the Sundance formation. Somewhat similar rocks of the same general age to the west and northwest are called the Ellis formation.

Erosion preceded and at least locally followed the deposition of the Jurassic beds, which consequently exhibit somewhat abrupt changes in thickness. These changes, however, are not believed to be great enough to introduce gross inaccuracy in an estimate of the thickness of the formation under the Ingomar anticline. The Ellis formation of the Little Rocky Mountains is about 250 feet thick.[18] In the Snowy Mountains it is about 150 feet thick.[18] In the Pryor Mountains the Sundance shows a maximum thickness of 625 feet, and on the Soap Creek dome it may be as thick as 680 feet. A thickness of 425 feet measured just north of the mouth of Big Horn Canyon,[19] on the east side of the mountains, is a reliable

[18] Bauer, C. M., and Robinson, E. G., Comparative stratigraphy in Montana: Am. Assoc. Petroleum Geologists Bull., vol. 7, No. 2, pp. 174–175, 1923.

[19] Thom, W. T., jr., Oil and gas prospects in and near the Crow Indian Reservation, Mont.: U. S. Geol. Survey Bull. 736, p. 40, 1922.

measurement. On the northwest slope of the Black Hills[20] the Sundance formation is about 325 feet thick. The position of the Ingomar anticline is probably much closer to the center of the Logan Sea, in which the marine Jurassic accumulated, than the Little Rocky Mountains or the northwest slope of the Black Hills. It is therefore reasonable to think that the formation will be considerably thicker under the Ingomar anticline than it is in those places. Perhaps 350 to 400 feet is a reasonable figure to assign to the Ingomar area.

These rocks are a possible source of oil and gas. The Sundance has yielded small amounts of heavy black oil in fields in central Wyoming, and the principal production of the Kevin-Sunburst field of Montana is derived from the Ellis. It must be conceded that there is no absolute proof in any of the fields that the oil originated in the Jurassic, and in the Kevin-Sunburst field a more probable source is the underlying Madison limestone. It is not justifiable to prospect in southern Montana solely in hope of finding oil at the Jurassic horizon, and the presence of these beds adds comparatively little to the possibilities of a region.

TRIASSIC (?) ROCKS

Triassic rocks are probably absent under the Ingomar anticline and to the north. If present they probably consist of not more than 50 or 100 feet of red shale that possibly may be interbedded with layers of white gypsum, and they would be of little importance either as reservoir beds or as a source of oil. The possibility that oil may have originated in these rocks can not be entirely disregarded, however, for occurrences of oil in the basal part of the Chugwater formation (which the writer thinks accumulated in shallow salt water) have been noted in the Casper-Alcova region of central Wyoming, and it is thought that the oil there originated in the "Red Beds" (Chugwater) rather than in overlying or underlying strata.

PERMIAN (?) STRATA

Permian strata are probably absent in the Ingomar region. This means that the Phosphoria formation (lower part of the Embar) of the Big Horn Basin, which serves both as a source and as a reservoir for heavy asphaltic oil in the vicinity of Thermopolis and Grass Creek, can not be expected to contribute to the oil-yielding possibilities of the Ingomar region.

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[20] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Devils Tower folio (No. 150), p. 2, 1907.

PENNSYLVANIAN STRATA

Beds of Pennsylvanian age are almost certainly present in the Ingomar region. To the south, in the Pryor Mountains and in the Crow Indian Reservation, there is the Tensleep sandstone, of Pennsylvanian age, with a maximum thickness of about 75 feet, and below it strata that have been referred to the Amsden formation[21] of Pennsylvanian and Mississippian age, which may include as much as 365 feet of red shale, thin beds of red and white limestone, and quartzitic sandstone. Most of the oil in the Soap Creek pool was found in these strata. To the southeast, in the Black Hills, the Minnelusa sandstone, with a maximum thickness of about 1,000 feet, consists of massive to thin-bedded gray to buff sandstone, sandy shale, lentils of red shale, and thin dolomitic limestone.[22] Locally it contains thick lenses of gypsum.

In view of these observations it seems probable that from 600 to 1,200 feet of Pennsylvanian strata are present in the Ingomar region, comprising sandstone, limestone, and shale of marine origin. The Pennsylvanian beds contain some oil in the Black Hills region, in the Soap Creek pool, in the Big Horn Basin, and in the Devils Basin. In all these regions the oil is black, heavy, and asphaltic. In none of them have large pools been developed.

The chances for oil in the Ingomar region are critically though not exclusively dependent upon the presence of an oil-yielding phase of these Pennsylvanian strata. The writer believes that the lower beds in the Pennsylvanian—the local coarse materials immediately overlying the unconformity at the top of the Madison limestone—are more likely to contain oil than the higher beds.

MADISON LIMESTONE

The Madison limestone, of Mississippian age, apparently underlies all of eastern Montana and most of Wyoming. Where not exposed its character is of course largely unknown, but presumably it closely resembles the Madison limestone exposed in the Big Horn Basin, which in places comprises more than 1,000 feet of limestone or dolomite, without any appreciable amount of interbedded shale. Parts of this limestone are decidedly bituminous, and it is probably the source of oil that has been found in the overlying Amsden formation in the Big Horn Basin and in the Casper region of Wyoming.

A well 4,800 feet deep on the crest of the Ingomar anticline would probably test the upper 100 feet of the Madison limestone. The pres-

[21] Thom, W. T., jr., Oil and gas prospects in and near the Crow Indian Reservation, Mont.: U. S. Geol. Survey Bull. 736, p. 41, 1922.

[22] Rubey, W. W., The Rocky Point plunging anticline: U. S. Geol. Survey press notice, Nov. 14, 1924.

ent cost of drilling to such a depth, the practical certainty that oil, if found, would be heavy and asphaltic, and the low present value of such oil would all discourage such prospecting, even were the chances of finding oil much brighter than they appear to be. When to these factors is added the failure to find any appreciable quantity of oil in the Madison in a number of wells that have been drilled into that formation, it is apparent that an attempt to test the Madison limestone in the Ingomar region is unjustified until wells drilled elsewhere have demonstrated the worth of the formation as a source of oil.

IGNEOUS ROCKS

On the south end of the anticline, in the NW. ¼ sec. 21 and adjoining parts of sec. 20, T. 8 N., R. 36 E., Treasure County there are several small dikes of igneous rock intruded into the Judith River and Bearpaw formations. These dikes are from a few inches to a few feet in width and are composed of extremely weathered light to dark greenish-brown material. According to E. S. Larsen, formerly of the Geological Survey, the rock is a porphyritic lamprophyre, too much altered for accurate study but containing recognizable biotite, calcite, serpentine, and apatite. In the dikes are numerous inclusions, commonly several inches in diameter, of massive, finely crystalline light brownish-gray limestone and some small fragments of reddish quartzite, light-gray shale, and weathered igneous rocks.

The dikes are notably discontinuous—for example, one that has a maximum width of 5 feet is traceable only 35 feet horizontally. The strike of the dikes is generally east, ranging between N. 83° W. and N. 68° E.; the longest one, which is from 1½ to 3 feet wide and extends continuously for nearly half a mile, strikes N. 70°–80° E. and is slightly curved.

The fissures in which the dikes occur are small normal faults, which show displacements of less than 5 feet and which dip steeply both to the north and to the south. Two of the shorter dikes are nearly vertical, but the longest one dips about 65° N. The shale and sandstone of the Judith River and Bearpaw formations are practically unaffected by the intrusions, and along only one of the dikes are the adjacent sedimentary beds even noticeably hardened, and this effect is not recognizable more than a few inches from the dike walls.

Near the southwest corner of sec. 24, T. 8 N., R. 35 E., 3 miles west of these dikes and approximately in the line of their strike, stands a rather low but conspicuous knoll known locally as Froze-to-Death Butte, which is formed by an eastward-trending dike in the

Bearpaw shale. In this dike, as in the others, the igneous rock is badly weathered and contains many inclusions. In some small limestone inclusions from this locality were found fossils that, according to G. H. Girty, of the Geological Survey, are of Carboniferous age. If, as seems likely, these small rock fragments came from the Madison limestone, they have been carried up a vertical distance of probably more than 5,000 feet by the intrusion. It is of considerable interest that the magma that formed these dikes was both sufficiently liquid to travel a mile or more and so cool that it did not appreciably alter the small limestone fragments that it carried.

STRUCTURE

The Ingomar anticline, in outline, is shaped somewhat like an inverted canoe with sharp ends and a bulge in the middle, although it is not symmetrical enough to more than suggest the resemblance. (See structure map, pl. 1.) A longitudinal cross section would show

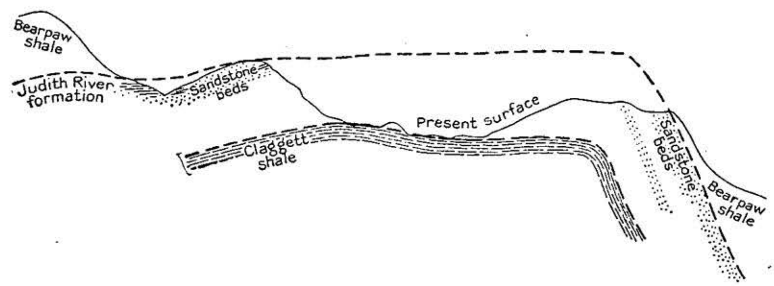

FIGURE 3.—Idealized cross section across the Ingomar anticline, Mont.

a smoothly curved line, concave downward, with a pronounced steepening of the rate of curvature at the northwest end of the fold. A transverse cross section would show great unevenness in rate of curvature, for the dips on the east side of the arch are in places as steep as 20°, whereas on the west side they are everywhere 4° or less.

The presence of the anticline is clearly revealed by the hills that form a rim roughly outlining it. These hills are due to the greater resistance to the weathering and erosive action of rain and possibly of wind that is offered by the sandstone ledges in the Judith River formation than by the weaker beds above and below. Figure 3 shows the general conditions on a line crossing the highest part of the anticline in a northeasterly direction.

The axis of the anticline trends northwest. It is clearly defined as far south as the center of sec. 21, T. 8 N., R. 36 E., and probably extends several miles farther southeast. At the northwest extremity of the fold as mapped there appears to be a sharp swing to the east in the SW¼ sec. 5, T. 9 N., R. 35 E. However, it is entirely possible that this apparent change in the trend of the axis is due to a fault, and that the axis of the main fold continues to the northwest, although if so it apparently plunges steeply. The length of the part of the anticline that was mapped is about 11 miles, and its greatest width is probably 5 to 6 miles.

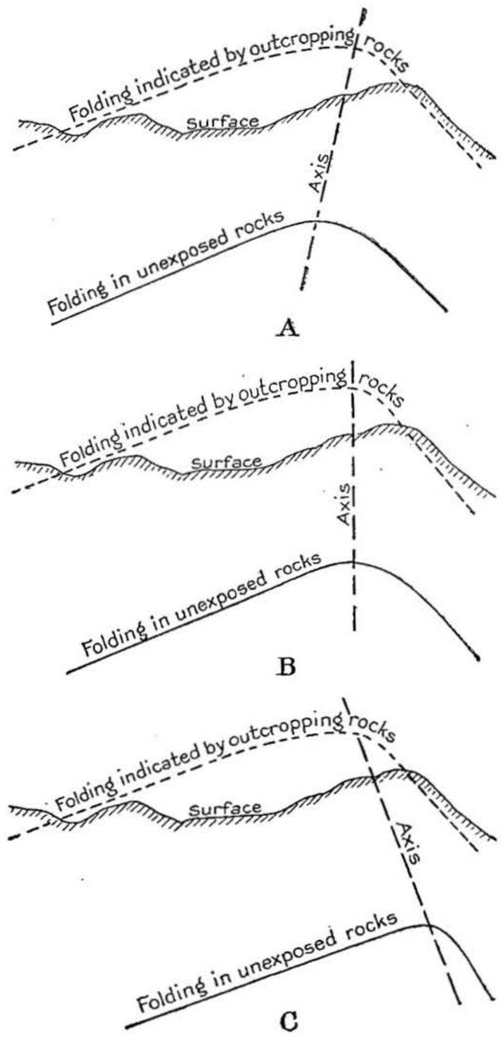

FIGURE 4.—Possible relations between the surface fold and a fold lying in depth on the Ingomar anticline, Montana

The closure of the anticline is known to be at least 600 feet, and it is believed to be about 1,000 feet, although proof of the extra 400 feet of closure was not obtained. The highest point on the anticline is indicated by the dips of the outcropping beds to be just north of the quarter corner between secs. 22 and 23, T. 9 N., R. 35 E. From this point the beds dip in every direction.

Position of the crest with depth.—The east flank of the anticline is so much steeper than the west flank that the fold is decidedly asymmetrical, and this suggests the possibility that the crest of any fold in rocks several thousand feet beneath the surface may not lie vertically below the crest of the fold that was mapped by determining the dips of the surface rocks. Three possibilities must be considered. The crest of the deep-lying fold may be west of that of the surface fold, as is indicated in Figure 4, A. This is the relation that would exist if the anticline were due to pressure applied from the side with equal intensity on every bed of rock, and if all the beds were equally strong. Again, the axial plane of the fold may be vertical, and the anticline in depth may be vertically below the anticline on the surface, as shown in Figure 4, B. It is the writer's opinion that folds of this type occur where the arching of the beds is due to subsidence or compacting of soft beds over a buried core of hard, rigid rock. Finally, the axis may incline toward the steep side of the fold, as shown in Figure 4, C. An anticline of this type may be due to a fault that breaks the deep rocks, but merely stretches the surface strata if they are comparatively plastic.[23]

The writer believes that the Ingomar anticline does not conform exactly to any one of these three types, but that in the relations of the beds in depth to those at the surface it agrees more nearly with the second than with the first and third. It must of course be recognized that the deductions here presented regarding the relations between surface and deep-lying structure are based solely on theoretical grounds and are therefore speculative. They are advanced because it is believed that future prospecting, if attempted, should be guided by a definite theory concerning such relations rather than by the structure indicated by outcropping rocks.

Faults.—The gently dipping west flank of the Ingomar anticline is broken by at least eight and probably many more small faults that trend almost at right angles to the axis of folding of the anticline. The direction of trend ranges from N. 45° E. to N. 80° E., showing a progressive change from northwest to southeast along the fold. The greatest displacements on these faults occur very low on the flanks of the anticline, and the faults appear to die out as they near the axis. There are a number of faults with throws less than 10 feet that cut the east flank of the anticline and that have the same general trend as those on the west flank, but it was impossible to find evidence indicating that any fault crosses the axis, and it is certain that no fault with a throw of more than 20 feet cuts the east flank of the anticline between sec. 5, T. 9 N., R. 35 E., and sec. 16, T. 8 N., R. 36 E.

The faults are all of the normal type, but on some of them the strata south of the fault have dropped, while on others the beds north of the fault have dropped. This is shown diagrammatically in Figure 5. The greatest throw noted was on a fault in the south-central part of sec. 2, T. 8 N., R. 35 E., where the south side has dropped about 80 feet with respect to the north side.

It is believed that the greatest northeastward-trending fault that cuts the anticline is probably in sec. 6, T. 9 N., R. 35 E., but its presence was neither proved nor disproved, because the exposed strata there belong to the Bearpaw shale, and except where they

[23] Lee, Wallace, personal communication, 1921.

are cut by gullies it is difficult to determine the precise structural conditions. The probable presence there of a fault with large throw is suggested by an abrupt change in the strike of the beds in sec. 5, T. 9 N., R. 35 E., and by an apparently abrupt increase in the north dip along the line between secs. 5 and 6. If no fault is present, then the anticline is terminated on the northwest by a sharp synclinal flexure, trending almost due northeast.

A fault with a throw of about 110 feet was noted on the east flank of the syncline that borders the Ingomar anticline on the east. The axis of this syncline passes a little east of the west line of sec. 31, T. 9 N., R. 36 E., and the fault was noted in the central part of the same section. The trend of this fault agrees with that of the faults on the flanks of the anticline. Its downthrown side is on the north. It is important, as it indicates that the faults are not restricted to the anticline.

It is believed that the faults all originated at approximately the same time, regardless of whether the strata are dropped to the north

FIGURE 5.—Sketch showing the general relations along a line drawn northwest through secs. 33 and 29, T. 9 N., R. 35 E., Mont., on the surface of the Judith River formation. Not drawn to scale

or to the south. This is suggested by the apparent continuity of a fault in secs. 28 and 29, T. 9 N., R. 35 E., which has a downthrow to the north at the west end of the fault and to the south at the east end. Presumably there must be some place on this fault where the fault plane is vertical and there is no throw at all. Such faults are commonly called "scissors faults" and are not rare. As a rule such faults are almost vertical.

Origin of anticline.—The writer believes that the Ingomar anticline originated by underthrust from the northeast during the period of folding that affected northern Wyoming and south-central Montana early in Eocene time and that it has been altered little if at all by any subsequent deformation. The ultimate cause of this thrust to the southwest is at present a matter of opinion rather than of demonstrated fact, though what seems by far the most plausible explanation would connect it with the regional uplift that produced the Porcupine dome, a broad uplift more than 40 miles long and 25 miles broad, with consequent readjustment of the surrounding strata.

If the anticline originated as has been suggested here, and the thrust was transmitted through the competent deeper Pennsylvanian and older beds, the upper 3,000 feet of strata presumably were merely lifted more or less passively on the back of the stronger underlying beds, and the fold shown by the surface rocks will agree very closely with and almost overlie the anticline in the Pennsylvanian rocks, though there will probably be a slight eastward inclination of the axis in depth.

Summary statement.—The Ingomar anticline is a northwestward-trending fold, more than 11 miles long and 5 or 6 miles wide at its widest point, with a steep northeast flank dipping about 20° and a gentle southwest flank dipping about 4°. The highest point on the anticline is just north of the quarter corner between secs. 22 and 23, T. 9 N., R. 35 E., and from this point the beds descend more than 600 feet in every direction, although the descent along the crest of the anticline is very gradual. On the gently dipping southwest flank there are eight or more small faults that trend about at right angles to the axis of the anticline. The presence of these faults, together with the asymmetrical shape of the anticline and the known softness of the upper 3,000 feet of strata that underlie the surface over its crest, leads to the conclusion that it was formed by underthrust from the northeast, and also that the folding in the Pennsylvanian beds will probably conform closely to that manifested by the surface strata.

REVIEW OF OIL POSSIBILITIES

The failure of a single-test well does not condemn an anticline that is as large as the Ingomar anticline, although it may well retard further drilling until the price of oil promises a reward that will justify exploration in areas where the probability of failure is higher than it is in wholly undrilled territory. The Ingomar anticline was tested by an excellently located well that penetrated a sandstone (Dakota?) at the base of the Colorado shale and went a short distance into the Kootenai. The strata that lie below the bottom of this well must be given almost the same rank as possible containers of oil as they had before the well was drilled. Those that were penetrated by the well may carry oil elsewhere on the anticline. The lack of oil in the well discourages this belief but does not preclude it. The lack of gas in the well is more condemnatory than the lack of oil, for gas will escape from a sand that is too tight to release any oil it may contain.

POSSIBLE OIL-YIELDING BEDS

The shallowest of the strata that may carry oil or gas on the Ingomar anticline is the Eagle sandstone. This sandstone, according to the log of the Absaroka well in sec. 26, is present on the anticline as a sandy shale with about 10 feet of sand at the base. Apparently a layer about 30 feet above this sandstone is particularly porous, for it was recorded as showing a little gas. Gas occurs at this general horizon in many parts of Montana, and it would be surprising indeed if none should be found there in the Ingomar region. Possible sources of gas both overlie and underlie the sandstone, and as it grades into shale toward the east the artesian water from the west is prevented from washing it clean of any gas or oil it may contain. Small amounts of gas are to be expected at this horizon in wells drilled on the crest or west flank of the domed part of the Ingomar anticline. It lies about 450 feet below the base of the Judith River formation. The gas-bearing stratum is probably less than 15 feet thick everywhere on the anticline.

The beds at the horizon of the Frontier formation, which is the premier oil-yielding zone of Wyoming, can not be expected to bear oil on the Ingomar anticline. In fact, there is no certainty that the Colorado shale is any more sandy or otherwise more favorable for yielding oil at the Frontier horizon than it is elsewhere. A sand 4 feet thick was struck at a depth of 1,806 feet in the Absaroka well, and this may indicate that the adjacent shale is sandy, but there is no certainty of this, and the sandstone mentioned may not even be one of the Frontier sandstones.

In the Big Horn Basin and in the Lost Soldier field of Wyoming the Mowry shale has yielded high-grade oil. No oil has been produced from this shale either in Montana or in Wyoming as far east as the Ingomar anticline. It may carry some oil here, but even if it does, appreciable accumulations are not to be hoped for unless fissuring has made conditions favorable for oil to gather in the gashes or cracks, or unless there is some local condition that resulted in the formation of sandstone beds in the Mowry.

A lower portion of the Colorado shale that has yielded some oil is a sand or sandy zone in its lower part. This is known as the Muddy sand throughout most of the Wyoming oil fields, and in the Black Hills region a sand at a similar horizon is called the Newcastle sandstone. It is not believed that one continuous sandstone at this horizon underlies much of Wyoming and Montana, but there is a zone of shale in which one and locally more beds of sandstone are present. Apparently this sandstone is entirely absent or represented by sandy shale in the Ingomar region.

The sandstone at the base of the Colorado group (the Dakota? sandstone) yields oil in the Cat Creek field, where it is known as the First Cat Creek sand. A sand at a similar horizon yields gas in the Elk Basin field and either oil or gas in many fields in the Big Horn Basin, as well as in more southerly fields, and it was the primary objective of wells drilled on the Ingomar anticline and on the McGinnis Creek and Porcupine domes, but it failed to yield oil on any of these anticlines and also on many others more remote from the Ingomar anticline. Even in Wyoming it is apparently barren except on anticlines that are severely shattered by faulting. This may mean that the main source of oil is above the sandstone and that the oil percolates into it only when faulting brings a raw edge of the sandstone in contact with an oil-saturated shale. Again it may mean that the source of the oil is some distance below the sandstone and that the oil will not reach it unless fracturing of the underlying beds provides openings up which the oil and gas can rise. This hypothesis seems the more likely one, particularly as a number of the fields that yield oil from this Dakota (?) sandstone also yield it from deeper beds.

This faulted condition, which apparently is favorable for the occurrence of oil in this Dakota (?) sandstone in Wyoming and in the Cat Creek field, is not present on the Ingomar anticline. The nearest approach to it is in secs. 20, 21, 22, 27, 28, 29, and 33, T. 9 N., R. 35 E., where a number of small faults were noted. However, these faults are not comparable in magnitude to those on the productive anticlines, nor is their location with respect to the highest part of the anticline such as to make them effective in localizing a pool of oil. There is no certainty that they persist in depth and cut the oil sand. If they do they might permit upward migration of oil from deeper beds, and that oil, if prevented by tight sand from reaching the top of the dome might accumulate near the faults or east of them, in secs. 22 and 27. This is a possibility that should be considered in any future prospecting of the anticline, and a well to test the Dakota (?) sandstone in this respect should be located about in the center of the SW. ¼ sec. 22, T. 9 N., R. 35 E.

The Kootenai, below the Dakota (?), has yielded oil in the Cat Creek field of Montana. The oil is very similar to that in the Dakota (?) sandstone and apparently is derived from the same source. That source, in the opinion of the writer, may possibly be in the Kootenai or in the Morrison (?) but is more probably in the deeper-lying Jurassic or the still deeper Pennsylvanian. The statements about the absence of oil in the Dakota (?) where the field is not strongly faulted also apply to the sandstones in the Kootenai.

The well on the Ingomar anticline did not reach the heavy basal sandstone of the Kootenai, nor did any other well in the region except the one drilled on the McGinnis Creek dome. That well went much deeper than the basal Kootenai but did not encounter any oil. A well on the crest of the Ingomar anticline would have to drill to a depth of about 3,250 or 3,300 feet to go through this basal sandstone.

The Morrison is productive of some oil and a great deal of gas in fields of the Big Horn Basin in Wyoming, but nothing has been noted to encourage a hope that the beds in Montana that are tentatively correlated with the Morrison will carry oil except the productivity of sands in the Kootenai in the Cat Creek oil field. If the oil in these sands rose along faults from a deep source, it must have passed by the Morrison (?) sandstones, and under such conditions it would presumably impregnate these sandstones to some extent. The Morrison (?) beds can not be entirely disregarded, for they contain sandstones suitable to serve as reservoirs, but they hold little promise.

The Jurassic should be looked on as the next logical objective of prospecting below the Dakota (?). It is true that beds at this horizon have yielded comparatively little oil in either Montana or Wyoming, but both the origin of the beds and their position immediately above Carboniferous strata demand that some consideration be given to them. They should be ranked as a possible rather than a probable container of oil, particularly in view of the probable absence of thick sands and of their location with respect to the shores of the sea in which the strata were deposited.

Probably next below the Jurassic will be found the Pennsylvanian strata, and these carry greater promise of oil than any others except perhaps the Dakota (?) sandstone. A well drilled on the crest of the anticline in the NW. ¼ sec. 23, T. 9 N., R. 35 E., should reach these strata at about 4,000 feet or possibly a little less.

A good site for a deep test on the anticline is near the center of the N. ½ sec. 22, T. 9 N., R. 35 E. This location is a short distance down the west flank of the fold, but the highest point on the fold in the deep strata may not exactly underlie that on the surface as discussed under the heading "Structure." If the axial plane inclines to the west to bisect the angle made by the flanks of the anticline, the crest of the anticline at a depth of 4,000 feet will be more than 400 feet west of the crest at the surface.

The several zones mentioned do not include all the possible oil-carrying beds. If the faulting on the west flank of the anticline acted on parts of the Colorado shale in such a way as to increase its porosity—perhaps by developing a great many joints or shear planes, or perhaps by shattering and jumbling the strata—it is entirely possible that "shale oil" is present. This is oil that accumulated in fissures, joints, or other openings in shale. Notable quantities of oil have been obtained from the Colorado shale in the Salt Creek, Teapot, and Lost Soldier fields, in Wyoming. The

Moffat and Iles domes, in Rio Blanco County, Colo., and the Osage field, in Wyoming, also contain shale oil. Large amounts of gas and oil have come from the Florence field, Colorado, and from several pools in the Mid-Continent and Appalachian fields. As a rule this "shale oil" is not considered worth prospecting for, as the total yield of the wells in the Wyoming fields is not commonly great, and the occurence of the oil is so erratic that there is great uncertainty about striking it even when it is known to be present on an anticline. It may therefore be regarded simply as one possibility that will decrease somewhat the hazard of loss that will attend drilling on the faulted west flank of the Ingomar anticline. Shale oil is most likely to be found on the west flank in secs. 16, 17, 20, 21, 22, 27, 28, 29, 32, 33, and 34, T. 9 N., R. 35 E. If found at all it will almost certainly be in the Colorado shale and probably in the upper 1,600 feet of the shale.

TYPES OF OIL

Any oil found above the base of the Colorado shale will very probably be comparable to that found in other fields that yield oil from this formation. It may be expected to be light green in color, have a specific gravity between 30° and 45° Baumé, be of mixed paraffin and asphalt base, and be a fair oil for the production of gasoline.

Oil from the Dakota (?), Kootenai, Morrison, and Jurassic beds, if present, may be either a green light oil of mixed base or a heavy dark oil of asphalt base. To judge from the results in fields that have yielded oil from these strata the probability is that any oil occurring in these beds in the Ingomar region will be dark and heavy.

Oil from the Pennsylvanian will almost unquestionably be heavy, dark, and asphaltic, with a rather high sulphur content. Its value for the production of gasoline will probably be low. Whether or not it will be comparable to the Gulf coast oils as a source of lubricants can not be said. At the present time the heavy black oils of the Rocky Mountain fields are a drug on the market, but there is no doubt that they will be eagerly sought during the next 10 years.

DRILLING THAT HAS BEEN DONE ON THE INGOMAR ANTICLINE AND OTHER FOLDS IN THIS REGION

The well on the Ingomar anticline, which reached a depth of 3,040 feet, found no oil and only a slight showing of gas, which came from a thin bed of sandy shale at 520 feet, probably in the Eagle sandstone. The well was located on the axis though not on the highest structural point of the anticline. This point is about half a mile north-northwest of the well and is probably about 35 feet higher structurally, although it may be as much as 50 feet.

The well passed completely through the Dakota (?) sandstone, which, according to the log, was dry, not only of gas and oil but also of water. As this sandstone commonly carries water where oil is absent, this record shows an unusual condition, which is probably to be interpreted as meaning that pores between the sand grains have been filled by fine sediments or by some cementing material, such as calcite, silica, or iron oxide. The fact that the driller records beds at this horizon as "lime" and "sandy lime" lends strength to the view that the pores are filled by a calcareous cement.

It can not be said, however, that the Dakota (?) sandstone horizon on the Ingomar anticline has been thoroughly tested, for "tight" patches of small extent in sandstone are not unusual and do not necessarily represent conditions that persist throughout the area.

At least three other wells in this general region have been drilled through the Dakota (?) sandstone. One of these, at Vananda, about 7 miles south and 8 miles east from the Ingomar well, encountered water in the Dakota (?) which rose within 50 feet of the surface. A well drilled on the Porcupine dome unquestionably passed through the Dakota (?) and according to newspaper statements found a small quantity of black oil some distance below this horizon. It is believed that this well went through the Kootenai. In spite of reports that oil was encountered at a number of horizons, none has been produced either from this well or from other wells on the Porcupine dome. The third well is on the McGinnis Creek dome, 30 miles north of the Ingomar well. This well was reported to have reached a depth of 3,810 feet. No oil was obtained, but it is reported that water was found in the Dakota (?) and in lower sands as well.

POSSIBILITIES OF THE REGION AS A WHOLE

The fact that out of four wells drilled on pronounced anticlinal folds in the Porcupine-Ingomar region three found water in the Dakota (?) and the fourth failed to find either water or oil is ample justification for refusing to drill further in this region with the Dakota (?) as an objective, unless conditions are found that are decidedly different from those that proved unfavorable. The most desirable condition would be pronounced faults. If such faults, trending approximately north, and consequently at right angles to the supposed direction of artesian flow in the sandstones, are found it will be justifiable to test the Dakota (?) sandstone on the east side of the faults, provided the sandstone does not lie at prohibitive depth, and the prospects of success would be enhanced if shale oil is found in the Colorado and gas in the Eagle.

So far as the writer can learn, the Jurassic has been tested by only a single well in this region, and the deep-lying Pennsylvanian has been touched by only one well and has not been deeply penetrated by any well. The Pennsylvanian strata in Wyoming are more generally oil bearing than the Cretaceous strata, although the yields both of fields and of individual wells that draw from the Pennsylvanian are much lower than those of fields where the oil is found in Cretaceous beds, and the black, heavy Pennsylvanian oil has sold for so little during the last few years that prospecting for such oil has had little encouragement. Deep drilling in areas of good anticlinal structure in the Ingomar region may possibly discover oil in the Pennsylvanian rocks and in the Jurassic or the basal part of the Morrison (?) beds, but the Pennsylvanian is much more promising than the higher beds.

In many respects the Porcupine dome is the most attractive field for prospecting in this part of Montana. It must be recognized, however, that all parts of this great uplift are not equally favorable, and that prospecting should be confined to areas where not only the regional but also the local structure is attractive. The writer believes that attention should first be given to the north and northeast flank of the dome, which should be carefully examined for anticlinal wrinkling and for faulting. If this dome is due to vertical uplift, as appears most likely, there should be sharper local folding and more profound faulting on the flanks than over the summit.

To the west of the Ingomar anticline the Eagle may yield considerable volumes of gas on anticlines where this sandstone lies under several hundred feet of strata. It has proved to be gas bearing in the Lake Basin field, in the territory just south of the Bearpaw Mountains, in the Havre district, and elsewhere in Montana. It has never yielded any great amount of oil, although small amounts have been found in it in a number of localities and although the Shannon sandstone of Wyoming, which occupies the same general position in the stratigraphic column as the Eagle, has yielded oil in the Salt Creek, Big Muddy, and Pilot Butte fields.

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