U18300 3577218

SOME ANTICLINES
OF
MOFFAT COUNTY

BY

MELVIN J. COLLINS

A THESIS

SUBMITTED TO THE FACULTY OF THE GRADUATE
SCHOOL OF THE UNIVERSITY OF COLORADO
IN PARTIAL FULFILMENT OF THE RE-
QUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

UNIVERSITY OF COLORADO

1921

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

Acknowledgments.- The writer is indebted to Professors R. D. Crawford and R. D. George for the assignment of a thesis which has presented many interesting problems and for suggestions that have proved very helpful. Professor P. G. Worcester has given suggestions and help whenever asked, which were appreciated very much. Credit should be given to T. J. Kreps and W. O. Thompson for field assistance. To many ranchers and residents of Moffat County gratitude is due for their cooperation with the Survey party. To all others who have aided the work of this party in any way the writer is very grateful.

Purpose of field work.- In the summer of 1920 the Colorado Geological Survey sent a party into Moffat County to investigate some of the oil and gas possibilities of that county. This party consisted of Mr. T. J. Kreps, an instrument man, and the writer until the first of September when Mr. W. O. Thompson succeeded Mr. Kreps. A brief report of the field work done by that party may be found in Bulletin 24 of the Colorado Geological Survey, but a more detailed report with considerations of certain problems will be made at this time.

Area worked.- The area considered in this paper occupies the southeastern corner of Moffat County. It is bounded on the north and west by Yampa River, on the east by East Fork and on the south and west by Morapos and Deer creeks. All of the structures worked, with the exception of the Pagoda fold, lie in Moffat County. The larger part of the Pagoda structure is in Moffat County, but the eastern end extends into Routt County a short distance, probably not more than a mile.

PHYSIOGRAPHY

Drainage.- Yampa River is the most important stream in this locality and is the main channel for run-off. All of the streams in the vicinity of the structures worked form parts of the Yampa River drainage system. The largest tributary of Yampa River and next to it in size is Williams Fork River. This river, with its tributaries, drains most of the area mapped. The larger perennial streams which flow into Williams Fork River are the following: South Fork Creek, East Fork Creek, Beaver Creek, Waddle Creek, and Morapos Creek.

The age of the streams varies from youth through maturity to old age. Most of them are approaching maturity, but the topography along Yampa River gives evidence of its old age in places. Some of the streams in this area have been considered antecedent in character, especially

Yampa River. Many geologists who had not studied Yampa River in the vicinity of Juniper, accepted C. A. White's[1] version and considered it as antecedent.

E. T. Hancock[2] has recently studied Yampa and Green rivers. He concluded that both rivers are probably superimposed streams, both having originated after the deposition of the Browns Park group. This explanation is very satisfactory, for it seems to answer all of the conditions as observed in the field. C. A. White's explanation does not account sufficiently for the presence of the Browns Park formation and the part that it had in determining the present course of Yampa River.

Topography.- The relief of this part of Moffat County is very irregular. Most of the valleys lie at elevations of 6,100 to 6,600 feet. The valley or canyon walls, which are for the most part composed of Mesaverde sandstones and shales, attain elevations of 600 to 1,000 feet above the floors of the valleys.

Many valleys occupy the crests of anticlinal structures, sometimes following the axes quite closely. Such valleys were noted on Williams Fork River, Yampa River and Beaver Creek. The streams do not always follow the crests of the anticlines or the troughs of the synclines but some-

1 White, C. A., On the geology and physiography of a portion of northwestern Colorado and adjacent parts of Utah and Wyoming: U. S. Geol. Survey Ninth Annual Report, p. 709, 1887-88.

2 Hancock, E. T., The history of a portion of Yampa River, Colorado, and its possible bearing on that of Green River: U. S. Geol. Survey Prof. Paper 90-K, p. 188, 1915.

Fig. 1. "Pagoda-like" weathering of Mesaverde formation near Pagoda postoffice

Fig. 2. Intensely folded Mancos shale

times cut across such structures at random as do the South Fork and Waddle creeks.

The valley walls when composed of a series of alternating shales and sandstones weather into characteristic forms such as step-like cliffs. This condition has been brought about through differential erosion. The harder sandstone beds form persistent ledges and the shales form the slopes. In Williams Fork valley where this type of weathering is best illustrated the face of the cliff with its numerous benches resembles the roof of a Japanese pagoda. A postoffice located at this point has been named "Pagoda" because of this striking resemblance.

In certain parts of the Daton Peak quadrangle there are high, flat-topped mesas more than 9,000 feet above sea-level. These mesas are commonly capped by basalt sheets which have partially protected the softer underlying rocks from erosion. As a result of the superior hardness of the basalt, erosion has not advanced as far in the basalt-capped areas as in the surrounding country.

The amount and character of folding in the area studied varies greatly in different places. And the present topography bears a close relationship to the folding. In the Williams Fork region the folding has been rather sharp and pronounced and the relief is high. In Axial Basin the relief is not so high - partly because of the more gentle folding and partly because of the sedimentary rocks present. This basin occupies the crest of a large anticline, and since erosion has exposed shales, it is characterized by a rolling topography.

Slumps, which are features common to steeply inclined strata, are present in the vicinity of Williams Fork but were not noted elsewhere.

Soils.- The rocks of this region are for the most part siliceous or argillaceous in character. The most important siliceous rocks are the sandstones of the Mesaverde, Laramie, and Browns Park formations. When these sandstones are weathered, a light colored, sandy soil results. This sandy soil is very barren and does not make a good soil for farming purposes. The Mancos, Mesaverde and Lewis formations contain most of the exposed argillaceous rocks of Moffat County. These formations contain a great deal of shale. This shale is easily eroded and weathers to a light blue to black clayey soil which is sometimes very fertile and often produces large crops of grain and hay.

In certain parts of this district the weathering of basalts and other igneous rocks has produced extremely rich and fertile soil. The potash and other salts that serve as fertilizers have been derived from the disintegration of those igneous rocks. Around the basalt-capped mesas this soil is present and the copious vegetation found there clearly shows its fertility.

Along the banks of the larger stream there is a very rich, black alluvial soil that supports very large crops. The richness of the soil and the ease with which it can be irrigated have made the land bordering the streams most desirable for farming.

Vegetation.- The farming land lies in the valley bottoms, on the slopes and sometimes on mesas. The land adjacent to the larger streams has much alluvium and is very fertile. Most of the land under cultivation lies in the eastern part of Moffat County along such streams as Yampa River, Williams Fork River and Morapos Creek, but considerable land not bordering on streams is being "dry farmed" in various parts of the county. In 1920 the dry farmers were very successful in raising large crops of grain and potatoes.

To the south and west of Williams Park near the high mesas mentioned previously there are thick forests in which there is luxuriant plant growth. There, the vegetation is so dense that travel through it is very difficult. The soil derived from the disintegration of the basalt and the springs fed by the melting snows of the basalt capped mesas are responsible for the heavy growth of vegetation.

In Axial Basin, however, conditions are different from those just described. The low rolling shale hills support very little vegetation - grass and sage brush being the dominant forms. The sparsity of vegetation in

Axial Basin is caused largely by the aridity of the climate. There is very little rainfall and perennial streams are few.

Climate.- The winters in Moffat County are long and very cold. Deep snow covers the land for several months at a time in the winter and renders communication rather slow and difficult.

The summers are short - being limited to June, July, August, and September. The climate is semi-arid. The annual precipitation rarely exceeds 15 inches. The table given below was taken from the records of the weather observation station at Lay, Colorado, by the U. S. Department of Agriculture. This record is applicable to all of the area discussed in this paper.

Record of U. S. Department of Agriculture at Lay, Moffat Co., Colo.

Climate 1920	Temperature Maximum	Minimum	Mean	Precipitation in inches
January	72	-2	17.2	1.30
February	50	-10	22.8	.77
March	56	-5	29.2	----
April	70	-8	36.0	3.13
May	80	20	50.6	1.15
June	85	24	57.6	.15
July	--	--	----	----
August	90	28	63.4	1.53
September	86	21	53.6	1.20
October	80	14	44	1.50
November	60	7	31.1	1.82
December	51	-22	21	.80
				13.35

STRATIGRAPHY

The formations which constitute the stratigraphic column range from pre-Cambrian granites, gneisses and schists to alluvium or present day deposits. The granites and related rocks which form the core of the Rocky Mountains are generally supposed to underlie all of the area described. The formation directly overlying the granites is not exposed and it is questionable whether the Uinta quartzite and other rocks observed in exposures on Juniper Mountain continue as far east as the western boundary of Routt County. If it is assumed that the stratigraphy of the Williams Fork region is essentially the same as that of Juniper Mountain, there should be approximately 7,000 feet of pre-Cretaceous rocks underlying the "Dakota" formation which is known to be present and overlying the Algonkian (?) rocks.

Inasmuch as the structures described have the Mancos as the oldest exposed formation, it would not be advisable to attempt to drill deeper than the base of the "Dakota". Because of the great depth of the pre-Cretaceous rocks and the lack of information concerning their oil-bearing properties the writer has deemed it unnecessary to give a detailed description of those strata.

The following table will give a general idea of the formations present in the eastern part of Moffat County as given in Bulletin 415 of the United States Geological Survey:

Periods	Formations	Thickness in feet
Cretaceous	Laramie	1200
	Lewis shales	1500±
	Mesaverde formation	3500 - 4500
	Mancos shales	4000 - 4500
	Dakota formation	200 - 250
Jurassic	Flaming Gorge formation	800
	White Cliff sandstones	800
Triassic	Vermilion Cliff sandstones	600
	Shinarump group	1000
Carboniferous	Weber sandstones	2500
	Wasatch limestones	1000
Cambrian	Lodore shale	500
Algonkian ?	Uinta quartzite	12000±

"Dakota Formation"

The formation described here as "Dakota" has been so named by earlier geologists. It has been correlated with the type locality of the "Dakota" sandstone largely on lithologic grounds and stratigraphic position. It overlies the vari-colored shales of the Jurassic and lies conformably below the black shales of the Mancos. Because of the massive sandstones near the base and top of the formation there are two parallel ridges formed when the "Dakota" is exposed to erosion. These two ridges are very characteristic of the "Dakota" and make it valuable as a key formation for geological work.

The bed of conglomerate at the base of the formation is usually brown to green in color and is composed of small, rounded pebbles of feldspar, chert, and granite. The matrix is siliceous in character. This member is twenty feet thick at Juniper, and thin bands of sandstone or sandy material are intercalated at irregular intervals. This tends to show that conditions of deposition were not uniform. Directly overlying the conglomerate member is a series of sandy brown shales thirty feet thick, which is mostly covered. Above this shale member there is a ten-foot ledge of massive, coarse-grained sandstone white to brown in color. This sandstone has a siliceous cement and is sufficiently porous to permit the migration of water. A series of brown shales rather sandy in places and mostly covered, about 145 feet in thickness, caps the sandstone ledge previously mentioned, and underlies the upper sandstone member, the top of the "Dakota". This upper sandstone member is 40 feet thick and is composed of white to brown coarse-grained sandstone with some thin bands of quartzite. This sandstone seems to be porous enough to allow water to pass through it.

A very good exposure of the "Dakota" was found near Juniper where a section of it was taken. The section is as follows:

<u>Top</u>	Feet
Gray to brown sandstone with some thin beds of quartzite	40
Gray to brown sandy shales (mostly covered)	145
Gray to white massive sandstone	10

Light brown sandy shales	30
Green to brown stained conglomerate with intercalated sandy beds	20
Base	
Total	245

Mancos Formation

The formation immediately overlying the Dakota is known as the Mancos. It is composed mostly of argillaceous shales with some sandy and calcareous zones. It can be divided into two members on lithological bases. The lower member consists of black slaty shales lying directly on the "Dakota" and a bed of sandstone at the top that is approximately 25 feet thick. The upper member includes all those rocks which lie between this sandstone and the base of the Mesaverde.

The thickness of the Mancos formation is not constant - widely different results have been obtained in the sections taken. Professor R. D. George[1] determined the thickness of the Mancos to be 4100 feet in T. 3 N., R. 92 W.

Professor R. D. Crawford[2] has figured the thickness of the Mancos shale to be approximately 4400 feet in Williams Park. K. M. Willson[2] determined the Mancos shale to be about 2100 feet thick north of Yampa River

[1] Colorado Geological Survey Bulletin 23, p. 12, 1920.

[2] Cited above in Colorado Geological Survey Bulletin 23.

in the area worked by him. H. S. Gale[1] gives a thickness of 5000± feet for the Mancos formation in northwestern Colorado. The Mancos shale was determined to be 5800± feet at Axial by E. T. Hancock[2]. The thickness of the Mancos formation as determined in T. 2 N., R. 92 W. by the writer is 4000 feet. This figure may be somewhat low since most of the formation was covered and its true attitude may not have been determined.

From the figures given above it can easily be seen that the thickness of the Mancos varies widely from place to place, or that different boundaries have been taken for the same formation. In the section measured by the writer the lowest sandstone ledge of the Mesaverde that was continuous was taken as the top of the Mancos. The highest sandstone member of the Dakota was taken as the base.

Lower member.- Lying conformably on the Dakota formation is a series of black slaty carbonaceous shales. These shales are about 400 feet thick according to measurements taken near Juniper. Above the black shales mentioned there is a sandstone horizon 26 1/2 feet thick. This sandstone is white to gray in color with some black streaks or seams in it. It is coarse grained and

---

1 Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bulletin 415, pp. 45 and 62, 1910.

2 Lee, W. T., Relations of the Cretaceous formations to the Rocky Mountains in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 95 C, pp. 53 to 55, 1916.

rather porous. Professor Crawford[1] found a spring of water issuing from this member at one locality.

This sandstone is sometimes calcareous, and at places it is very fossiliferous. The fossils collected from this member show it to be Benton in age. No systematic collection of fossils was attempted in this work.

Upper member.- The remainder of the Mancos formation is composed of shales, very calcareous in places, and locally limestones have been noted. In parts of this area a calcareous zone of shales 50 to 200 feet thick has been noted 600 ± feet[2] above the Mancos sandstone. This calcareous zone carries fossils of Niobrara age. Above this calcareous zone the shales are very homogeneous in character, becoming lighter in color and more sandy as the Mesaverde formation is approached. When the upper part of the Mancos is weathered a light-colored clayey soil results. This soil is extremely plastic and sticky when wet. Crystals of selenite are often scattered over the surface of the weathered Mancos shales and are characteristic of that formation.

Mesaverde Formation

The Mesaverde formation lies conformably on the Mancos. It can easily be distinguished from the underlying Mancos by its sandy aspect and the presence of com-

---

[1] Colorado Geological Survey Bull. 23.

[2] Perini, V. C., Colorado Geological Survey Bull. 24, p. 14, 1920.

mercial coal seams. The base of the Mesaverde was considered to be the first sandstone horizon overlying the thick series of Mancos shales. This formation is composed of sandstones, shales, and coal beds. The thickness of this formation varies from 3000 to 4000 feet.

The lower part of the Mesaverde or lower one third is composed of thin bedded sandstones alternating with shales. The sandstones form ledges or ridges when this member is subjected to erosion. Marine fossils have been found in this part of the formation. They show that the change from marine to fresh or brackish water condition was very gradual and that a definite line can not be drawn between the Mancos and Mesaverde formations. No commercial coal horizons are found in this member which is known as the Barren Group of the Mesaverde. The Barren Group is capped by a massive sandstone bed, sometimes more than 100 feet thick, and was called the Tow Creek sandstone by the Colorado Geological Survey in 1919. The Tow Creek sandstone lies 800$\pm$ feet above the base of the Mesaverde.

The remainder of the formation consists of sandstones, shales, and coal seams, and varies from 2000 to 3000 feet in thickness. A detailed description of this formation as it occurs in the area covered in this report may be found in Bulletin 297 of the United States Geological Survey.

On Williams Fork River only the lower two thirds of the Mesaverde is present; the upper third having been removed by erosion. A section of the Mesaverde as taken by the United States Geological Survey[1] at a point two and one half miles east of Pagoda postoffice is as follows:

Section taken two and a half miles east of Pagoda postoffice

Top		Feet
1.	Sandstones and shales	300
2.	Sandstones and shales, much is colored red by the burning of coal seams	100
3.	M. ssive sandstone	25
4.	Thin sandstones and shales containing 3 coal beds of unmeasured thickness, lying at the top, middle, and bottom respectively	69
5.	Massive sandstone	35
6.	Not exposed	176
7.	Thin sandstones and shales with three strong sandstone beds in the upper half	180
8.	Group of massive sandstones	149
9.	Massive sandstone (single stratum) (Tow Creek of Colorado Geological Survey)	111
10.	Debris-covered slope, probably alternating sandstones and shales	371
11.	Sandstone of second hogback	80
12.	Soft sandstone and shale	282
13.	Lower Hogback sandstone	50
	Dark shale (Mancos shale)	
	Thickness above Mancos shale	1928

[1] United States Geological Survey Bull. 297, p. 24.

Lewis Shales

Conformably overlying the Mesaverde formation is a series of gray to black shales having a thickness of 1500± feet. Since the Lewis shales were not studied in detail by the party, the thickness given above is an average taken from the report of the United States Geological Survey as given in Bulletin 297, page 29.

This formation is very homogeneous, being composed almost entirely of shale. The only prominent exposure of shale in this area is along Yampa River near Craig. Inasmuch as the purpose of this report was to determine the oil possibilities of this region the Lewis formation is of little interest.

Laramie Formation

The Lewis shales are conformably overlain by the Laramie formation. This formation consists of sandstones and shales, with some sub-bituminous coal beds. The Lewis shales are gray to almost black in color, while the sandstones of the Laramie are white. On account of this fact the boundary between these formations is taken at the base of the lowest sandstone overlying the Lewis. This boundary is not everywhere at the same horizon, and fossils have been found in the sandstone, which are Lewis in age, so that the true age and history of this formation is not definitely known.

The formation considered here as Laramie is approximately 1200 feet thick on Fortification Creek north of Craig according to measurements taken by H. S. Gale[1].

The top of the Laramie formation is better defined than the base. The Tertiary or Quaternary gravels, conglomerates, and sandstones overlie the Laramie unconformably.

At the present time there is a question as to what is meant by "Laramie", since the type locality of that formation is not definitely known to be Laramie in age.

Tertiary or Quaternary Formations

At one locality on Beaver Creek, a tributary stream of South Fork Creek, an exposure is found which shows a conglomerate bed about 8 feet thick unconformably overlying the Mancos shale. Immediately overlying this conglomerate bed is 20 feet of sandy material, more or less arkosic in character, with several thin beds of conglomerate intercalated with the sand. Capping this sandy horizon is a bed of sandstone several feet thick with large angular basalt bowlders scattered irregularly through it. At another locality the conglomerate is not present, but approximately 200 feet of white coarse sandstone, rather soft on account of its calcareous cement, was observed to occupy essentially the same stratigraphic position. And

---

[1] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, p. 74, 1910.

in parts of the sandstone there were tubular forms which suggested plant stems, worm tubes, or burrows. From the lithological character and the stratigraphic position this formation would probably correspond to the Browns Park group found a few miles west of the area under discussion, in Axial Basin. In some places this sandstone is capped by sheets of basalt which form high mesas. Most of the flat tops within this area showed this sandstone member associated with the basalt sheets. The character of the sediments, the close association of the basalt and this sandstone formation indicate that it is at least Tertiary or younger in age. There would have to be a sufficiently long time for erosion to remove the Mesaverde, (possibly the Lewis and Laramie), and part of the Mancos before this formation could occupy the horizon which it does. And if this period of erosion took place previously to the deposition of the sandstone it would probably be later than the beginning of Tertiary time, because the period of erosion would mark a time interval between the Cretaceous and Tertiary.

The thickness of the Browns Park group varies from 1200 to 1800 feet. In most places the part of the formation which has not been eroded will not exceed 400 feet in thickness.

Igneous Rocks

Rocks other than sedimentary are few in number and restricted to the basalt sheets and basalt bowlders derived from the weathering of those sheets. The basalt bowlders are dark gray to black in color, sometimes very porous and vesicular in character. When the bowlders are not badly weathered the small cavities are often filled with secondary calcite.

The period of igneous activity in which the igneous sheets reached their present position was at least post-Cretaceous and was probably in part contemporaneous with the deposition of the Browns Park group. The evidence for the above statement is given in exposure of Browns Park on Beaver Creek where angular bowlders of basalt are included within the sandstone.

The basalts are of the greatest importance in the Williams Fork country where high mesas are capped with lava sheets. In Axial Basin and the surrounding area very little evidence of igneous activity was noted, but some hot springs are found at Juniper which might indicate the presence of igneous rocks.

Surficial Deposits

At numerous localities within the area described there are alluvial deposits of sand, gravel, and soil. The character of the material composing these deposits depends to a large extent upon the nature of the land from which the detritus or eroded material is derived. If the stream follows a sandstone formation, the nature of the deposit would probably be sandy, and, if it follows a shale formation, the deposit would be clayey, varying from gray to black in color. Basalt bowlders are widely scattered over the surface in the vicinity of Williams Fork River and, when weathered, they form a rich, black soil.

Another form of surficial deposit frequently encountered is talus. A great many talus deposits are present in the Daton Peak quadrangle, and in many places they entirely obscure the geology.

STRUCTURE

Major Features

The Yampa coal field, as described by Fenneman and Gale in Bulletin 297 of the United States Geological Survey, occupies a huge basin. The axis of this basin seems to have a northwest-southeast trend extending through Yampa on the southeastern end to a point some miles northwest of Craig. This large basin is bisected by a cross fold which is known as the Tow Creek anticline. As a result of this, a small basin is formed to the southeast of the Tow Creek anticline in the region drained by Fish Creek, Trout Creek, and Oak Creek.

Axial Basin, although somewhat to the south and west of the above area, occupies a valley roughly following the crest of the Axial Basin anticline. This anticline was formed by the inceptive forces of the Uinta unlift, and the trend of the axis is northwest-southeast in general. A few miles northeast of Axial Basin is a syncline, which passes through Round Bottom, with an axis which is roughly parallel to that of the Axial Basin fold. The folds of the Yampa field with few exceptions have the same general trend as that of the Axial Basin structure. In some parts of this field there has been some cross folding such as the Tow Creek fold, and there are numerous other minor folds trending in the same general direction as the Tow Creek structure.

Faults

To the east of Waddle Creek in Section 9, T. 4 N., R. 90 W. a small fault, with a displacement less than 100 feet, was noted. The sedimentary rocks in which the evidences of faulting were found are lower Mesaverde in age. The nature of the fault was not definitely determined, but, in general, it seems to have been of a dip-slip type. It seems probable the movement of one block was towards the west in the direction of the dip, but, owing to the fact that evidence was meager, the conclusions put forth are more or less speculative in character. It is not probable that this fault was of sufficient magnitude to materially affect the oil possibilities of the Beaver Creek structure.

Near the Williams Fork River, upon the western side of Peck Homestead Gulch, a small vein or fissure of solid bituminous material about one inch in thickness was found. This bituminous material was very similar to elaterite in character. The presence of such a hydrocarbon in vein form indicates that some movement has taken place that was of sufficient magnitude to develop a fissure through which the elaterite (?) could pass. The vein has a northeast trend, and is so narrow and local that the writer does not consider it large enough to have drained whatever accumulation of oil that may have taken place below the surface.

Folds

Pagoda fold.- The Pagoda structure is composed of two anticlines having axes trending northwest and southeast with a syncline between them.

The anticline to the north, or that structure which lies along Williams Fork River, has a small dome on the western end of the structure in the immediate vicinity of Deakins ranch. To the east of this dome, along the same axis, it is found that this anticline proper does not close on the eastern end, but swings around more or less in the shape of a horseshoe. This anticline has a curved axis, and, as a whole, pitches gently to the northwest so that the eastern end is the structurally highest point. The dips along the northern limb of the structure are fairly uniform, averaging about 12°. Along the southern limb the dips are steeper than those of the northern limb and range from 9° to 30°. The fold is therefore asymmetrical in character and the axis will be closer to the southern limb than to the northern.

There appears to be more or less of a constriction or closure on this structure in the vicinity of Pagoda postoffice. The only part of this anticline that holds any structural possibility whatsoever of oil or gas would be the small dome extending from Pagoda postoffice to the Deakins ranch. There is one dip shown on the map of 17°S 70°W., which does not adjust itself to the rest of the data taken for this area. It might indicate faulting, or slumping, or some kind of local movement. No other evidence of such a movement was noted, but evidences may have been so obscured that they were overlooked.

The syncline, which parallels the anticline just described, is pitching from the southeastern end in Section 28, T. 4 N., R. 89 W. to the northwest. It can be traced more or less accurately to Peck Homestead Gulch in Section 35, T. 5 N., R. 90 W. The dips on the northern limb of the syncline range from 10° to 30°, but those of the southern limb are not so high. They vary from 4° to 10°, thus effecting an asymmetrical syncline.

The southernmost anticline, or the Beaver Creek structure, also pitches rather gently to the northwest. The dips on the northern limb of the fold vary from 5° to 10°. On the other limb the dips are greater, and range from 10° to 58°, probably averaging 30°. A closure on the western end of the anticline was found in Section 9, T. 4 N., R. 90 W. In Section 5, T. 3 N., R. 89 W. the swing in the strike of the beds indicates a closure on that end, but inasmuch as no northeast dips were obtained nearer than the northwest quarter of Section 32, T. 4 N., R. 89 W. there is a possibility that this axis curves and that the structure does not close. Had it been possible to obtain dips and thus find the general attitude of the formations in Section 35, T. 4 N., R. 89 W. and in Section 5, T. 3 N., R. 89 W., the general structure could have been worked out more closely. In view of the fact that the only evidence tending to complete a closure on this end of the fold is the swing in the strike of the beds on the southern limb of the fold and considering the deficiency of dips with lack of definite information concerning the southeastern end of this anticline, the writer does not feel justified in asserting that there is an unquestionable closure for this structure. It was very difficult to determine the true geologic relations of this end of the fold because of the covering of the Mancos shale and the Mesaverde formation by the Browns Park (?) formation and the lava sheets which are very numerous in this part of the field.

Near Shirkey's ranch in Section 31, T. 4 N., R. 89 W. the dips indicate a constriction, but probably not a closure, since the sandstones on the south limb are very constant and continuous. In Section 15, T. 4 N., R. 90 W. a dip of 9°N 7° E was obtained in the shale of a newly made gully. This dip was the only one obtainable on the northern limb of this anticline owing to the capping of basalt and sandstone which seems to be ever present in the Daton Peak quadrangle above elevations of 7500 feet. This dip of 9° would indicate a constriction at this point, but, since other dips were not available, it is not conclusive or worthy of great consideration.

The dome located on Williams Fork, previously de-

Fig. 3. Browns Park (?) formation

Fig. 4. View of Mesaverde formation on Williams Fork dome

scribed, is a structural possibility for oil and gas since the dips taken point to a closed structure. The outcropping formations in this structure are the lower part of the Mesaverde formation and the upper part of the Mancos. Approximately 200 feet of Mancos has been eroded from the crest of the anticline. The possible oil sands in this region are the "Dakota" sandstone, the Mancos sandstone lying about 400 feet above the base of the Mancos, and possibly some lenticular sands within the Mancos formation. From a section taken of the Mancos formation in the vicinity of Yellow Jacket Pass near Wyman's ranch the thickness was found to be 4000 feet. It is possible that this thickness may be a trifle low because of the following facts: (1) Exposures were so scarce that the exact attitude of the beds may not have been determined; (2) The contact between the Mancos and "Dakota" was not sharply defined.

In calculating the depths of the wells necessary to reach the "Dakota" formation, the thickness of the Mancos was taken as 4000 feet. Taking the above thickness for the Mancos the "Dakota" sand could probably be reached at a depth of 3800 to 4000 feet in this dome, but the sandstone in the Mancos should be reached at approximately 3500 feet. This would mean a deep well, and the structure is so small that the writer does not see fit to recommend it for drilling until production is found in the general region.

From the crest of the Beaver Creek anticline about

1600 feet of Mancos shale has been eroded. On account of this fact a well drilled to the "Dakota" formation would probably at least be 2500 feet deep. The highest point on the structure, according to data collected, is in Section 5, T. 3 N., R. 89 W., very close to the center of the section. This would probably be the proper position for a test well. Until production is assured in Williams Park or neighboring structures, which look more promising than this one, the writer would suggest that definite action be delayed and that a very thorough examination be made of the geology in Sections 5 and 8, T. 3 N., R. 89 W. As mentioned previously, there is a possibility that this end of the structure swings rather than closes, and to effect a closure the strike symbols of beds in outcrops two miles apart must be prolonged to an intersection.

Hamilton dome.- In Section 33, T. 5 N., R. 91 W. and in Section 4, T. 4 N., R. 91 W. there is a dome elliptical in shape, known as the Hamilton dome. The axis of this structure trends approximately due northwest. The dips along the northeastern limb are rather gentle and range from 5° to 12°. The southern or southwestern limb is inclined somewhat greater than the northern. Dips on this limb vary from 13° to 34°, averaging about 25°. This structure is asymmetrical in character. All of the Mesaverde formation has been removed from the crest of this structure, and the horizon followed in working out this fold was a sandy zone near the top of the Mancos.

Approximately 800 feet of Mancos shales have been removed from the crest of this anticline. If the thickness of the Mancos is the same in this structure as that obtained for Yellow Jacket Pass, the "Dakota" should be reached at a depth of 3300± feet. This figure would be much higher if the Mancos shale is thicker than 4100 feet at this locality. The Hamilton dome is one of the most favorable structures in Moffat County as a possible oil reservoir. It is rather small, but has sufficient drainage to make a good accumulation possible, if the strata are oil bearing. It would be rather expensive to drill this dome because of the depth. As a location for a test well this dome would be splendid, for it is situated near the Craig-Meeker road, water for drilling is at hand, and it is structurally perfect. For a test well the writer would suggest a location about three-eighths of a mile S 70°W. of Weyand's house.

Craig anticline.- There is a small structure about 3 miles southwest of Craig, with a general northeast-southwest trend. Yampa River follows the axis of this anticline very closely. The bed followed in mapping this structure was one of the sandstones of the upper Mesaverde. The dips along the northern limb range from 5° to 10°, but on the southern limb the dips are slightly higher, varying from 8° to 12°, averaging about 9°. This structure is small and situated so high in the stratigraphic column that very little time was spent on this anticline. This report should be considered as more or less of a reconnaissance nature.

About 500 feet of Mesaverde formation has been removed from the crest of this structure. Since the lowest exposed formation is the upper part of the Mesaverde and the most probable oil sands are located in the Mancos and Dakota formations, there are between six and seven thousand feet of strata that would have to be pierced by the drill to reach the "Dakota". Because of the great depth to the oil sands mentioned above the writer is not disposed to recommend that this structure be drilled for oil. It has been suggested that there is a possibility of finding oil in some of the lower sandstone members of the Mesaverde formation. There are three sandy horizons in the lower part of the Mesaverde formation alternating with shale beds. These conditions would make it possible for the sand members mentioned to be oil bearing, but in the well drilled by the Richmond Petroleum Company on Wilson Creek these sandy horizons were not found to be productive. In no locality has the writer observed any oil seeps or other favorable signs of oil in the lower sandstones of the Mesaverde, and, hence, is disposed to regard them as more or less barren. However, should oil in commercial quantity be found anywhere within the Yampa field, this structure would be worthy of further investigation.

SOME THEORETICAL CONSIDERATIONS

The question as to whether or not Moffat County and northwestern Colorado will become a future oil field is one that will be answered when the presence or absence of oil-bearing sands or horizons is proved. At the present time it is considered possible for the sandstones and sandy zones of the Mancos formation to be oil bearing. This seems quite probable, for the Mancos contains large quantities of black carbonaceous shale succeeded by a porous sandstone bed approximately twenty-five feet thick. And in turn this sandstone is capped by a thick series of impervious shales. This succession is theoretically favorable for the accumulation of oil in commercial quantities when the strata have the proper attitude. There are several sandy horizons in the stratigraphic column of this region, which are equally favorable for the accumulation of oil. Some of the sands are the sandstone at the top of the "Dakota", a sandstone bed near the middle of the "Dakota", and the basal "Dakota" conglomerate. Some of the lower Mesaverde sandstone strata have been suggested as possible oil horizons, but, so far as known, these sands have not given evidence of oil accumulation in the area worked. However, in the San Juan oil field of Utah, evidences of oil in the form of oil seeps have been noted in this formation.

In the well drilled by the Twentymile Oil Company on a structure in Williams Park an enormous pressure of gas was encountered. It had to be cased off before drilling operations could be continued. In a well drilled by the Richmond Petroleum Company on Wilson Creek gas was found in a sand of the Mancos, and it furnished fuel for drilling purposes for nearly a year. Gas was found on the Chimney Creek dome recently in a Mancos sand. And in a well drilled in Axial Basin several years ago considerable gas was present in the Mancos. The Dakota formation was penetrated by the drill in Williams Park but oil was not found in commercial quantities.

The fact that gas is usually present wherever the sands of the Mancos are tapped and that oil is derived from the Mancos in the Rangely field in northwestern Colorado about sixty miles southwest of this area indicate that the strata of the region carry hydrocarbons. Another indication given by the preceding example is either that the folding of the shale has been sufficiently great to volatilize the oil or the wells drilled in every case have been located too high on the structures. The wells in some cases have been located on different parts of the structure, but without greatly improving conditions.

David White[1] has done considerable work to determine the relationship existing between the intensity of the metamorphism that a region has undergone and the quali-

[1] White, David, Genetic problems affecting search for new oil regions: Amer. Inst. Min. and Met. Eng., No. 158, Section 21, p. 5, Feb. 1920.

ty of the oil found there. He has arrived at some very interesting conclusions. In determining the amount of metamorphism he used analyses of coals occurring in the supposed oil-bearing formation, or those from the formation immediately overlying it. He states, "More observations and tests are necessary to fix more exactly the stage of regional alteration beyond which commercial oil pools, though formerly present, will not have survived, but it is probable that the limit falls, in general slightly lower than the point at which coals of the ordinary bituminous type show a fuel ratio of 2.2 or 68 per cent. of fixed carbon in the pure coal; it may approach nearer the ratio of 2.0 or 66 per cent fixed carbon".

Some analyses of coals from the Mesaverde, the formation directly overlying the Mancos are as follows:

Locality	Fuel ratio	Fixed carbon in pure coal
1 Hayden Gulch	1.4	50.9
2 Thornburg Mountain (Wilson mine)	1.33	57.1

Sample 1 taken from Bulletin 297 of the United States Geological Survey, page 84.

Sample 2 taken from Bulletin 415 of the United States Geological Survey, page 248.

Sample 1 was taken near the Pagoda fold, and its fuel ratio percentage of fixed carbon comes within the limits prescribed by White. Sample 2 is from the Thornburg Mountain area, very close to the Hamilton dome. These samples show that this region has not undergone sufficient

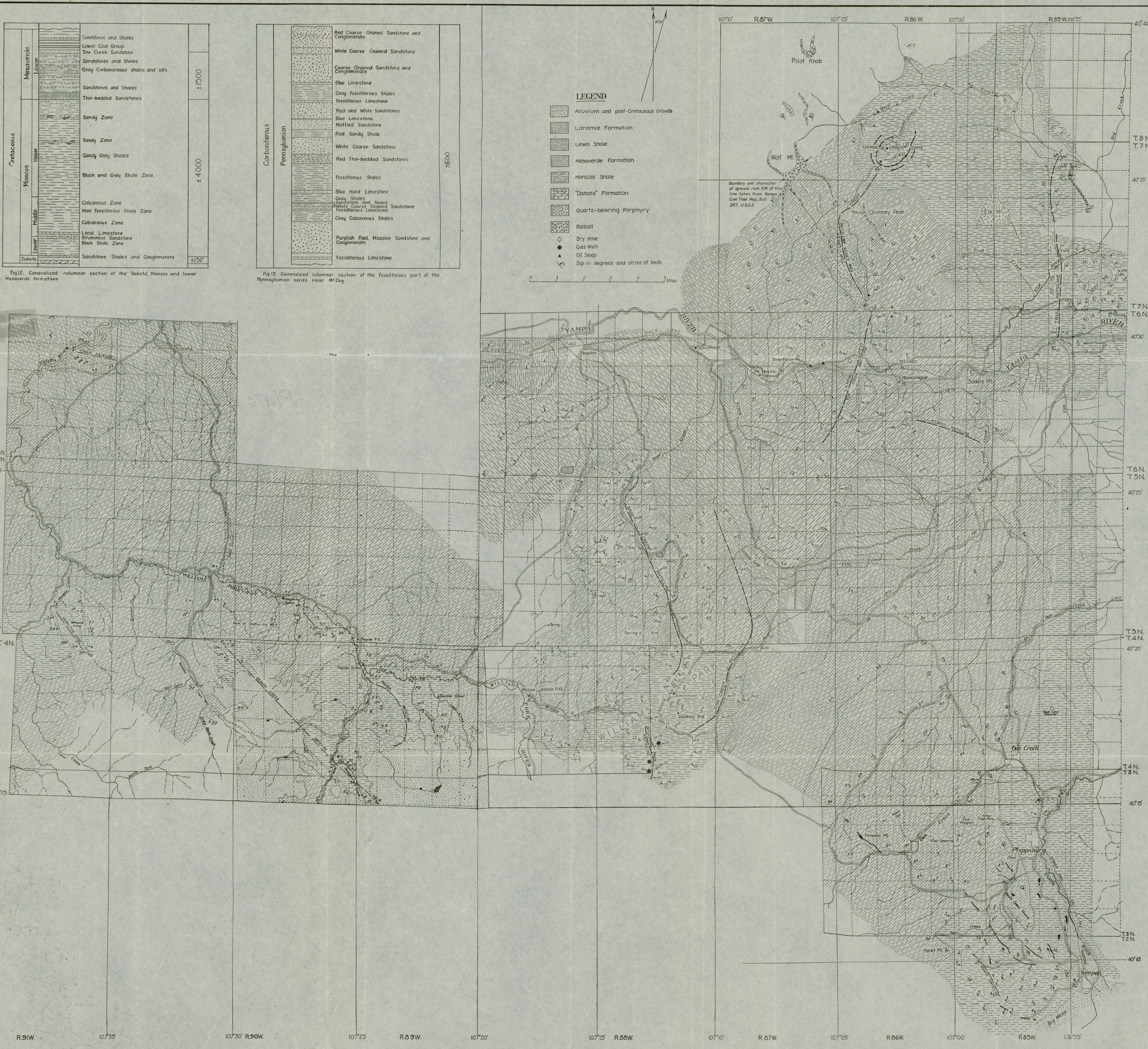

Fig. 12. Generalized columnar section of the 'Dakota', Mancos and lower Mesaverde formations

Fig. 13. Generalized columnar section of the fossiliferous part of the Pennsylvanian series near Mc Coy.

MAP SHOWING ANTICLINES IN ROUTT AND MOFFAT COUNTIES, COLORADO

Geology of southeastern part by V. C. Perini, Jr., and C. S. Lavington (1920); geology of southwestern part by M. J. Collins, T. J. Kreps, and W. O. Thompson (1920); the remainder of the geology was mapped by the Colorado Geological Survey in 1919 and shown on Plate I, Bulletin 23, 1920. Land lines and drainage taken from United States Geological Survey topographic maps of the Hahns Peak and Daton Peak quadrangles and United States Surveyor General's township plats. In parts of the map, particularly in and near Williams Park, the roads have been sketched in to show lines of travel and are not accurately placed.

folding, according to David White, to seriously impair the accumulation of oil in commercial pools.

BIBLIOGRAPHY

Crawford, R. D., Willson, K. M., and Perini, V. C., Some anticlines of Routt County: Colorado Geological Survey Bull. 23, 1920.

Fenneman, N. M., and Gale, H. S., The Yampa coal field, Routt County, Colorado: U. S. Geol. Survey Bull. 297, 1906.

Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, 1910.

Hancock, E. T., The history of a portion of Yampa River, Colorado, and its possible bearing on that of Green River: U. S. Geol. Survey Prof. Paper 90-K, 1915.

Lee, W. T., Relations of the Cretaceous formations to the Rocky Mountains in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 95-C, 1916.

Perini, V. C., Jr., and Collins, M. J., Some anticlines of Routt and Moffat counties: Colorado Geological Survey Bull. 24, 1920.

White, C. A., On the geology and physiography of a portion of northwestern Colorado and adjacent parts of Utah and Wyoming: U. S. Geol. Survey Ninth Ann. Rept., 1887-88.

White, David, Genetic problems affecting search for new oil regions: Amer. Inst. Min. and Met. Eng., No. 158, 1920.