GEOLOGY AND OIL AND GAS PROSPECTS OF PART OF MOFFAT COUNTY, COLORADO, AND SOUTHERN SWEETWATER COUNTY, WYOMING.

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INTRODUCTION.

PURPOSE OF REPORT.

The existence of oil-saturated rocks and of well-developed domes and anticlines at several places in Moffat County, Colo., together with the nearness of the productive Rangely district, in Rio Blanco County, has in recent years drawn the attention of oil operators and local business men to the possibility of finding petroleum and natural gas in commercial quantities here. Interest in this region has been intensified by the completion in January, 1924, of a producing oil well at the Moffat (Hamilton) dome, in southeastern Moffat County. The origin and accumulation of oil and gas in any field are dependent upon many geologic conditions, which should be considered before money is spent in testing by the drill. To aid those interested in this area to gain a clearer understanding of these conditions, parties in charge of the writer were assigned during the field seasons of 1921 and 1922 to make a detailed geologic study of a large part of Moffat County and a few adjacent townships in southern Sweetwater County, Wyo. In the course of this study special attention was paid to the possible occurrence of oil and gas and to the places at which their accumulation in commercial quantities seems most likely. The results of this investigation are given in the following report.

LOCATION AND EXTENT OF THE AREA.

Moffat County is in the extreme northwest corner of Colorado and is bounded on the east by Routt County and on the south by Rio Blanco County. The field described in this report includes most of the northwest and southeast quarters and the east half of the southwest quarter of the county, together with parts of eleven adjacent townships in Wyoming, a total area of about 2,800 square miles. The exact location of the field is shown on the index map in Plate XXXV (in pocket).

EARLIER INVESTIGATIONS.

Northwestern Colorado falls within the regions visited nearly half a century ago by explorers of various Government surveys. The work of such pioneers as Powell,[1] King,[2] Hague and Emmons,[3] White,[4] and Hayden[5] was of the highest order, but their reports contain few details that are helpful to-day in the study of economic problems.

In 1906 and 1907 Gale[6] made a rapid examination of the coal resources in northwestern Colorado and northeastern Utah, including a strip along the southern border of Moffat County, and studied the geology of the Rangely oil district, in Rio Blanco County.[7]

In 1907 and 1908 Schultz[8] examined the Rock Springs coal field, in Sweetwater County, Wyo. At that time and later he made reconnaissance trips southward, reaching the northwest part of Moffat County. His observations were combined in a report on the oil prospects of the region.[9]

In 1912 and 1913 Hancock[10] made a detailed study of the geology and coal resources of the Axial and Monument Butte quadrangles, in southeastern Moffat County. The writer has made extensive use of Hancock's unpublished material and with a few changes and the addition of a number of dip and strike readings has incorporated his geologic map in this report.

In 1919 and 1920 the Colorado Geological Survey[11] made examinations of anticlines in the western part of the State, including two in eastern Moffat County.

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[1] Powell, J. W., Report on the geology of the eastern portion of the Uinta Mountains, U. S. Geol. and Geog. Survey Terr., 2d div., 1876.

[2] King, Clarence, U. S. Geol. Expl. 40th Par. Rept., vol. 1, 1878.

[3] Idem, vol. 2, 1877.

[4] White, C. A., Report on the geology of a portion of northwestern Colorado: U. S. Geol. and Geog. Survey Terr, Tenth Ann. Rept., pp. 5–59, 1878; Report 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., pp. 683–712, 1889.

[5] Hayden, F. V., U. S. Geol. and Geog. Survey Terr. Fourth Ann. Rept., 1872; Tenth Ann. Rept., 1878; Atlas, 1881.

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

[7] Gale, H. S., Geology of the Rangely oil district, Rio Blanco County, Colo.: U. S. Geol. Survey Bull. 350, 1908.

[8] Schultz, A. R., The northern part of the Rock Springs coal field, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 341, pp. 256–282, 1909; The southern part of the Rock Springs coal field, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 381, pp. 214–281, 1910.

[9] Schultz, A. R., Oil possibilities in and around Baxter Basin, in the Rock Springs uplift, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 702, 1920.

[10] Hancock, E. T., The geology and coal resources of the Axial and Monument Butte quadrangles, Moffat County, Colo.: U. S. Geol. Survey Bull. 757 (in press).

[11] Coffin, R. C., Perini, V. C., jr., and Collins, M. J., Some anticlines of western Colorado: Colorado Geol. Survey Bull. 24, 1920.

AVAILABLE MAPS.

In addition to the maps that accompany the reports mentioned in the preceding section, others that may be of value to those interested in this area are topographic maps of the Craig, Axial, Monument Butte, White River, and Rangely quadrangles (U. S. Geological Survey) and the geologic map of Colorado (Colorado Geological Survey). Township plats prepared by the General Land Office give much useful information; the older surveys, made by contractors, were in general poor, and the corner stones can not now be found; but recent surveys have been of much higher grade, and most of the stones or iron posts can be found readily. A key map on Plate XXXV shows the status of land surveys.

FIELD WORK.

The investigations on which the present report is based were made during the seasons of 1921 and 1922 by parties in charge of the writer. In 1921 the party included W. H. Bradley and K. K. Landes; in 1922 it included Mr. Bradley and James Gilluly. Mr. Bradley also aided in the office in the preparation of this report. The capable and loyal assistance given by these geologists has contributed largely to the success of the project.

Tps. 4 to 7 N., Rs. 91 to 94 W., which had been examined by E. T. Hancock in 1913, were first visited, and additional details concerning the structure were obtained. The work was then extended to the north, northwest, and west, connecting near the south end of the Rock Springs uplift, Wyo., with the detailed work of A. R. Schultz. Many monuments and flags were set up, and a triangulation system for primary control was carefully established for the whole field. Mapping was in general done by means of telescopic alidades and 15 by 15 inch plane tables; locations were found by triangulation, and altitudes of points were determined by vertical angles. In a few complex areas greater refinement was obtained by the use of the stadia rod; in three other areas (that covered by the Browns Park formation along East Boone and West Boone draws, that in the Bridger formation in the western part of Sand Wash Basin, and that in the Wasatch formation near Canyon and Vermilion creeks) the structure was mapped by pace traverses.

The results obtained are brought together in a general geologic map of the field (Pl. XXXV, in pocket). The base for this map was prepared from topographic maps of the Axial, Monument Butte, and Craig quadrangles, from township plats of the United States General Land Office, and from the geologic field sheets. West of R. 94 W. the roads are only sketched, but their location is essentially correct. The mapping of the geology and structure near Powder Wash is based on long-range observations by the writer from a point near Powder Spring and from the hills north of Sunny Point. In order to round out a better regional setting for the field, certain geologic boundaries, shown by dotted lines along the southwestern and western edges of the map, were taken from the work of Gale [12] and from a manuscript map by Schultz, part of which was published in his report on Baxter Basin.[13]

ACKNOWLEDGMENTS.

The writer takes pleasure in expressing his gratitude to Messrs. Hamilton, Gross, Morgan, Finlay, and Herrick, to geologists of the Ohio Oil Co., and to others interested in the region, who supplied valuable information, and to the many ranchers, especially Messrs. Sparks, Crozier, Grounds, Draughn, and Iles, who gave cordial assistance and hospitality.

GEOGRAPHY.

SURFACE FEATURES AND DRAINAGE.

The total relief within the area mapped is almost 5,000 feet, the altitude ranging from 5,180 feet along Green River at the canyon of Lodore to 9,925 feet on Diamond Peak. Northward from Cold Spring Mountain, which is an outlier of the main Uinta Range, stretches a broad rolling upland that slopes eastward into the valleys of Vermilion Creek and its tributaries. Farther east are badlands that rise to the westward-facing cliffs known as Vermilion Bluffs and Kinney Rim. Eastward from Vermilion Bluffs the land slopes gently into the broad Sand Wash Basin; beyond the eastern margin of this basin the surface breaks sharply down into the low country along Little Snake River.

South of Cold Spring Mountain is the broad valley known as Browns Park, through which flows Green River before it turns to the south and enters the Uinta Range by way of the Canyon of Lodore. The valley rises gently southeastward to the divide between Little Snake and Green rivers. Farther southeast this zone of low land continues as the valleys of lower Yampa and Little Snake rivers and still farther to the southeast as Axial Basin. Cross Mountain and Juniper Mountain rise as isolated masses in this low country.

[12] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, pl. 18, 1910.

[13] Schultz, A. R., Oil possibilities in and around Baxter Basin, in the Rock Springs uplift, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 702, pl. 1, 1920.

From Vermilion Creek to Juniper Mountain the low land is separated on the north from Sand Wash Basin and the valley of upper Little Snake River by an almost continuous ridge; farther southeast, in Axial Basin, it is bounded on the north by a series of rolling hills through which Yampa River has developed intrenched meanders. On the south the low land is bounded by the eastern part of the Uinta Range, known as Douglas Mountain, and by Citadel Plateau and the Danforth Hills, which form the divide between Yampa and White rivers.

The field is crossed by the three rivers mentioned above—the Green, Yampa, and Little Snake. It lies entirely in the drainage basins of these rivers, with the exception of a few townships in the southwestern portion, which drain southward into White River. Vermilion Creek, which enters Green River in Browns Park; Williams Fork, which joins the Yampa a few miles southwest of Craig; and several branches of the Yampa that run through Axial Basin are among the few tributaries that maintain a flow throughout the year.

CLIMATE AND VEGETATION.

Northwestern Colorado is similar in climate and vegetation to much of the semiarid high plateau region west of the Rocky Mountains. Figures gathered by Hancock[14] for the years 1906–1916 show an average annual rainfall of about 16 inches, and a maximum range in temperature (in 1913) from −43° F. in January to 90° F. in July.

Much of the flat country is covered with sagebrush, greasewood, and other plants and grasses typical of a high, dry region. The ridges and hills are in general covered with scrub cedar and piñon, and the higher hills and mountains show larger pines and patches of quaking aspen. Cottonwoods and willows grow along the rivers and a few of the larger streams.

CULTURE.

The greater part of Moffat County is thinly settled, the distribution of ranches and homesteads being largely controlled by the available supply of water. In all that part of the field lying between the road from Irish Canyon to Rife's ranch, the Kinney Rim, Powder Wash, Little Snake River, and the ridge bounding Sand Wash Basin on the south there is not a single settler, and this land is used almost entirely as a winter range for sheep and cattle. Many ranches and dry farms are scattered through the rest of the field; in the river valleys

[14] Hancock, E. T., The geology and coal resources of the Axial and Monument Butte quadrangles, Moffat County, Colo.: U. S. Geol. Survey Bull. 757 (in press).

and at a few other places there are farms irrigated by river water, by springs, or by artificial lakes.

Sunbeam, Lay, and Axial are small settlements that maintain post offices. Maybell, a larger village, contains also a bank, a hotel, a general store, and two garages. Craig, the county seat, is an attractive town in the eastern part of the county; it has grown rapidly since it was made the western terminus of the railroad from Denver, and according to the census for 1920 has a population of about 1,300.

TRAVEL ROUTES.

The most direct route to Moffat County is the Denver & Salt Lake Railroad ("Moffat Line"), which has its western terminus at Craig. Steep mountain grades on this railroad make freight rates very high, and during the winter the road is frequently blocked by snow for many days at a time. These difficulties will be largely removed by a 6-mile tunnel through the mountains, now under construction. Alternative routes of approach to the county are from Rifle, on the Denver & Rio Grande Western Railroad (97 miles to Craig, 92 miles to Maybell), and from Wamsutter or Rawlins, Wyo., on the Union Pacific Railroad (100 miles to Craig). The northwestern part of the field may be reached from Craig, or from Rock Springs, Wyo., on the Union Pacific Railroad (70 miles to Sparks Ranch, 90 miles to Ladore post office).

The main automobile road of the county runs west from Craig through Lay, Maybell, and Sunbeam, thence southwest to Vernal, Utah. It is surfaced with gravel for 7 miles west of Craig; thence as far as Elk Springs it runs through a sandy formation, which makes a fair surface in dry weather and is even better after rains; west of Elk Springs the road is in shale, which is very slippery or sticky and rough in wet weather. This road forms a link in the transcontinental Victory Highway and carries much tourist as well as local traffic. A daily stage is maintained between Craig and Sunbeam, and another line runs less frequently from Craig to Vernal. A branch of this road turns off at Sunbeam and runs northwest to Ladore post office, thence through Irish Canyon north to Rock Springs, Wyo. A mail stage is maintained over this route between Sunbeam and Ladore. The road throughout is open to automobiles, although there are several rocky and sandy stretches.

Other important roads are those running northward from Craig to Baggs, Wamsutter, and Rawlins, Wyo.; from Craig southwest through Axial to Meeker and Rifle, which carries several stage lines; and from Maybell southward to Meeker. Other roads connect small post offices, ranches, and homesteads to the main routes of travel.

WATER AND FUEL SUPPLY.

The question of an adequate supply of water is important not only to settlers but also to those who may plan to drill. Near the rivers and a few of the larger streams plenty of water can be had throughout the year, but in much of the field the only sources are wells, springs, or reservoirs filled by intermittent streams. Details of the water supply are given farther on in this paper, in connection with the descriptions of folds which seem favorable for the accumulation of oil and gas.

Fuel is easily obtainable in most parts of the field. Great quantities of high-grade subbituminous coal are contained in the Mesaverde and post-"Laramie" formations in the area between Craig, Maybell, Elk Springs, and the southeast corner of the field. Somewhat poorer coal is found in the Wasatch formation in the upper drainage basin of Vermilion Creek and is now being taken for local use from the Canyon Creek and Sparks mines. The scrub cedar and piñon which grow on most of the hills and ridges, except on the east and north rims of Sand Wash Basin and on the east rim of Vermilion Creek basin, offer a satisfactory supply of firewood. Many of the pines on Douglas Mountain are of size and quality valuable for lumber and heavy timber and form the source of supply for a sawmill several miles south of Greystone post office.

GEOLOGY.

SEDIMENTARY ROCKS.

GENERAL SECTION.

Within the area described in this report are exposed beds ranging in age from pre-Cambrian to Recent. Paleozoic rocks crop out in the Uinta Mountain fold and in the Cross Mountain and Juniper Mountain uplifts. Mesozoic rocks crop out on the flanks of the Uinta Mountain-Axial Basin arch, and Eocene beds occupy the basins adjoining this arch on the north and south. Much of the Axial Basin fold and the east end of the Uinta Mountain arch is covered by flat-lying Miocene (?) sediments of the Browns Park formation. Many of the river and stream valleys have been scoured out and refilled with Recent alluvium.

The stratigraphy of this field is made complex by the great lateral variations of the formations in both thickness and lithology, by interfingering, and by numerous unconformities and overlaps. Many details of the stratigraphy, although of scientific interest, have no place in an economic report and must be reserved for a more comprehensive paper on the geology of the region. In the present report are given brief descriptions of the formations, with especial emphasis on those which may act as sources or reservoirs for oil and gas.

The areal distribution of the formations is shown in Plate XXXV (in pocket). Their succession and character are given in the following general section:

General section of geologic formations exposed in Moffat County, Colo., and southern Sweetwater County, Wyo.

System.	Series.	Group and formation.	Thickness (feet).	Character.
Quaternary.		Alluvium; terrace gravels.		Sandy clay along streams and in valley bottoms; terrace gravel on benches along rivers.
		—Unconformity—		
Tertiary.	Miocene (?).	Browns Park formation. / Bishop conglomerate.	Browns Park, 1,200+; Bishop, 0–200	Browns Park is mostly soft chalk-white sandstone; beds of chert; conglomerate at base. Bishop conglomerate (in the writer's opinion equivalent to basal conglomerate of Browns Park formation) consists of water-worn and subangular pebbles and boulders embedded in finer gravel and sand matrix.
		—Unconformity—		
Tertiary.	Eocene	Bridger formation.		Ash-gray and greenish clay shale; gray, buff, and blue-green sandstone; light-gray and white marl, limestone, and chert; conglomerate.
		—Unconformity locally—		
		Green River formation (including Laney shale member and Tipton tongue).	1,500±	Gray fissile shale and oil shale; gray clay shale; gray and buff sandstone and limestone; oolitic layers and alga reefs.
		Wasatch formation (including Cathedral Bluffs tongue).	3,000–5,600	Variegated clay shales; gray, buff, and pink sandstone, grit, and conglomerate; coal beds.
		—Unconformity—		
Tertiary (?).	Eocene (?).	Post-"Laramie" formation.	0–800	Gray and brown sandstone; gray and drab shale; coal beds; conglomerate at base.
		—Unconformity—		
Cretaceous.	Upper Cretaceous.	"Laramie" formation.	1,020–2,350 (?)	Sandstone, shale, and some coal.
		Lewis shale.	900–1,600	Gray marine shale and thin sandstones.
		Mesaverde group: Williams Fork formation.	1,600–3,400	Gray, white, and brown sandstone; gray shale; valuable coal beds.
		Mesaverde group: Iles formation.	1,350	Gray, white, and brown sandstone predominant; gray shale; some coal beds.
		Mancos shale.	5,085–5,370	Gray marine shale; thick lenticular beds of sandstone in upper 1,000 feet, and one thick sandstone near base.

General section of geologic formations exposed in Moffat County, Colo., and southern Sweetwater County, Wyo.—Continued.

System.	Series.	Group and formation.	Thickness (feet).	Character.
Cretaceous—Continued	Upper Cretaceous—Con.	Dakota sandstone.	155-250	Gray sandstone, at places quartzitic; gray and greenish clay shale; conglomerate of black chert pebbles.
		—Unconformity—		
Cretaceous (?).	Lower Cretaceous (?).	Morrison formation.	500	Variegated clay shale; thin lenticular sandstones, conglomeratic.
Jurassic.		Twin Creek limestone.	125	Gray thin-bedded limestone above; gray shale below.
		Nugget sandstone.	950	White and gray cross-bedded sandstone; some red sandy shale in upper part.
Triassic (?).		Ankareh (?) shale.	200	Red and gray sandy shale; sandstone and grit.
		-Unconformity-		
Triassic.		Thaynes (?) formation and Woodside shale.	760	Mostly gray and drab shale; thin beds of limestone and sandstone.
Carboniferous.	Permian and Pennsylvanian.	Park City formation.	115	White and gray limestone; chert; sandstone and shale; phosphate beds.
	Pennsylvanian.	Weber quartzite.	900	White and buff quartzitic sandstone.
			525	Limestone, shale, sandstone, and thin coal beds.
	Mississippian.		600	Gray cherty limestone; white quartzose sandstone and conglomerate at base.
		-Unconformity-		
Devonian (?) to later Cambrian.			0-200	Red and green shale; red, green, and white sandstone; pink limestone; conglomerate.
		-Unconformity-		
Earlier Cambrian and pre-Cambrian.			12,000+	Red quartzite and sandstone.

DETAILED SECTION NEAR VERMILION CREEK.

An almost complete succession of the Paleozoic and Mesozoic formations is splendidly exposed in a small area near Vermilion Creek. This locality, made famous by the descriptions of Powell, King, and others, has been visited many times by petroleum geologists who wished to gain some knowledge of the rocks which in neighboring districts are deeply buried. Because of its stratigraphic and economic importance, the following detailed section was measured in 1923 by J. B. Reeside, jr., W. H. Bradley, and the writer:

Section of Paleozoic and Mesozoic formations west of Vermilion Creek, in T. 10 N., R. 101 W., Colo.

	Feet.
Mesaverde group:	
Williams Fork (?) formation: White and gray sandstone; gray and drab shale; coal beds; upper part cut off by faulting against Wasatch formation	500+
Iles (?) formation: Massive white sandstone predominant; a little gray shale and carbonaceous shale	1,700±
Mancos shale:	
Gray shale, increasingly sandy toward top	100
Gray to slate-colored shale; at top and also 490 feet lower are lines of rusty-brown fine-grained calcareous sandstone concretions several feet in diameter, containing fossils of Montana age	1,224
Rusty-brown medium-grained sandstone in short lenses at four horizons, separated by gray shale; most prominent lens, 6 feet thick, at base; next lens, 2 feet thick, 25 feet higher; third lens, 1 foot thick, 88 feet above base; last lens, 1 foot thick, at top; sandstone contains fossils of Eagle age	140
Gray to slate-colored shale, irregular bedding; line of gray calcareous septarian concretions at base; thin beds of soft, fine-grained gray sandstone at 647, 657, 1,213, 1,233, and 1,269 feet above base; fossils of Niobrara age in lowest 400 feet; fossils of Telegraph Creek (early Montana) age at 657 feet above base	2,285
Dark slate-colored shale, including five or six bands of fine-grained gray sandstone that weather to low ridges; fossils of Niobrara age throughout	75
Light bluish-gray shale, laminated, breaking into flat pieces when fresh; line of gray calcareous septarian concretions as much as 1 foot in diameter at base; fossils of Niobrara age throughout	75
Dark slate-colored shale, irregular bedding; zones of light-gray laminated shale; many thin layers of shaly sandstone that weather into papery flakes; lines of gray calcareous septarian concretions as much as 1 foot in diameter at 75 and 90 feet above base; reddish sandy streaks with some reddish concretions at 125 and 190 feet above base; fossils of Niobrara age throughout	320
Light bluish-gray shale, laminated, breaking into flat pieces when fresh; line of gray calcareous septarian concretions at 335 feet above base	430
Dark slate-colored shale, irregular bedding; fossils of Niobrara age	106
Large dark reddish-brown sandstone concretions	1

	Feet.
Mancos shale—Continued.	
Dark slate-colored shale, irregular bedding; fossils of Carlile age	315
White sandstone, stained somewhat brown on surface; makes dip slope	2
Gray and brown carbonaceous shale; lens of coal up to 18 inches thick	4
Massive fine to medium grained sandstone; upper part white, lower part buff; slightly cross-bedded; a little gray shale; fossils of Carlile age	55
Gray sandy shale	25
Gray fine-grained sandstone in layers 1 to 6 inches thick, and gray sandy shale, interbedded; fossils of Carlile age	54.5
Limy shale with cone-in-cone structure	.5
Hard platy shale; bluish white to cream-colored on weathered surface, dark brown on fresh surface; abundant fish scales	34
Bentonite	3
Hard platy shale; bluish white to cream-colored on weathered surface, dark brown on fresh surface; abundant fish scales	118
Total thickness of Mancos shale	5,367
Dakota sandstone:	
Gray coarse-grained sandstone; gritty and conglomeratic bands	50
Gray shale and thin sandstones	15
White medium-grained sugary sandstone, friable	22
Dark-gray shale	24
Light-gray shale, greenish tint	16
White coarse-grained sugary sandstone, friable; contains many black grains	3
White and light-gray conglomeratic sandstone; many zones of small pebbles, mostly of black chert	27
Total thickness of Dakota sandstone	157
Morrison formation:	
Variegated clay shale, mostly mauve and gray; some soft gray sandstone	110
Lens of hard gray to dark-brown coarse-grained sandstone; small black chert pebbles; clay pebbles	2
Variegated clay shale, mostly mauve and gray	20
Hard brown fine-grained sandstone; breaks into blocks	1
Variegated clay shale, mostly mauve and gray	24
Lens of hard gray to dark-brown coarse-grained sandstone; small black chert pebbles	12
Greenish-gray clay shale	10

	Feet.
Morrison formation—Continued.	
Lens of hard gray to dark-brown coarse-grained sandstone; small black chert pebbles; clay pebbles; abundant fragments of dinosaur bones and silicified wood	18
Variegated clay shale, mostly mauve and gray; some soft gray sandstone; abundant gastroliths in this and higher members	64
Variegated clay shale and soft sandstone, largely red and white; local indurated layers; a few hard brown sandstone concretions	234
Total thickness of Morrison formation	495
Twin Creek limestone:	
Greenish-gray shale and gray to white soft sandstone; some local indurated layers	20
Gray to brown, mostly fine-grained limestone; blocky fracture; in part a well-developed oolite	6
Greenish-gray calcareous shale and lenses of brown impure limestone	10
Brown to gray impure platy limestone; in part fine grained, in part coarse grained and crystalline; some sandy layers	10
Greenish-gray shale	8
Gray to brownish fine-grained calcareous sandstone; breaks into thin plates	6
Greenish-gray shale; basal 20 feet yellowish and sandy; much obscured by débris	65
Total thickness of Twin Creek limestone	125
Nugget sandstone:	
Gray and tan fine to medium grained sandstone; much cross-bedding	160
Brick-red sandy shale	20
Gray and tan fine to medium grained sandstone; much cross-bedding	770
Total thickness of Nugget sandstone	950
Ankareh (?) shale:	
Sandy shale; predominantly red, to a lesser extent light green or gray; thin platy gray to pink limestone in uppermost 5 feet; thin red sandstones	120
Gray medium to coarse grained sandstone; lenses of grit and pebbles of gray chert and flint as much as 1 inch in diameter	88
Total thickness of Ankareh (?) shale	208

	Feet.
Thaynes (?) formation and Woodside shale:	
Light-gray sandy shale	249
Light-gray fine-grained sandstone; breaks into thin plates; forms dip slope	2
Light-gray sandy shale; many 6-inch layers of greenish-gray fine-grained platy sandstone at intervals of about 5 feet	185
Buff fine-grained sandstone, in thin papery plates separated by buff sandy shale; forms cliff	30
Light-gray sandy shale	80
Light-buff sandy shale	56
Light-gray fine-grained sandstone, in thin contorted plates; makes dip slope	3
Light-gray sandy shale	157
Total thickness of Thaynes (?) formation and Woodside shale	762
Park City formation:	
Buff fine-grained, probably calcareous platy sandstone	10
Light-buff sandy shale; contains many small dark-brown ferruginous berry-like concretions and streaks of yellow limonitic sandstone	44
Gray fine-grained laminated calcareous sandstone	1
Light-gray sandy shale	10
Gray fossiliferous limestone; makes notable dip slope at upper end of Vermilion Creek canyon	12
Gray and white chert and some interbedded limestone	21
Lens of gray fossiliferous limestone	1
Gray to white chert	6
Gray thin-bedded limestone	7
Gray sandstone	.5
Sandy shale and chert	.5
Total thickness of Park City formation	113
Weber quartzite: Gray, white, and yellow-brown fine to medium grained cross-bedded sandstone	898
Older Pennsylvanian rocks: Gray hackly limestone, gray and red sandstone, gray shale, carbonaceous shale, and thin irregular beds of coal	525
Mississippian rocks: Gray thick-bedded limestone, weathering to deep buff; basal part is old-rose sandy material containing small white quartz pebbles (reworked from the red quartzite on which it lies with a wavy contact); this grades upward into coarse-grained white sandstone, which is followed by the main body of gray limestone	585
Pre-Cambrian and early Cambrian rocks: Red quartzite and sandstone (thickness unknown).	

PRE-CAMBRIAN AND EARLY CAMBRIAN ROCKS.

The oldest rocks in the area described in this report are red quartzite and sandstone which form the core of the Uinta Mountain, Cross Mountain, and Juniper Mountain uplifts. This body of rock, which is estimated to be not less than 12,000 feet thick, was named the "Uinta group" by Powell and has been assigned to various ages from pre-Cambrian to Carboniferous. The writer follows Schultz [15] in calling these beds pre-Cambrian and early Cambrian.

LATER CAMBRIAN TO DEVONIAN (?) ROCKS.

In the canyon of Yampa River at Cross Mountain, according to Reeside,[16] who with J. B. Eby visited this locality in 1923, the red quartzite is overlain with angular unconformity by beds thought to represent the Lodore "group" of Powell. The lower part, estimated to be 175 feet thick, consists of flaggy medium to coarse grained sandstone, which on weathered surfaces is red and rusty brown to light gray and on fresh surfaces is white with a mottling of green and brown specks; the basal part of this sandstone contains quartz pebbles as much as a quarter of an inch in diameter. Between this sandstone and the overlying Mississippian limestone are soft unexposed beds forming a prominent slope; the surface débris includes fragments of fine-grained, rather soft green sandstone and pink dense fine-grained limestone.

A conglomerate of white quartz pebbles which lies between the red quartzite and the Mississippian limestone in Juniper Mountain may represent either the basal part of the Lodore "group" or the basal part of the Mississippian.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

Gray cherty limestone about 600 feet thick crops out on the flanks of the Uinta Mountain arch and forms much of the crest as well as the flanks of the Cross Mountain and Juniper Mountain uplifts. At Irish Canyon, near the southeast end of Cold Spring Mountain, this formation rests directly upon an irregular surface of the red quartzite. Its base is reddish sandy material with small quartz pebbles, evidently reworked from the underlying quartzite; this grades upward into coarse white sandstone, which is overlain by the main body of gray cherty limestone. This limestone is proved by abundant fossils to be of Mississippian age and is probably equivalent to the

[15] Schultz, A. R., Oil possibilities in and around Baxter Basin, in the Rock Springs uplift, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 702, pl. 1, 1920.

[16] Reeside, J. B., jr., personal communication.

Madison limestone of adjoining regions. Reports of oil in the Madison limestone in Montana, Wyoming, and Utah make the possible occurrence of oil in this formation worth considering, but so far as known there are no indications of oil in the Mississippian limestone of this field. In anticlines where the formation is under cover it is too deep to be reached by the drill.

PENNSYLVANIAN SERIES.

OLDER PENNSYLVANIAN ROCKS.

Conformably above the Mississippian limestone is a succession of gray limestone, gray and red sandstone, gray shale, and coal, about 525 feet thick, shown by its fossils to belong to the Pennsylvanian series. So far as known these rocks have no importance in the search for petroleum.

WEBER QUARTZITE.

The older Pennsylvanian rocks are conformably overlain by 900 feet of white and buff fine-grained cross-bedded quartzitic sandstone known as the Weber quartzite. No oil was observed in this formation by the writer. Its equivalent, the Tensleep sandstone, is the lowest formation that has yielded oil in central Wyoming.[17]

PENNSYLVANIAN AND PERMIAN SERIES.

PARK CITY FORMATION.

Overlying the Weber quartzite is about 115 feet of fossiliferous limestone, chert, sandstone, shale, and phosphate beds that compose the Park City formation. Owing to its superior hardness and its position below a thick body of soft, easily eroded shale, the lower part of the formation makes a conspicuous dip slope along the northern flank of the Uinta Mountain arch.

Indications of oil have been noted in the Park City formation and its equivalents at many localities in the Rocky Mountain States. It is possible that the formation is a source of oil, which at many places has migrated into adjacent sandstones. A probable example is seen in this field; in sec. 6, T. 9 N., R. 100 W., the coarse sandy matrix of the basal conglomerate of the Browns Park formation, which lies unconformably on upturned Paleozoic and Mesozoic beds, is heavily saturated with oil. At this place the Browns Park probably rests on the edge of the Park City formation, in which the oil may have originated. Schultz[18] collected a sample of phosphate

[17] Heald, K. C., personal communication.

[18] Schultz, A. R., Oil possibilities in and around Baxter Basin, in the Rock Springs uplift, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 702, p. 81, 1920.

rock near Vermilion Creek, in sec. 36, T. 10 N., R. 101 W., which by dry distillation yielded oil in the ratio of 2.34 gallons to the ton.

TRIASSIC SYSTEM.

WOODSIDE SHALE AND THAYNES (?) FORMATION.

The body of gray and drab shale about 760 feet thick overlying the Park City in this field has been mapped by Schultz[19] as the Woodside shale and Thaynes (?) formation. Farther west, where these formations are more definite, they and the overlying Ankareh shale are predominantly red. Because of their different appearance and the uncertainty of division in their small outcrops near Vermilion Creek, the beds between the Park City formation and the Nugget sandstone have not been separated on the accompanying map (Pl. XXXV).

TRIASSIC (?) SYSTEM.

ANKAREH (?) SHALE.

Overlying the Thaynes (?) formation is about 200 feet of red and gray sandy shale, sandstone, and grit, which Schultz[20] has called the Ankareh shale. These beds, which may prove to be the basal part of the Nugget sandstone in this field, are grouped with the underlying shale on the map in this report (Pl. XXXV, in pocket).

JURASSIC SYSTEM.

NUGGET SANDSTONE.

Above the Ankareh (?) shale is about 950 feet of white and buff sandstone, which is correlated with the Nugget sandstone of southwestern Wyoming. This formation is medium to fine grained, friable, and everywhere strikingly cross-bedded. In the upper part are included beds of red and gray sandy shale.

The sandstone is heavily saturated with oil for several hundred feet on the outcrop in the SE. ¼ sec. 6, T. 9 N., R. 100 W. It is probable that this oil originated in the Park City formation and moved upward through the shale.

According to Schultz,[21] "indications of oil have been observed in these beds [Nugget sandstone] at several points along the Uinta Mountains. * * * At a number of places along the outcrop on the south side of the Uinta Mountains some of the oil has escaped to the surface and formed small asphaltic deposits on the ground."

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[19] Schultz, A. R., op. cit., pl. 1. [20] Idem, pl. 1. [21] Idem, p. 78.

TWIN CREEK LIMESTONE.

The next formation in ascending order is the Twin Creek limestone, about 125 feet thick. It is composed of a gray marine shale member below and a light-gray thin-bedded fossiliferous limestone above. These beds are equivalent to at least the upper part of the marine Jurassic Sundance formation of central Wyoming. They are believed to be of no importance as a source of oil in Moffat County.

CRETACEOUS (?) SYSTEM.

LOWER CRETACEOUS (?) SERIES.

MORRISON FORMATION.

Above the Twin Creek limestone is a body of variegated clay shale with a few lenses of conglomeratic sandstone, which, in the opinion of the writer, represents the Morrison formation. Schultz [22] has grouped these beds with the overlying sandstone, shale, and conglomerate of the Dakota under the name Beckwith formation; such grouping, which is at variance with the practice of earlier workers in this field, seems undesirable to the writer.

The formation as here described is about 500 feet thick. Around the east end of the Uinta Mountains it does not in general contain sandstone beds such as elsewhere are considered possible reservoirs for oil.

CRETACEOUS SYSTEM.

UPPER CRETACEOUS SERIES.

DAKOTA SANDSTONE.

The Dakota sandstone ranges in thickness from 155 to 250 feet. Although varying somewhat in minor details from place to place, it maintains its characteristic lithology throughout the field and also where seen by the writer along the south flank of the Uinta Mountains as far west as the Utah line. Its lowest member consists of black chert pebble conglomerate and conglomeratic sandstone; the middle member is a somewhat variable body of thin sandstones and gray clay shale, the shale at many places of a greenish or purplish tint; the uppermost member includes white sugary sandstone, quartzite, and conglomeratic sandstone. This threefold division suggests that the formation is possibly equivalent to the Cloverly of several localities in Wyoming.

For several hundred yards on the outcrop in sec. 23, T. 9 N., R. 100 W., the conglomerate at the base of the Dakota is heavily saturated

[22] Schultz, A. R., op. cit., pp. 75–77.

with oil. (See Pl. XXXVI.) Other occurrences and signs of oil at this horizon at many localities in Wyoming are cited by Schultz,[23] who designated this conglomerate the third member of the Beckwith formation. Oil in commercial quantity has now been found in the Dakota at the Moffat (Hamilton) dome, in the southeastern part of Moffat County.

MANCOS SHALE.

The Mancos shale, about 5,300 feet thick, lies conformably upon the Dakota sandstone. The greater part of the formation is an almost homogeneous mass of marine shale which upon weathered surfaces is light gray or drab and flaky; below the surface the moist shale is dark gray, and stratification is obscure except where indicated by thin sandy or limy layers.

The basal member of the formation throughout the field includes dark blocky or platy shale, which weathers to a light blue or cream color and in which there is an abundance of scales and other fish remains; this member, 155 to 200 feet thick on outcrops, possibly represents the Mowry shale, from which oil is produced at several localities in Wyoming. In the banks of the gulch in the SW. ¼ sec. 24, T. 9 N., R. 100 W., oil was found in joints and between the laminae of the blocky shale of this member; at no other place in the field was oil observed at this horizon by the writer, although Hancock[24] says that "the dark calcareous and fossiliferous shale beds a few hundred feet above the base of the Mancos shale on the south side of Yampa River, in sec. 16, T. 6 N., R. 94 W., usually appear moist on the fracture planes and emit the odor of petroleum to a marked degree." It is possible that this member is a source of oil.

Above the basal shale member is a sandy zone which at places is marked by a heavy sandstone ledge. Possible correlation of this zone with the sandy Frontier formation has been suggested by several writers, and the matter is of importance because oil is produced from the Frontier in Wyoming. The character of this zone and of the underlying shale near Vermilion Creek is shown in the section on page 279; the basal 155 feet of the Mancos shale may represent the Mowry, and the overlying 141 feet of sandstone and shale may represent the Frontier formation. It is not yet certain whether this sandstone represents the upper or the lower of the two sandstones, about 400 feet apart, from which gas is produced in the Baxter Basin field, Wyo.; if it represents the upper, then the lower gas sand at Baxter Basin is the Dakota; if it represents the lower, then the upper gas sand of Baxter Basin is absent on Vermilion Creek. On the south side of the Uinta Mountains, north of the road from Craig

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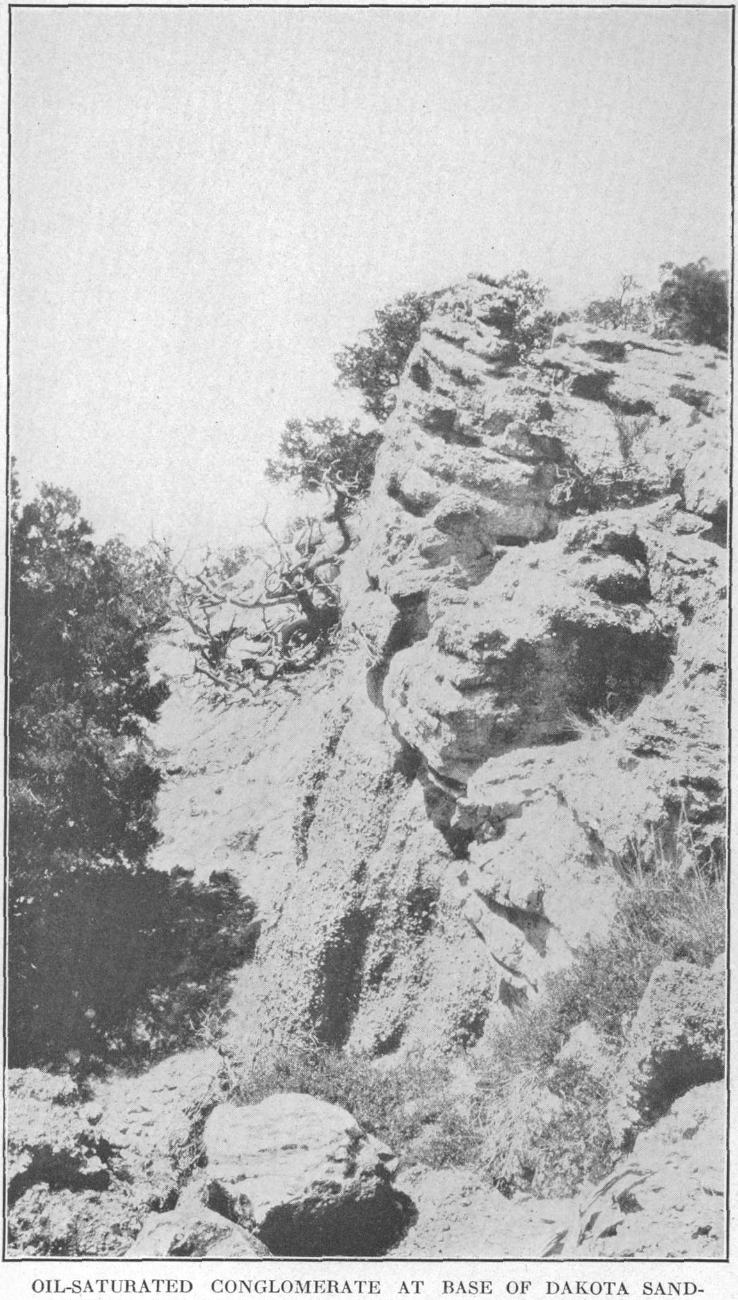
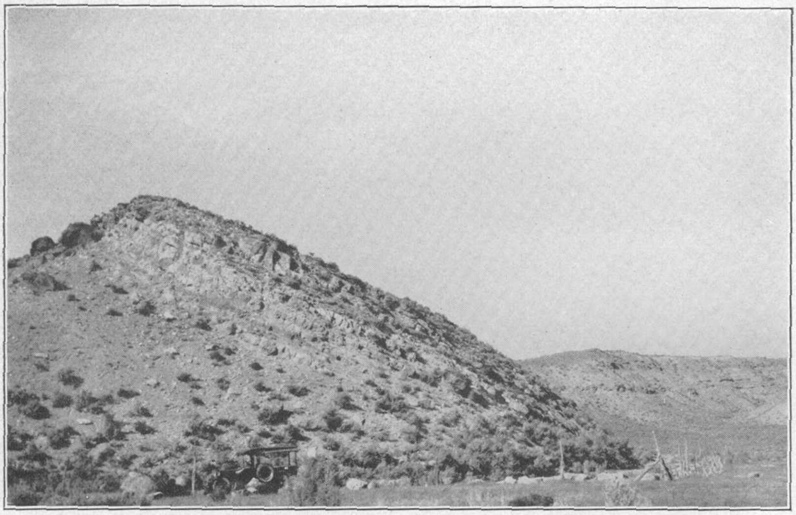
[23] Schultz, A. R., op. cit., pp. 76–77.

[24] Hancock, E. T., op. cit.

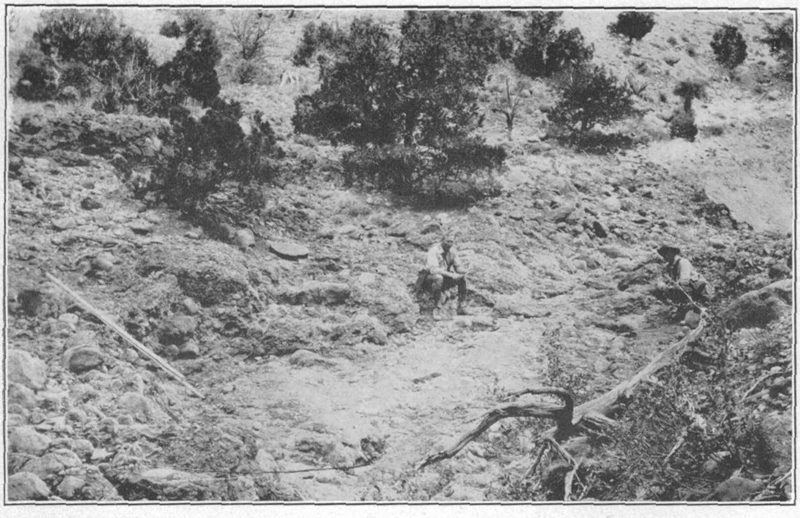


OIL-SATURATED CONGLOMERATE AT BASE OF DAKOTA SANDSTONE, SEC. 23, T. 9 N., R. 100 W., MOFFAT COUNTY, COLO.



A. SANDSTONE NEAR BASE OF MANCOS SHALE, EAST OF JUNIPER MOUNTAIN, MOFFAT COUNTY, COLO.

Horizontal Browns Park formation in background



B. BASAL CONGLOMERATE OF BROWNS PARK FORMATION, SEC. 6, T. 9 N., R. 100 W., MOFFAT COUNTY, COLO.

Sandy matrix is heavily saturated with oil to Vernal, the sandy zone is marked by thin-bedded sandstone and shale, and some of the sandstone is coarse and porous. East of Juniper Mountain a conspicuous sandstone at this horizon makes a ledge crossing Yampa River (see Pl. XXXVII, *A*); the character of this sandstone and of the underlying and overlying shale is shown in the following section measured by the writer near Juniper Hot Springs, in sec. 16, T. 6 N., R. 94 W.:

Section of lower part of Mancos shale near Juniper Hot Springs.

	Ft.	in.
Shale, gray and drab, poorly exposed.		
Shale, gray, platy, very thin layers, perfect bedding planes	10	6
Shale, gray, somewhat platy, fairly resistant	29	
Shale, gray, platy, paper-thin layers, perfect bedding, fairly resistant; makes conspicuous small ledge on slope	3	
Clay shale, gray; weathers drab; flaky on weathered slopes; below surface, bedding is obscure in moist shale, which breaks in lumps	11	6
Shale, limy, resistant; forms noticeable ledge across slope		4
Shale, argillaceous, gray	182	
Interval, poorly exposed; shale and a little thin sandstone	77	
Sandstone, gray, thin-bedded; some is more or less quartzitic. Near top is a thin gritty layer containing shark teeth	5	
Interval, poorly exposed, probably shale; several sandstones each about 6 inches thick; one of these, near top, has distinctly fetid odor when freshly broken	25	8
Sandstone, gray, thin-bedded	4	
Shale and thin layers of sandstone	6	
Sandstone, gray, mostly fine grained; much comminuted black organic material, especially in lower part; quartzitic, resistant; makes ledge crossing river	45	
Shale, gray, flaky and drab on weathered surface; several 2 to 6 inch layers of sandstone, the upper of which are quartzitic	64	6
Shale, gray, lumpy	35	10
Sandstone, gray, quartzitic	1	10
Shale; upper part dark gray to black, paper-thin, flaky; lower part gray, lumpy	56	4
Shale, mostly dark gray to black, platy; many fish scales found near top; bottom part more flaky	28	8
Dakota sandstone: Sandstone, quartzitic.		

It is possible that the thickness of the shales in the lower part of this section is not accurate, as faults near by indicate that displacing and squeezing may have distorted the shale. The log of the well at the Moffat (Hamilton) dome indicates that the lower shale

(Mowry ?) thickens somewhat toward the east; the interval from the top of the sandy zone (Frontier ?) to the Dakota in the well is 385 feet, as compared to the corresponding interval of 273 feet near Juniper Hot Springs.

The absence of sandstones in the main body of the formation is noteworthy; only a few very thin outcropping layers were observed in any part of the field. The uppermost 1,000 feet of the Mancos in Axial Basin, however, contains several thick lenses of sandstone. The most prominent of these, 930 feet below the top of the formation, was called by Hancock[25] the Morapos sandstone member; it is exposed almost continuously from sec. 36, T. 5 N., R. 92 W., eastward into the valley of Morapos Creek, where it is faulted and offset a mile to the west. Thence the sandstone extends southwestward to the center of sec. 26, T. 4 N., R. 92 W., where it is cut by a large fault that offsets the bed a mile to the east, and from that point it extends southeastward beyond the limits of the field. The sandstone also forms a rim around the Moffat (Hamilton) dome, in the southern part of T. 5 N., R. 91 W., and the northern part of T. 4 N., R. 91 W., where it reaches a thickness of about 75 feet. The member is probably represented south of Duffy Mountain, in T. 5 N., R. 93 W., where it makes a low bench in the shale. In this vicinity an upper sandstone of the Mancos, lying about 100 feet below the base of the Mesaverde, forms a prominent bench for several miles. On the south side of Axial Basin the sandstones of the upper Mancos are poorly developed or absent; in sec. 20, T. 4 N., R. 92 W., east of the road between Axial and Craig, there is a heavy ledge of sandstone thought to be the Morapos. The Morapos sandstone member would probably form an efficient reservoir for oil, but outcrops indicate that it is lenticular and that its presence can not be relied on except for some distance eastward and northeastward from Hamilton post office. Elsewhere in the field even the upper Mancos is practically without sandstones, except for a few thin transitional sandy beds very near the top.

The thickness of the Mancos is about 5,370 feet near Vermilion Creek, about 5,300 feet near Juniper Hot Springs and about 5,085 feet at the Moffat (Hamilton) dome. The stratigraphic limits of the formation probably correspond closely throughout the field. Near Vermilion Creek, however, the Mancos as mapped by the writer includes not only the Aspen shale, Frontier formation, and Hilliard shale as mapped in this area by Schultz[26] but also beds corresponding to those in the neighborhood of Rock Springs, Wyo., which Schultz included in the lower part of the Mesaverde group.

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[25] Hancock, E. T., op. cit.

[26] Schultz, A. R., Oil possibilities in and around Baxter Basin, in the Rock Springs uplift, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 702, pl. 1, 1920.

This apparent discrepancy is due to the lateral changes of several formations which the writer has observed in the Rock Springs uplift. Southward from the Union Pacific Railroad the lower part of the Mesaverde (Rock Springs coal group of Schultz) and the Blair formation (upper part of the Hilliard shale as mapped by Schultz) become less and less sandy, and at the south end of the uplift they consist almost entirely of shale, with little sandstone and no coal. Near Vermilion Creek the "middle Mesaverde" of the Rock Springs area rests directly upon the homogeneous shale body here mapped as Mancos shale.

MESAVERDE GROUP.

The series of sandstone, shale, and coal beds lying conformably upon the Mancos shale on the flanks of the Axial Basin anticline was referred by Hancock[27] to the Mesaverde group; the lower part he named the Iles formation, and the upper part the Williams Fork formation. This classification, which differs only slightly from that adopted by Fenneman and Gale,[28] will be used in this report.

Iles formation.—Two measurements by Hancock show that the Iles formation is 1,350 feet thick. In his section measured on Milk Creek, on the south side of Axial Basin, the formation includes 746 feet of sandstone, 112 feet of shale, 16 feet of coal, and 476 feet of concealed beds. Even if the concealed intervals are assumed to contain only shale, an assumption contrary to Hancock's opinion, the formation still consists of at least 55 per cent sandstone. The beds are mostly of marine and brackish-water origin.

The base of the formation is mapped below a white and brown sandstone which ranges in thickness from 15 to 25 feet. About 75 feet above the basal bed is another sandstone, which forms the conspicuous rim of Axial Basin; the upper part of the rim rock is white and weathers into rounded forms; the lower part weathers into great rectangular blocks of yellowish-brown color.

The upper boundary of the formation is drawn on top of the massive white Trout Creek sandstone member, which is very prominent on its outcrop around the Axial Basin anticline and farther east in the Yampa coal field.

In the vicinity of Vermilion Creek the Mancos shale is overlain by massive white sandstone and subordinate shale, which in turn is overlain by less conspicuous sandstone, drab shale, and coal beds. The white sandstones, 1,700 feet thick, which contain marine fossils

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[27] Hancock, E. T., op. cit.

[28] Fenneman, N. M., and Gale, H. S., The Yampa coal field, Routt County, Colo.: 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.

of Montana age, have been identified by the writer as the "middle Mesaverde" of the Rock Springs uplift;[29] the name Iles formation is tentatively extended to Vermilion Creek and applied to these white sandstones.

Williams Fork formation.—Sandstone, shale, and thick coal beds comprising the upper part of the Mesaverde group were named by Hancock[30] the Williams Fork formation. In general the sandstones are less resistant and conspicuous than those of the Iles. The Williams Fork is distinguished also in this field and in the Yampa field to the east by the number of beds of baked shale and red sandstone produced by the burning of coal beds.

Fossils collected from the formation are of marine, brackish-water, and fresh-water types, showing that during its deposition there were long periods of swamp and estuarine conditions, interrupted by invasions of the sea. The upper part of the formation carries a preponderance of marine fossils, indicating that sands were laid down in the shallow marginal portion of a sea which afterward grew deeper and was filled with finer sediments of the overlying Lewis shale.

On the north side of the Axial Basin anticline the thickness of the formation is 1,600 feet, according to the writer's measurement on Williams Fork. Its upper boundary is drawn on top of the highest prominent white sandstone below the soft gray shale of the Lewis. On the south side of the anticline the Mesaverde group is overlain unconformably by beds of Wasatch age, without apparent discordance of dip. In this area the Williams Fork formation is about 3,400 feet thick, according to measurements by Bradley and Gilluly in Freeman and Bob Hughes gulches. This striking increase of thickness within 20 miles and the absence of recognized Lewis shale and "Laramie" beds are interpreted by the writer as showing a lateral variation in sediments by which the Williams Fork on the south side of the anticline includes beds equivalent to the Lewis shale and "Laramie" formation north of the anticline.

In the Vermilion Creek area the sandstone, drab shale, and coal beds that lie above the white sandstone formation called in this report the Iles (?) are identified by the writer as equivalent to the Almond coal group mapped in the Rock Springs uplift by Schultz[31]; in the present report they are tentatively assigned to the Williams Fork formation.

LEWIS SHALE.

Within the field covered by this report the Lewis shale is exposed only on the north flank of the Axial Basin anticline between Craig

[29] Schultz, A. R., op. cit., pl. 1.
[30] Hancock, E. T., op. cit.
[31] Schultz, A. R., op. cit., pl. 1.

and Maybell. The formation consists of gray marine shale and a few thin beds of soft sandstone. It is about 1,600 feet thick in the vicinity of Craig, and 900 feet thick on Spring Creek. On the south flank of the anticline it may be represented by a zone of marine shale in the upper part of the beds there mapped as Williams Fork. Gale[32] believed that the absence of the Lewis shale and the "Laramie" formation south of Axial Basin was caused by the erosion or nondeposition of those beds. The writer believes, on the contrary, that the Lewis shale thins westward and southwestward, and that the "Laramie" merges with the Williams Fork as a continuous formation.

"LARAMIE" FORMATION.

The Lewis shale is overlain by a succession of shales, thin coal beds, and prominent sandstones which resemble those of the Mesaverde except that they are less resistant. These rocks were called by Gale[33] the "Laramie" formation, on evidence afforded by fossil plants from the upper part. Later collections of marine invertebrates by Hancock[34] indicate that at least the lower 250 feet of the formation is of Lewis age, but the exact boundary is unknown and is not of practical value. For convenience in field mapping, the boundary chosen by Gale and used in the present report is the base of the lowest of the sandstones that make prominent ridges or ledges north of the valley eroded in soft Lewis shale. The basal sandstone of the "Laramie" as here mapped forms a conspicuous cliff just north of Craig. At this locality the formation is 1,020 feet thick; calculations from outcrops and dip readings indicate that 5 miles west of Craig the formation is very much thicker, but poor outcrops and certain small faults and anomalous dips make the figures seem very questionable.

TERTIARY (?) SYSTEM.

EOCENE (?) SERIES.

POST-"LARAMIE" FORMATION.

On the flanks of the Axial Basin anticline the Cretaceous rocks already described are overlain by a conspicuous conglomerate which includes pebbles of red and white quartzite, sandstone, chert, and igneous rock and is more or less indurated. In the writer's opinion, this conglomerate is the earliest Tertiary deposit of the region and marks a notable unconformity. Although a long period of uplift and erosion may have intervened, no discordance of dip has been

[32] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, p. 69, 1910.
[33] Idem, pp. 72–74.
[34] Hancock, E. T., op. cit.

observed in the beds above and below the unconformity. The similarity of the conglomerate on the two sides of the anticline suggests that it is of the same age throughout, but considerable question has arisen as to the correlation of the next younger beds. On the south flank the conglomerate rests on beds mapped as Mesaverde and is directly overlain by rocks mapped as Wasatch; in this vicinity the Wasatch is predominantly variegated clay shale but contains in its lower part many sandstones that resemble those of the Mesaverde. On the north flank the conglomerate rests on a massive white sandstone of the "Laramie" and is overlain by about 800 feet of sandstone, shale, and coal beds, which closely resemble both the "Laramie" and the Mesaverde. These beds were called by Gale[35] the post-"Laramie" formation. Their upper limit is an inconspicuous zone of small quartz pebbles which is overlain by the variegated clay shale and sandstone of the Wasatch. Gale[36] discusses the problem at some length and concludes that the stratigraphic and lithologic evidence favors correlation of the post-"Laramie" with the lower beds of the Wasatch as mapped south of the anticline, although such correlation is not accepted as logical by paleontologists. The writer has no new data on this problem, and in the present report the separation of the post-"Laramie" formation from the Wasatch formation on the north flank of the anticline is continued.

Some of the coal beds of the post-"Laramie" formation are thick enough to be of commercial value and have been opened in small mines on Lay and Spring creeks and west of Cedar Mountain.

TERTIARY SYSTEM.

EOCENE SERIES.

WASATCH FORMATION.

In the eastern and southern parts of Moffat County the Wasatch formation consists chiefly of clay shale banded with various shades of red, purple, orange, gray, green, and buff, which weathers to badlands. At several horizons there are zones of more resistant sandstone and grit; one of these zones, near the middle of the formation, makes a conspicuous low escarpment east of Godiva Ridge, in the valley of Sand Creek. As described in the preceding section, the basal sandy portion of the Wasatch near Escarpment and Wapiti peaks may be of the same age as the post-"Laramie" formation mapped between Craig and Sunbeam. Calculations from

[35] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, pp. 79–80, 1910.

[36] Idem, pp. 75–83.

outcrops and structure between Godiva Ridge and Sand Creek show that the formation is 5,600 feet thick in this part of the field.

In the basin of Vermilion Creek, in northwestern Moffat County and southern Sweetwater County, the Wasatch is of somewhat different character. The lower part contains much more sandstone and some conglomerate; its clay shale is chiefly gray or buff, although brightly colored at some horizons; and it includes several beds of coal, one of which is worked at the Canyon Creek mine and another at the Sparks mine. Owing to the pronounced overlap of the formation on older beds its base is not definite, and the thickness of the lower part is not known. The upper part consists of 600 to 1,200 feet of clay shale, similar to that in the eastern portion of the field, except that here various shades of red are predominant. The upper and lower parts of the Wasatch are separated by the Tipton tongue of the Green River formation. This tongue, which is characterized by gray fissile shale and oil shale, wedges out southward; and the main part of the Wasatch and the upper part, here called the Cathedral Bluffs tongue, merge into a continuous formation comparable to that east of Godiva Ridge. According to Schultz [37] the Cathedral Bluffs tongue, which he called a member of the Green River formation, passes northwestward by lateral variation into typical Green River shales.

GREEN RIVER FORMATION.

Above the Wasatch are beds of gray fissile shale and oil shale, thin sandstones and limestones, oolitic beds, and alga reefs, which are correlated with the Green River formation. In this region the Laney shale member of Schultz is persistent and makes up the bulk of the formation; southeastward from the neighborhood of Lookout Mountain this member is the actual base of the formation. The Tipton tongue appears as a wedge between the two parts of the Wasatch in sec. 4, T. 10 N., R. 100 W., and thickens toward the north and northwest. Still farther northwest, beyond the limits of the field, the Cathedral Bluffs tongue of the Wasatch loses its identity and the Tipton tongue merges with the overlying Green River shales.

The stratigraphic relations of the Wasatch and Green River formations are shown in Figure 23. These relations and the oil-shale deposits of the Green River are described more fully in another report.[38]

The upper boundary of the Green River formation around Sand Wash Basin is difficult to locate with precision, as the uppermost

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[37] Schultz, A. R., op. cit., pp. 28–30.

[38] Sears, J. D., and Bradley, W. H., Relations of the Wasatch and Green River formations in northwestern Colorado and southern Wyoming: U. S. Geol. Survey Prof. Paper 132–F (in press).

100 to 150 feet contains beds typical of both the Green River and the Bridger. Near Sand Wash the boundary chosen is the base of a deep-green gritty sandstone, above which are the predominantly light-gray clay shales of the Bridger; the bottom of this sandstone

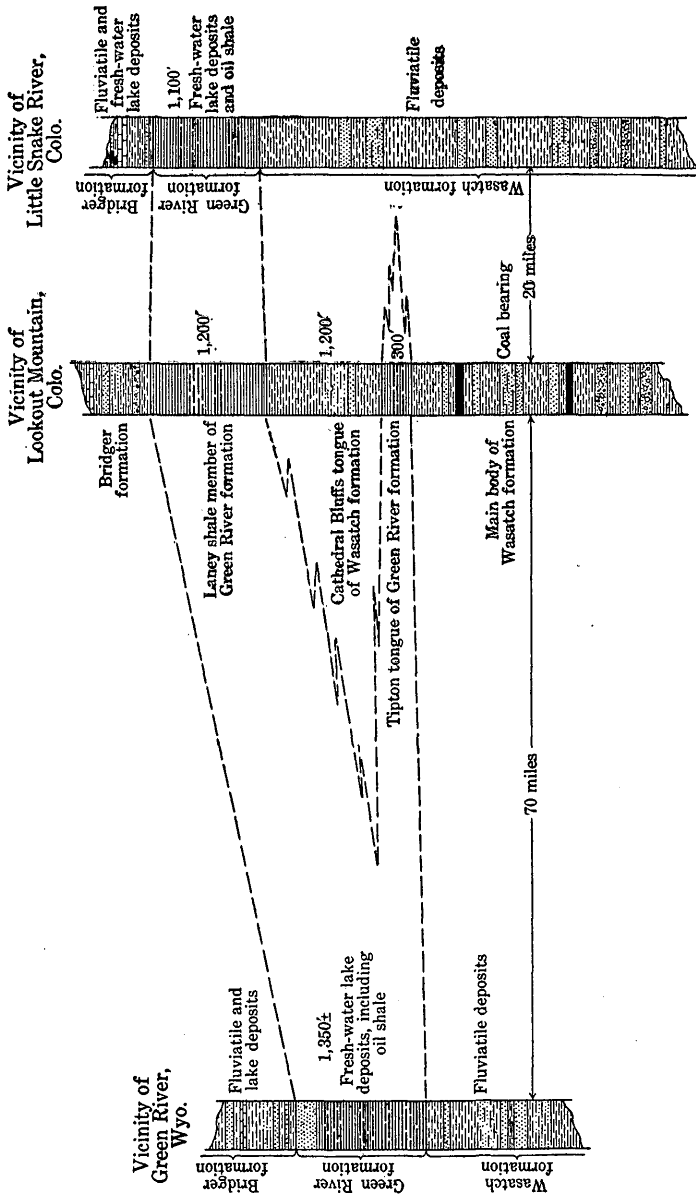

FIGURE 23.—Sections in Green River Basin, Wyo., showing interfingering of Wasatch and Green River formations.

is an uneven plane, apparently marking a small local unconformity. The transition zone at the top of the Green River is possibly equivalent to the "Upper Green River" ("Tower sandstone" and plant beds) of Powell.

BRIDGER FORMATION.

Overlying the Green River shales in the structural depression of Sand Wash Basin are rocks of Bridger age, presumably the erosional remnant of beds once continuous with those now exposed in Washakie and Bridger basins. The formation consists chiefly of ash-gray clay shale but includes soft sandstone, chert, marl, limestone, and conglomerate. A few bands of light and dark bluish-green sandstone and sandy shale are conspicuous in the otherwise monotonously colored outcrops.

MIOCENE (?) SERIES.

BROWNS PARK FORMATION.

Resting with great angular unconformity upon all older rocks of the field, from pre-Cambrian to Bridger inclusive, is the Browns Park formation, at least 1,200 feet thick. It consists principally of chalk-white sandstone made up of quartz grains cemented with calcareous material. In general the formation is well bedded; east of Little Snake River cross-bedding is fairly common. Many beds are very friable and break down readily into drifting white sand; other layers are more resistant and weather with a very characteristic lumpy or jagged surface. The lower part of the formation contains many hard cherty layers, especially near Little Snake River and on the southern margin of Cold Spring Mountain. At the latter locality, in secs. 7 and 18, T. 10 N., R. 102 W., a distinct local unconformity occurs within the formation; the lower beds, including many cherty layers, dip 23° S., and the upper beds, consisting chiefly of soft fine-grained sandstone, dip only 7°. A mile farther southeast the unconformity has apparently died out.

Almost everywhere the base of the formation is marked by a conglomerate, which has very different characteristics in the eastern and western parts of the field. East of Little Snake River the pebbles rarely exceed 2 inches in diameter and consist of metamorphic and igneous rock, red and white quartzite, chert, and vein quartz. West of the Little Snake the conglomerate includes some pebbles of gray cherty limestone, probably of Carboniferous age, but consists predominantly of red quartzite pebbles and boulders which reach a maximum diameter of several feet; the conglomerate ranges in thickness from a few inches to 300 feet.

BISHOP CONGLOMERATE.

Diamond Peak and Lookout Mountain are capped with material to which Powell gave the name "Bishop Mountain conglomerate." Other patches of this formation are found high on the flanks of the

Uinta Mountains and on hills as far north as Aspen Mountain, in the Rock Springs uplift, Wyo. A full description of its character and origin is given in an excellent paper by Rich.[39] The conglomerate is made up of waterworn and subangular pebbles and boulders embedded in a finer gravel and sand matrix; the material is chiefly red quartzite and cherty gray limestone. The Bishop conglomerate has always been considered younger than the Browns Park formation, although, so far as the writer knows, it is nowhere found resting upon the Browns Park. The lithology of the Bishop conglomerate and many features of structure and paleophysiography that are discussed fully in another report[40] make the writer lean strongly toward the belief that the Bishop conglomerate is in reality the basal conglomerate of the Browns Park formation and that their present discordance in altitude is due to movement since deposition.

QUATERNARY SYSTEM.

Terrace gravel and alluvium are found at many places on the benches and in the valleys of the principal streams and rivers. As these deposits have no bearing on the search for oil and gas, they are omitted from the geologic map and need not be described in detail in this report.

IGNEOUS ROCKS.

Cedar Mountain is capped by basalt that rests upon white sandstone of the Browns Park formation. Hancock[41] reports that he found some of the sandstone resting upon the basalt, proving that the basalt is of upper Browns Park age.

Small outliers of basalt cap several hills in T. 4 N., R. 91 W.

STRUCTURE.

GENERAL FEATURES.

The term structure as applied to rock beds means their present attitude. Most sedimentary rocks were deposited in approximately horizontal beds, but many such beds have been later warped into other positions by the great forces that slowly modify the earth's crust. Some beds have been uplifted thousands of feet without being tilted; others have been inclined or bent into more or less complicated folds. Upward folds are called anticlines or, if nearly equal in

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[39] Rich, J. L., The physiography of the Bishop conglomerate, southwestern Wyoming: Jour. Geology, vol. 18, pp. 601–632, 1910.

[40] Sears, J. D., Relations of the Browns Park formation and the Bishop conglomerate and their rôle in the origin of Green and Yampa rivers: Geol. Soc. America Bull., vol. 35, pp. 279–304, 1924.

[41] Hancock, E. T., The history of a portion of Yampa River, Colo., and its possible bearing on that of Green River: U. S. Geol. Survey Prof. Paper 90, p. 187, 1915.

length and width, domes; downward folds are called synclines. In the process of deformation many beds have been broken, and the portions on one side of the break or fault have been raised or lowered with reference to those on the other side.

The structure must not be confused with the shape of the present land surface. At many places the topography bears a definite relation to the structure, but at others synclines underlie the hills and anticlines are eroded to form valleys.

Knowledge of the structure is important to the seeker of petroleum and natural gas, as these substances if present are likely to accumulate in certain types of folds. It is generally believed that oil and gas are formed by the decomposition of buried organic material and are forced through porous beds or fissures by capillary action or by water and gas pressure. Where the rocks are more or less saturated with water the oil and gas tend to collect in the crests or high on the flanks of anticlines or domes. Where little or no water is present oil is more likely to accumulate in synclines, but these conditions are less common, so that in general the upfolds are looked upon as the most favorable places to drill for oil and gas.

Consideration should be given also to the nature of any faults that may exist in the field. Formerly unbroken anticlines were regarded with greater favor, as faults were supposed to have permitted the escape of oil and gas. To-day there is a growing tendency among petroleum geologists to look upon faulting as advantageous, on the theory that freer circulation through fissures allows more oil and gas to migrate to the higher parts of the upfolds.

In much of the Moffat County field the Eocene beds rest upon older rocks with a pronounced angular unconformity and overlap. A still greater discordance of dip is shown between the Browns Park formation and all older rocks. Because of these unconformities the structure seen where younger rocks are at the surface may or may not be similar to that in older beds beneath. In this report the folds are described under three headings—those in Cretaceous and older rocks, those in Eocene beds, and those in the Browns Park formation.

METHODS OF REPRESENTING STRUCTURE.

One method of representing structure is by the dip and strike symbol, which consists of a bar showing the strike or direction of a level line on the bed, and an arrow and figure showing the direction and amount of the dip (or variation from a horizontal position). A second method is by lines giving the position of anticlinal and synclinal axes. These two methods are used in all parts of the geologic map accompanying this report (Pl. XXXV, in pocket).

A third method may be employed where the thicknesses of the formations are fairly constant and the boundary planes between them are nearly parallel. This method is the use of structure contours drawn on a key horizon. These contours are lines connecting points of equal elevation on the horizon; they are far apart where the dip is gentle and are closer where the dip is steep. The elevations on the key horizon are determined by direct readings in the field or calculated from readings taken on other beds at known intervals above or below the key horizon. Obviously such contours can not be drawn where the exposed rocks lie with marked unconformity upon the series containing the key horizon. In the present report structure contours are used for the Upper Cretaceous series (Dakota, Mancos, Mesaverde, Lewis, and "Laramie") on the flanks of the Axial Basin anticline. The key horizon chosen is the boundary between the Mancos and Mesaverde. Its depth below the surface at any point may be determined from the contours and the surface elevation at that point; by use of the table of formation thicknesses the depth of a bed at any horizon may be calculated.

The pronounced unconformity between Cretaceous and Eocene beds and the great variations in thickness of the Eocene make it impracticable to extend the structure contours of the Cretaceous rocks into areas where Eocene strata are exposed; in these areas the structure is indicated by means of strike lines. These lines may be regarded as very sketchy contours indicating no stated altitudes and being related to two key horizons instead of one. The method of their construction, illustrated in Figure 24, is as follows. Along each contact (M–N and N–O) is drawn a structure contour, based on that contact as a key horizon. These contours represent the strike of adjacent beds. If the stratigraphic interval between the two contacts were uniform, the upper contour could be referred also to the lower contact and would show its altitude; intermediate structure contours of definite interval could then be readily drawn. Variation of stratigraphic interval, however, makes this impracticable. For example, in Figure 24, disregarding the slight correction for dip, the altitude of contact M–N would be 4,000 feet at B, 3,500 feet at D, and 3,000 feet at F, yet the contour already drawn through these points is at a uniform level. As contact M–N drops 1,000 feet from A to B, the line A–B may be marked by equidistant points representing its intersection with contours of 250 feet interval; similar intersections (but more numerous, to correspond with the greater stratigraphic interval) may be plotted on the lines C–D and E–F. The broken lines then drawn from these intersections may be called strike lines; their directions show surface strikes, their spacing indicates the degree of dip, and their changing number indicates the varying stratigraphic interval.

Still another method of representing structure is by means of cross sections, several of which are included in this report. (See Pl. XXXV.)

FOLDS IN OUTCROPS OF CRETACEOUS AND OLDER ROCKS.

There is no reason to believe that in Moffat and Sweetwater counties a lack of underground water has caused segregation of oil in the synclines. Oil and gas, if present, have more probably followed the general rule and accumulated in the higher parts of the upfolds. For the purpose of this report, therefore, the synclines are of little importance, and only the anticlines and domes are described.

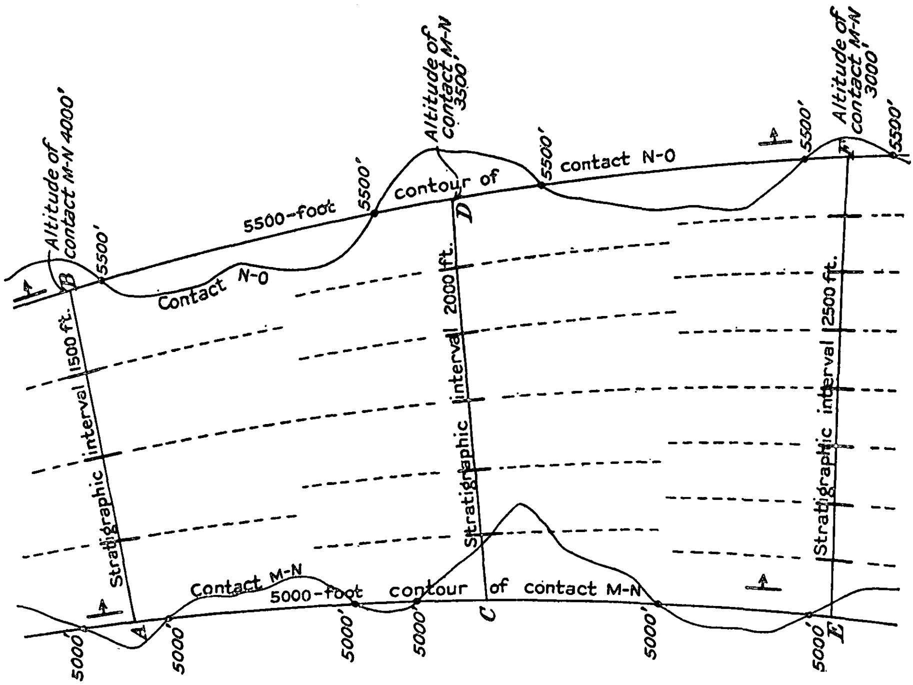

FIGURE 24.—Diagram illustrating method of drawing strike lines.

UINTA MOUNTAIN ANTICLINE.

The dominant structural feature of the area is the huge Uinta Mountain anticline, a flat-topped east-west arch about 150 miles long and 35 to 50 miles wide. Only the east end of the arch lies within the field here mapped. Along the axis of the fold is exposed the great body of thick-bedded brick-red quartzite and sandstone called by Powell the "Uinta group." The flanks consist of younger Paleozoic and Mesozoic rocks, which are clearly exposed on Vermilion Creek and on Yampa River west of Lily Park.

Most of the uplift occurred after Cretaceous time. Eocene sediments—Wasatch, Green River, and Bridger—were then deposited in the Green River and Uinta basins, overlapping the lower slopes of the arch and meeting around its east end. A second uplift followed, raising the Uinta Mountain arch still higher and tilting the edges of the Eocene deposits. During these and later periods of deformation the simple arch was complicated by minor flexures and by a number of faults, some of great magnitude.

The history of the Uinta Mountains, although of much geologic interest, can not be discussed with greater detail in this report.

AXIAL BASIN ANTICLINE.

A broad, low arch known as the Axial Basin anticline extends from the east end of the Uinta Mountain fold to the southeast corner of the field. On its flanks the Cretaceous formations are overlain by Eocene deposits without discordance of dip, a fact indicating that the uplift was part of the movement that caused the second arching of the Uinta Mountains. The Axial Basin anticline is accentuated at two places by the sharp local uplifts of Cross and Juniper mountains. Between these uplifts most of the anticline is buried beneath unconformable Browns Park beds, and its shape must be assumed from outcrops far out on the flanks. Southeastward from Juniper Mountain the Browns Park formation is partly eroded and the Mancos shale is exposed on the axis of the anticline. In this vicinity the arch is asymmetrical, the north flank having an average dip of about 10° and the south flank about 22°. Owing to the Juniper Mountain uplift, the anticline has a marked plunge to the southeast, interrupted by a terrace with possibly a small closure in the southwestern part of T. 5 N., R. 93 W. In the northwest corner of T. 4 N., R. 92 W., the anticline is crossed by a saddle that marks the northward extension of the Elkhorn syncline. At the center of the same township the anticline forks, one branch turning to the northeast, the other to the south; at this point, on Seeping Spring Gulch, a pronounced dome is developed on the anticline. Within a short distance the southern fork is offset half a mile to the west by the Monument Butte fault, from which it trends southward and passes beyond the limits of the field. The line of uplift continues still farther southward and thence eastward, merging with the folds of the White River Plateau, which are a part of the Rocky Mountain system.

CROSS MOUNTAIN UPLIFT.

Near the west end of the Axial Basin anticline the strata are further deformed by the sharp uplift of Cross Mountain, a northwest-southeast fold that brings up Carboniferous rocks and several patches of the underlying red quartzite. The west flank of Cross Mountain is faulted down, and rocks ranging in age from Weber to

Mancos are exposed in the sharp syncline that separates the uplift from the east end of the Uinta Mountain arch. The lower part of Cross Mountain is concealed on the north, east, and south by unconformable Browns Park beds, but a few miles farther south the effect of the uplift is shown by steep dips in the Mesaverde.

JUNIPER MOUNTAIN UPLIFT.

Juniper Mountain marks a second sharp uplift on the crest of the Axial Basin anticline. The top and the north flank of the mountain consist of Carboniferous limestone, sandstone, and shale; the south flank has been more deeply eroded, and the underlying red quartzite is laid bare.

ILES DOME.

At the fork of the Axial Basin anticline, near the center of T. 4 N., R. 92 W., is a dome that exposes beds near the middle of the Mancos shale. Toward the northwest the strata dip to the saddle formed by the intersection of the Elkhorn syncline with the Axial Basin anticline; toward the north and northeast, where they are cut by an east-west fault with downthrow on the south, they dip into the Round Bottom syncline; and toward the south they are cut by the west end of the Monument Butte fault.

WILLIAMS FORK ANTICLINE.

An anticline parallel to Williams Fork extends from the east end of the Monument Butte fault N. 20° W. to Bell Rock, and thence northward under Browns Park beds and dies out in Eocene rocks. This arch, the Williams Fork anticline, shows a general plunge to the northwest and north, the oldest rocks cropping out at the south and successively younger formations toward the north.

MOFFAT (HAMILTON) DOME.

The south end of the Williams Fork anticline is arched to form the Moffat (Hamilton) dome, an asymmetrical uplift with a closure of about 1,000 feet. An irregular escarpment of the Morapos sandstone member of the Mancos shale surrounds the center of the dome, in which is exposed shale about 1,300 feet below the top of the Mancos. The dome was originally named for the Hamilton ranch and Hamilton post office, situated on its north flank, but because of confusion with a fold of the same name in Wyoming, it has recently been called the Moffat dome by trade journals and oil geologists.

BELL ROCK DOME.

A second high area on the Williams Fork anticline is found in secs. 3, 4, 9, 10, and 11, T. 6 N., R. 92 W., near Bell Rock. The dome has a probable closure of 400 feet and exposes at its crest several hundred feet of the Williams Fork formation. The north end of the dome is concealed by Browns Park beds, and the closure on that side is inferred from the continued northward plunge of the Williams Fork anticline as shown in "Laramie" and post-"Laramie" beds farther north. Near the Browns Park contact the Mesaverde formation in the northern part of the dome is cut by several small faults and a sheared zone in which the beds dip 60° NE.

BEAVER CREEK ANTICLINE.

Only the northwest tip of the Beaver Creek anticline reaches into the field, and the structure was not examined in detail by the writer. It has been described by members of the Colorado Geological Survey.[42]

BREEZE ANTICLINE.

The west end of the Breeze anticline extends across the northern portion of T. 6 N., R. 91 W. Beds near the top of the Williams Fork formation are exposed along the crest, and the lower part of the Lewis shale crops out on the flanks. The north side is dropped about 200 feet by a fault approximately along the axis.

DANFORTH HILLS ANTICLINE.

Between Juniper Mountain and the syncline of Citadel Plateau the south flank of the Axial Basin anticline is warped into a subsidiary fold named by Hancock the Danforth Hills anticline. At its northwest end, where the Mancos shale is exposed, the anticline merges with the southward dips on the flank of the Axial Basin uplift. The anticline plunges southeastward for several miles, beyond which it continues as a broad flat-topped arch in Mesaverde rocks. The axis shows a saddle just south of Coal Mountain and a low dome several miles to the southeast. Beyond this, outside of the area mapped, the axis is crossed by a deep saddle formed by the southwest fork of the Collom syncline. Still farther to the southeast the arch rises to the Wilson Creek dome, recently drilled by the Richmond Petroleum Co.

ELK SPRINGS ANTICLINE.

Near Elk Springs the Mancos shale is poorly exposed and is in part covered by the unconformable Browns Park beds. In a brief visit to this locality the party examined the outcrops of the Mancos shale and found dips and strikes indicating an anticline plunging

[42] Coffin, R. C., Perini, V. C., jr., and Collins, M. J., Some anticlines of western Colorado: Colorado Geol. Survey Bull. 24, pp. 34–37, 1920.

steeply southeastward and dying out in the Iles formation. No closure was shown by the exposures in the shale, and the fold seemed to be the nose of a long anticline mapped by Schultz,[43] which extends westward to the Utah line. It has recently been reported that many deep pits dug just south of Elk Springs reveal a sharp reversal of the beds to a northwest dip, indicating a closed dome of small area developed in the main axis.

ANTICLINE NEAR MARSHALL'S SPRING.

North and west of Marshall's Spring, in T. 9 N., R. 100 W., a small "window" has been eroded through the unconformable Browns Park and Bridger formations; in this "window" are exposed some of the Mesozoic rocks on the north flank of the Uinta Mountain arch. These beds have been subjected to faulting during two or more periods but still maintain a general northward dip. The structure in the Nugget sandstone is somewhat obscured by cross-bedding and by many small faults, but in the SE. ¼ sec. 22 and the NE. ¼ sec. 23 an anticline is found in the sandstone, dipping 15° to 20° toward the north and south. The exact area covered by this fold is not known, because of the unconformable cover, but regional relations indicate that it is very small.

This arch is the only true anticline in pre-Tertiary rocks in the township. This fact is of importance, because interest throughout the county has been aroused by reports of an oil-saturated anticline in this vicinity. The Nugget sandstone and the base of the Browns Park in sec. 6 are saturated with oil; the Nugget dips to the northeast, the Browns Park to the southwest. As the Browns Park rests upon the Nugget sandstone with great angular unconformity, their relation can not in any sense be called an anticline.

FOLDS IN OUTCROPS OF EOCENE ROCKS.

From Sand Creek northwest to Diamond Peak the southern margin of the Eocene rocks is a zone of displacement marked by a series of faults and anticlines en échelon. The structure may be explained as follows: Originally the Eocene beds dipped gently to the north and northeast, partly by depositional slope, partly by tilting (*a*, fig. 25). Regional warping then lowered the rocks on the south with respect to those on the north. The first result was an anticline or series of anticlines en échelon, having gentle northward dips and steeper southward dips (*b*, fig. 25). Further warping caused a rupture of most of the anticlines (*c*, fig. 25) and in some places a drag of the beds along the fault planes (*d*, fig. 25).

[43] Schultz, A. R., unpublished map.

LITTLE SNAKE RIVER-SAND WASH ANTICLINE.

A faulted anticline (of type *d*, described above) crosses Little Snake River and Sand Wash. Beds of the Green River formation are exposed along the crest, except where Little Snake River has cut down into the upper part of the Wasatch. The north flank dips gently to the north and northwest. Steep southerly dips on the south flank are due partly to drag along the fault that drops the Bridger formation against Green River shale.

DRY MOUNTAIN ANTICLINE.

Along the southwestern border of Sand Wash Basin is a sharp fold called by Schultz[44] the Dry Mountain anticline. This fold is

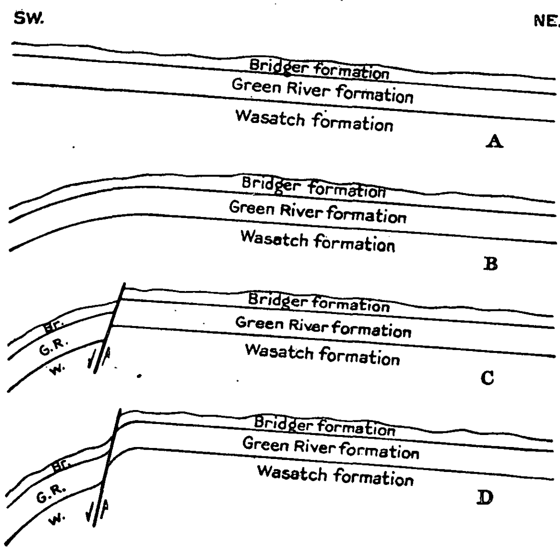

FIGURE 25.—Diagrams showing development of folds and faults in zone between Sand and Vermilion creeks, Colo.

of type *b*, described above, but shows steep dips on the north flank as well as the south. On the crest, near Dry Mountain, are exposed beds that may represent the transition zone at the top of the Green River; elsewhere the fold is in the Bridger formation. Most of the south flank is buried beneath the Browns Park formation, which lies upon the Bridger with an angular discordance of 10° to 15°. The extent of the south flank is therefore unknown, but it is probably not more than a mile wide, if the southward flattening of the Browns Park is taken into account. Owing to the reconnaissance nature of his examination, Schultz failed to interpret correctly the extent and

[44] Schultz, A. R., Oil possibilities in and around Baxter Basin, in the Rock Springs uplift, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 702, pp. 42–44, 1920.

relations of the anticline. He did not observe the angular unconformity between the Browns Park and Bridger and identified them as a single formation; for this reason he included all the southward-dipping beds of the Browns Park in the south flank of the anticline. The extension of the arch to Vermilion Creek is also unwarranted, as the structural features there mapped as forks of the anticline are in reality faults that cut the Paleozoic rocks.

VERMILION CREEK DOME.

The upper drainage basin of Vermilion Creek is eroded in a broad, low arch or dome, cut off on its southwest side by a great fault along the north flank of the Uinta Mountain anticline. The east side of the dome dips gently northeast and southeast into the structural depressions of Washakie and Sand Wash basins. In the center of the dome are exposed beds of the lower Wasatch, surrounded by the Tipton tongue of the Green River formation. Overlying these are the Cathedral Bluffs tongue of the Wasatch and the Laney shale member of the Green River, which form the escarpment of Vermilion Bluffs and Kinney Rim.

Several minor folds are developed on the dome. The most conspicuous anticline crosses Canyon and Vermilion creeks about a mile above their junction and dies out in the eastern part of T. 12 N., R. 100 W. A second pronounced anticline extends from the vicinity of the Canyon Creek mine northeastward across Vermilion Creek. A third anticline, which is less conspicuous, parallels Vermilion Creek near the mouth of Shell Creek

There is only the most scanty evidence as to the age and structure of the rocks underlying the Wasatch in the Vermilion Creek dome. Comparison with the Rock Springs arch suggests that in the Vermilion Creek basin the Wasatch may have been deposited on a partly eroded, low dome of Cretaceous rocks, and that renewed uplift increased the dips of the buried dome and slightly arched the Wasatch beds. As to which formation immediately underlies the Wasatch, there is even more doubt; so far as the writer knows, the only evidence bearing on this question is as follows: The Wasatch formation extends around the southeast end of the fault of Talamantes and Vermilion creeks and overlaps the edges of the several Mesozoic formations. In sec. 5, T. 9 N., R. 100 W., the Wasatch dips 7°–10° E. and overlies Mesozoic beds dipping 32° NE. In sec. 17, T. 10 N., R. 100 W., south of the fault, beds thought to be Wasatch lie without discordance of dip upon the upper part of the Mesaverde formation. These facts may be interpreted as showing that when Wasatch deposition began the northeasterly dip of the Uinta Mountain arch did not extend as far as the point just mentioned (sec. 17, T. 10 N., R.

100 W.), and in that locality the upper Mesaverde beds lay practically horizontal. If a pre-Wasatch dome existed on the present site of the Vermilion Creek dome, it was probably low, and pre-Wasatch erosion did not remove a great thickness of strata. To continue the hypothesis, the upper Mesaverde beds that were horizontal in sec. 17 may have formed the top of the arch farther north, and the erosion surface upon which the Wasatch was deposited may have been cut down into lower Mesaverde beds. This reasoning is purely speculative, but speculation is perhaps justified by the fact that the value of the dome for oil and gas depends largely upon the nature and structure of the rocks beneath the Wasatch.

POWDER WASH ANTICLINE.

A broad, low east-west anticline separates the structural depressions of Washakie and Sand Wash basins. This fold was seen by the writer at long range from the hills near Shell Point and Powder Spring and north of Sunny Point; the location of the axis is therefore not known with precision, but it is approximately as shown on the map accompanying this report (Pl. XXXV, in pocket). Dips recorded near Powder Spring and north of Sunny Point and dips and altitudes taken on several boundaries in the eastern part of the Vermilion Creek basin indicate that the Cherokee Ridge fold and the Lookout Mountain arch as previously mapped[45] do not exist. The Cherokee Ridge anticline described by King[46] and Emmons[47] is probably the western nose of a sharp east-west fold seen by the writer a few miles north of Baggs, Wyo.

FOLDS IN OUTCROPS OF THE BROWNS PARK FORMATION.

In large areas the older rocks are concealed by soft white sandstones of the Browns Park formation. In the course of the field work much time was spent in determining the structure of the Browns Park, in the hope that it might reflect the structure of underlying beds.

As a whole the present attitude of the Browns Park formation is that of a syncline superposed on the crest of the Uinta Mountain-Axial Basin anticline. Everywhere along its boundary the Browns Park lies upon older rocks with an angular unconformity ranging from 10° to 100°. In the central part of the present Browns Park exposures the sandstones are nearly horizontal, although resting upon concealed beds shown by regional relations to have steep dips. An example of structural discordance is seen in T. 7 N., R. 92 W.; here the belt of Browns Park rocks is underlain by the north end of the Bell Rock dome, the northward extension of the Williams Fork anti-

[45] Schultz, A. R., op. cit., pl. 1.
[46] King, Clarence, U. S. Geol. Expl. 40th Par. Rept., vol. 1, pp. 383–384, 1878.
[47] Emmons, S. F., idem, vol. 2, p. 218, 1877.

cline, and the west flank of the Big Bottom syncline, and no relation exists between the dips of the Browns Park and of the older formations.

From these facts it may safely be assumed that folds in the Browns Park do not reflect underlying folds. As the Browns Park itself is not believed to contain accumulations of oil and gas, anticlines in the formation need not be considered in this report.

FAULTS.

Large areas in the field are without faults of appreciable magnitude. In general, the faults mapped are isolated breaks, which seem to bear no relation to one another. A conspicuous exception is the zone of faults en échelon extending from Sand Creek northwestward to Vermilion Creek.

Most of the larger faults are described in preceding pages in connection with the anticlines. Considerable geologic interest is attached also to a fault that extends from the vicinity of Diamond Peak southeastward for nearly 15 miles and dies out near East Fork of Vermilion Creek. The south side has risen an unknown amount as compared to the north side on a nearly vertical plane. At the west end the fault is concealed by recent débris from the mountains, and its connection with the great Uinta fault is problematic. It is clear that the faulting was at least in part post-Eocene, for Mesaverde and Mancos beds are brought against the Wasatch, but possibly the movement was a renewed slipping on a post-Cretaceous fault plane. The pressure and throw were sufficient to cause a sharp drag along the fault, and the beds on both sides are nearly vertical or are overturned and inclined steeply to the southwest. There is reason to believe that later reversal has occurred on this and the Uinta fault, the south side dropping several thousand feet during the movement that produced the zone of faults en échelon extending southeastward to Sand Creek.

POSSIBILITIES OF OIL AND GAS.

PRODUCTION AND INDICATIONS OF OIL AND GAS IN THE FIELD.

WELLS ALREADY DRILLED.

Prior to 1923 three wells had been drilled in Moffat County; it is reported that they yielded small shows of oil and gas but no commercial quantity. In the writer's opinion these wells were poorly located and can not be considered adequate tests.

One of these wells, drilled in 1918 by the Longco Oil Corporation, is in the NE.¼ SW.¼ sec. 14, T. 4 N., R. 92 W., on the northeast flank of the Iles dome. It is reported that drilling was stopped because hot sulphur water was found in sandstone of Frontier (?)

age at 2,812 feet. The Dakota sandstone, now proved to be oil bearing in the Moffat (Hamilton) dome, a few miles to the east, was not tested. A site on the crest of the dome, about a mile farther southwest, would have been preferable.

A second well, drilled by H. A. Gross on the Axial Basin anticline, near the center of sec. 14, T. 4 N., R. 93 W., started approximately 1,500 feet below the top of the Mancos shale and reached a depth of 3,315 feet; so far as known it did not test the sandstone of Frontier (?) age in the lower part of the Mancos. Small shows of oil and gas are reported. The well is just south of the axis, but owing to the southeastward plunge of the anticline any oil or gas in the strata may have migrated up the axis toward the Juniper Mountain uplift.

The third well was drilled by David Morgan in 1921–22 near Elk Springs, in sec. 30, T. 5 N., R. 98 W. At the surface are nearly horizontal beds of the Browns Park formation, lying with angular unconformity upon the Mancos shale. The well was lost at 350 feet and probably did not reach the Mancos.

Interest in Moffat County was stimulated in August, 1923, by a strong show of oil in the Mancos shale, found in a well drilled by the Texas Production Co. on the Moffat (Hamilton) dome, in sec. 33, T. 5 N., R. 91 W. Geologists of several companies began studies in the vicinity, and the results of further drilling were eagerly awaited. After several more shows of oil, the Frontier (?) sandstone was reached at 3,415 feet, and a strong flow of hot salt water was encountered. Drilling was continued to the Dakota sandstone at 3,800 feet; 5 feet deeper the hole was filled with a high-grade light-green oil, which flowed at the estimated rate of 1,000 barrels a day. Several months later the estimate of its potential daily flow was increased to 4,500 barrels, as the result of a 24-hour test.

OIL SATURATION ON OUTCROPS.

Oil-saturated sand of the Browns Park formation is seen at two localities. For several hundred feet along the bottom of a gulch in sec. 6, T. 9 N., R. 100 W., the sandy matrix of the basal conglomerate (see Pl. XXXVII, *B*) is heavily saturated with oil; at this point the Browns Park probably rests upon the upturned edge of the Park City formation, in which the oil may have originated. A second and smaller area of saturation is just north of the Craig-Vernal road, half a mile east of Elk Springs, in sec. 30, T. 5 N., R. 98 W., where the Browns Park rests unconformably upon the upper part of the Mancos shale.

In sec. 9, T. 12 N., R. 98 W., Wyoming, the Green River beds are dragged sharply upward on the north side of the fault near Shell Point. A thin sandstone in the Green River shale is slightly saturated with oil for a few feet along the outcrop; the oil may have come from the oil shale of the Green River or may have risen in the fault from some older rocks.

Near Marshall's Spring, in the SW. ¼ sec. 24, T. 9 N., R. 100 W., oil is found in the joints and between the laminae of the blocky shale that forms the base of the Mancos, and a thin sandstone in this shale is saturated with oil. Hancock[48] reports that in sec. 16, T. 6 N., R. 94 W., the shales in the lower part of the Mancos "usually appear moist on the fracture planes and emit the odor of petroleum to a marked degree."

The sandy matrix of the conglomerate in the lower part of the Dakota is heavily saturated with oil for several hundred yards on the outcrop in sec. 23, T. 9 N., R. 100 W. Associated faults may have permitted migration of this oil from the Park City or some other underlying formation, or the oil may have originated in the basal shales of the Mancos, which everywhere in the field carries abundant fish scales.

In the SE. ¼ sec. 6, T. 9 N., R. 100 W., a 10-foot sandstone in the upper part of the Nugget shows heavy oil saturation for several hundred yards on its outcrop.

OIL SEEPAGES.

No true seepages of petroleum were observed in this field by the writer; several localities reported to show seepages were visited, but in each one the scum on springs was found to be formed by decaying vegetable material. According to Hancock,[49] "a few years ago, in the construction of a ditch about a quarter of a mile above the K Diamond Ranch, in sec. 31, T. 6 N., R. 93 W., the manager of the ranch is reported to have made the statement that certain holes would fill with oil about twice each day." If this report of seepage was authentic, the oil came from the upper part of the Mancos shale. Water from a well on Mrs. Arnold's homestead, in the S. ½ SW. ¼ sec. 11 and the N. ½ NW. ¼ sec. 14, T. 5 N., R. 95 W., is said to show traces of oil after standing in a bucket over night. This oil, according to her son, has been analyzed by two chemists and reported to be mineral oil. The surface rocks at this point are the Browns Park beds, unconformably overlying the Mancos shale.

GAS SEEPAGES.

Seepages of gas are found in springs and in stream beds at a number of places in Moffat County. In some of them the bubbles forming on the surface of the water can be ignited with a match. At

[48] Hancock, E. T., The geology and coal resources of the Axial and Monument Butte quadrangles, Moffat County, Colo.: U. S. Geol. Survey Bull. 757 (in press).

[49] Hancock, E. T., unpublished manuscript.

Juniper Hot Springs and in other springs near by along the banks of Yampa River the gas includes a considerable quantity of hydrogen sulphide, and the ground around the springs is covered with a yellow layer of sulphur.

Three samples of gas collected on Spring and Lay creeks were analyzed with the following results:

Analyses of gas samples collected in Moffat County, Colo.

[Analyzed by U. S. Bureau of Mines.]

No.	Locality.	CO_2	O_2	CH_4	C_2H_6	N_2
1	Bed of Spring Creek, sec. 15, T. 7 N., R. 95 W	2.07	.64	92.79	0.17	4.33
2	Bed of Lay Creek, sec. 31, T. 7 N., R. 93 W	.94	.33	94.2	.0	4.53
3	Bed of Lay Creek, sec. 32, T. 7 N., R. 94 W	50.9	.49	47.51	.0	1.1

In all three localities the surface rocks are of the Browns Park formation. At locality 3 the Browns Park probably rests upon the Mancos shale; the high percentage of carbon dioxide (CO_2) indicates that the bubbles are of marsh gas, not of natural gas. At localities 1 and 2 the Browns Park lies upon upper and middle Mesaverde rocks; here the high content of methane (CH_4) may show that the bubbles are of natural gas, or of marsh gas rising from buried coal beds, although the coal mines in Moffat County are generally free from gas. The ethane (C_2H_6) in the gas from locality 1 strongly suggests a gas associated with oil.

PRODUCTION AND INDICATIONS OF OIL AND GAS IN ADJOINING AREAS.

GAS WELL ON CHIMNEY CREEK DOME.

A well drilled by the Plateau Oil Corporation on the Chimney Creek dome, in sec. 4, T. 7 N., R. 86 W., is reported to have found gas with a flow of 4,000,000 cubic feet a day; the horizon at which the gas occurs was not stated, but it is presumably in the lower part of the Mancos shale. At 493 feet a show of oil and gas was obtained in a sandstone of the Mancos. A sandstone found at 945 feet was called Cloverly by the drillers, who expected to reach the Dakota at 1,100 feet. According to the latest report, drilling was continued to 1,400 feet, but information is lacking as to whether the Dakota sandstone was reached.

TOW CREEK SEEPAGE.

A seepage or "oil spring" in the canyon of Tow Creek, north of Yampa River between Hayden and Steamboat Springs, yields daily about a bucketful of black, heavy oil, which for many years has been used in the neighborhood for a lubricant. According to Hancock,[50] the oil comes from a bed of sandstone near the top of the Mancos shale.

GAS WELLS ON WILLIAMS PARK ANTICLINE.

Several wells have been drilled on the Williams Park anticline, near the southwest corner of T. 4 N., R. 87 W. Two of these wells encountered gas in large quantity; according to reports the first well had a flow of 15,000,000 cubic feet daily from the Mancos shale at 940 feet and got some oil, gas, and water from the Dakota sandstone at 1,725 feet; the second well had a flow of 10,000,000 feet daily from the Dakota sandstone at 350 feet.

ELATERITE VEIN NEAR WILLIAMS FORK.

A small vein of elaterite is exposed in the upper part of the Mancos shale near the northwest end of the Beaver Creek anticline, in the NE. ¼ sec. 34, T. 5 N., R. 90 W. The elaterite is a natural bitumen thought to have been formed as a residue from petroleum escaping through a fault.

WELLS ON WILSON CREEK DOME.

Two wells have been drilled by the Richmond Petroleum Co. on the Wilson Creek dome (Devil's Hole district), a structural high point on the Coal Mountain anticline. The first hole was abandoned because of mechanical difficulties. The second well, in sec. 27, T. 3 N., R. 94 W., was completed in 1921 at a depth of 4,826 feet. Only small shows of oil and gas were found. The following record of strata penetrated was furnished by the company; the formations have been identified by the writer:

Record of well on Wilson Creek dome, sec. 27, T. 3 N., R. 94 W., Colo.

	Feet.
Iles formation:	
Soil and wash	0–45
Hard sand	45–105
Dry sandy rock	105–149
Coal	149–199
Red sandy rock	199–230
Hard sand	230–250
Brown shale	250–365
Hard sand	365–490
Mancos shale:	
Brown shale	490–730
Sandy shale	730–795
Shells (small amount of gas)	795–800
Sandy shale	800–920
Gray shale	920–995
Brown shale	995–1,155
Gray shale	1,155–1,210

[50] Hancock, E. T., unpublished manuscript.

Mancos shale—Continued.	Feet.
Sandy shale	1,210–1,260
Dark-brown shale	1,260–1,330
Gray shale	1,330–1,490
Sandy blue shale	1,490–1,625
Gray sand (smells slightly of oil; no colors of oil on water	1,625–1,650
Gray shale	1,650–1,690
Dark-brown shale	1,690–1,867
Blue shale	1,867–2,050
Hard blue shale	2,050–2,075
Dark-brown shale	2,075–2,135
Sandy blue shale	2,135–2,160
Hard sand	2,160–2,165
Sandy blue shale	2,165–2,365
Blue shale	2,365–2,395
Dark-gray sand (showed a little gas and rainbow colors when washed)	2,395–2,420
Blue sandy shale	2,420–2,503
Dark-gray sand	2,503–2,508
Blue sandy shale	2,508–2,580
Blue shale	2,580–3,365
Hard dark-blue shale (small show of gas at 3,475 feet)	3,365–3,558
Dark-blue shale (small show of gas at 3,630 feet)	3,558–4,330
Dark sandy blue shale (rainbow colors at 4,345 feet)	4,330–4,350
Dark sandy shale	4,350–4,565
Hard dark shell	4,565–4,580
Dark-blue shale	4,580–4,592
Hard dark shell	4,592–4,595
Dark-blue shale	4,595–4,701
Light-blue shale	4,701–4,823
Dark sand and dark shale	4,823–4,826

According to this interpretation the well lacked nearly 1,000 feet of testing the basal Mancos and the Dakota sandstone. The record corroborates the writer's belief that the Morapos sandstone member, 930 feet below the top of the Mancos shale, is thin or absent on the southern flank of the Axial Basin anticline.

GAS WELLS IN THE WHITE RIVER FIELD.

A number of wells have been drilled in Rio Blanco County, near White River, in sec. 31, T. 2 N., R. 96 W., and secs. 25 and 36, T. 2 N., R. 97 W. Almost all the wells produced gas from depths of less than 1,000 feet. The flow in two of them was reported to be 15,000,000 cubic feet of dry gas a day. Some oil was found in at least one hole. The wells were drilled on a pronounced dome, from which about 1,000 feet of upper Wasatch beds have been eroded. As the Wasatch in this area is estimated to be 3,500 feet thick, approximately 2,500 feet of the formation underlies the dome. The Wasatch here includes variegated clay shales and many more coarse sandstones than occur in the formation farther north. These sandstones are described as sufficiently porous to serve as efficient reservoirs for oil and gas. The writer believes that the Wasatch is almost surely not the source of the hydrocarbons, but that the gas found in the White River field has migrated from the underlying Mesaverde and Mancos beds.

RANGELY OIL FIELD.

In the Rangely field, in northwestern Rio Blanco County, 1,500 to 2,000 barrels of oil a month is obtained from the Mancos shale. According to estimates by the writer, the oil produced by the Raven Oil Co. in sec. 31, T. 2 N., R. 102 W., at depths of approximately 500 feet, comes from beds about 1,900 feet below the top of the formation. Other wells of similar depth have produced oil in paying quantities, but most holes in the field gave little or no oil. The drillers and officials state emphatically that the oil does not come from sandstone but from shale that is not even sandy.

A deep test well drilled by the Richmond Petroleum Co. in sec. 21(?), T. 2 N., R. 102 W., ended in the Morrison formation at 3,825 feet. According to reports, gas with a daily flow of 2,500,000 cubic feet was found in hard shale at 3,519 feet; this shale is probably in the basal member of the Mancos, as a 13-foot sandstone identified as Dakota was encountered at 3,536 feet.

FREE OIL IN GREEN RIVER FORMATION.

It is well known that the Green River formation contains extensive beds of oil shale, which by destructive distillation will yield varying amounts of petroleum. In general, the oil does not exist as such in the shale, but during distillation is derived from an organic material known as kerogen. In some places, however, small amounts of free oil are found in the formation. Ball[51] reports that on Whiskey Creek, Colo., near Dragon, Utah, 50 barrels of oil of 17° Baumé gravity is mined daily from a tunnel which crosses a small fault in sandstone near the base of the Green River, above which is typical oil shale.

BAXTER BASIN GAS FIELD.

The earlier history of drilling operations in the Baxter Basin (Rock Springs) uplift has been described by Schultz.[52] The logs of four wells drilled near Dry Lake, in T. 18 N., R. 103 W., show that

[51] Ball, M. W., Oil is mined in Uinta Basin, in Colorado: Oil and Gas Jour., vol. 20, No. 40, p. 40, 1922.

[52] Schultz, A. R., Oil possibilities in and around Baxter Basin, in the Rock Springs uplift, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 702, pp. 83–96, 1920.

small amounts of oil and gas were found in rocks identified by Schultz as the Frontier formation and the Aspen shale; these rocks constitute the lowest part of the Mancos shale as defined in the present report.

In the summer of 1922 interest in the field was renewed by the completion of two large gas wells. The first well, drilled by the Ohio Oil Co. in sec. 16, T. 16 N., R. 104 W., is estimated to have a daily flow of about 36,000,000 cubic feet at a depth of 2,515 feet; the second well, sunk by the Midwest Refining Co. in sec. 11, T. 17 N., R. 104 W., to a depth of 2,426 feet, is reported to produce daily about 30,000,000 cubic feet. Several later wells on this uplift have also found gas in large amounts. The gas is obtained from two thick sandstones about 400 feet apart. The correlation of these beds with sandstones exposed near Vermilion Creek is discussed on page 286.

FORMATIONS MOST LIKELY TO CONTAIN OIL AND GAS.

Oil and gas have probably originated in the Park City formation and may still remain in it at various places. In the field here described, however, the Park City is buried under 5,000 feet or more of cover, except in the anticline near Marshall's Spring and on the outer flanks of folds in which are exposed the upturned edges of the formation. The Ankareh (?), Thaynes (?), and Woodside are not considered to be possible sources of oil and gas; their depth below the surface and the scarcity of sands in them that might hold oil and gas migrating from the Park City make drilling to them (as well as to the Park City) out of the question, except as an interesting deep test by some strong company well able to bear the expense.

The character of the Nugget sandstone and its saturation with oil in sec. 6, T. 9 N., R. 100 W., show that the formation must be considered as a possible reservoir for oil and gas originating in other beds. In secs. 22 and 23, T. 9 N., R. 100 W., a faulted anticline brings the Nugget sandstone to the surface; the extent of the anticline is concealed by Browns Park beds, but it is probably small and of little promise. Elsewhere, in folds in which the Nugget is under cover, the formation lies at least 3,400 feet below the surface.

Oil and gas may have originated in the fossiliferous Twin Creek limestone, but the formation includes little porous rock and should not be made the objective of drilling operations.

Because of showings of oil and yields of gas from the Morrison in Wyoming, Heald[53] believes that in that State the formation is important as a potential oil producer. Around the east end of the Uinta Mountains, however, the Morrison is distinctly lacking in persistent porous sandstones that could serve as reservoirs for oil

[53] Heald, K. C., The oil-bearing horizons of Wyoming: Am. Assoc. Petroleum Geologists Bull., vol. 5, pp. 195–196, 1921.

migrating from the Park City or Twin Creek, and it is thought by the writer to have slight chance of containing oil or gas.

The discovery of oil in the Dakota sandstone in the well on the Moffat (Hamilton) dome gives that formation rank as the most important objective for drilling in Moffat County. Oil or gas in it may have migrated upward from the Park City and Twin Creek or downward from the Mancos. The conglomerate at the base of the Dakota is saturated with oil on its outcrop in sec. 23, T. 9 N., R. 100 W., and indications of oil are found in the formation and its equivalents in neighboring fields.

The numerous citations on preceding pages of oil and gas indications and production in the Mancos shale show that there is a fair chance of getting production in Moffat County from this formation also. Shale near the base, rich in fish remains, is almost certainly a "mother rock" of petroleum, which may accumulate in beds of sandstone, in sandy shale, or, or as at Florence and at Rangely (?), in fissures through the main body of the shale. Absence of reservoir sands in the greater part of the formation in this field lessens considerably the chance of finding oil or gas in large quantities. The Morapos and other sandstones in the upper 1,000 feet are known to be lenticular. The sandstone of Frontier (?) age near the base seems persistent; its position above the fish-scale beds and its equivalence to one of the two gas-bearing sandstones in the Baxter Basin field would normally make it an important objective, but it is known to be water-bearing at the Moffat (Hamilton) dome and probably also under the Iles dome.

The accumulation of oil and gas in commercial quantities in the Iles, Williams Fork, Lewis, and "Laramie" formations is, in the writer's opinion, possible but not probable. The presence of numerous sands capable of serving as reservoirs for oil and gas migrating from the Mancos shale or less probably originating in the formations themselves to some extent justifies drilling to these formations where the structure is favorable, but the lack of known indications in this and adjoining areas does not offer much hope of success.

The Wasatch formation is practically barren of rocks that could be a source of oil, but some of its sandstones could be efficient reservoirs where the Wasatch lies on formations that could furnish oil and gas. Such a condition may prevail in the basin of Vermilion Creek, but the age of the rocks underlying the Wasatch in that area is highly problematic.

Extensive deposits of oil shale and small amounts of free oil at several localities in the Green River have led to a belief that the formation may be a source of oil that would collect in some of its sandstones. The lower part of the Laney shale member of the Green River and the Tipton tongue of the Green River (if present) are under cover in the Powder Wash anticline; the Laney underlies the Dry Mountain anticline. The low grade of the oil shale in this field and the lack of success in tests of the Green River in Utah indicate that drilling of these anticlines at this time would be a very questionable venture.

RELATIVE VALUE OF THE FOLDS FOR DRILLING.

Moffat (Hamilton) dome.—Oil from the Dakota sandstone in the Moffat (Hamilton) dome now seems assured by the results of the Texas Production Co.'s well; the producing area must be defined by further drilling. The closure of the dome is thought to be about 1,000 feet. Approximately 1,300 feet of Mancos shale has been eroded from the crest of the dome; as the Dakota sandstone was reached at a depth of 3,800 feet, the Mancos at this locality has a thickness of less than 5,100 feet, although in outcrops at Juniper Hot Springs and near Vermilion Creek it is 5,300 and 5,370 feet thick. The basal shale (Mowry?), however, is somewhat thicker under the Moffat dome than it is in outcrops farther west.

Iles dome.—In two respects the Iles dome is more attractive for prospecting than the Moffat dome. It has a slightly larger drainage area, and the depth to the Dakota is probably 1,200 feet less. Contours drawn on this dome are based on dips in the shale but are thought to be approximately correct. These contours show that about 2,500 feet of Mancos shale has been eroded from the crest, and the Dakota sandstone should therefore be reached at a depth of about 2,600 feet. In the writer's opinion the failure of the Longco well in sec. 14, T. 4 N., R. 92 W., did not condemn this fold. The well was drilled some distance down the flank of the dome and is separated from its crest by a fault of some magnitude. Moreover, the well did not reach the Dakota sandstone, now shown to be the producing bed in this vicinity, and the reported flow of hot sulphur water from the sandstone of Frontier (?) age probably was no more unfavorable than the flow of hot salt water from the same bed in the Moffat dome.

The most favorable location for a test is near the south quarter corner of sec. 22, T. 4 N., R. 92 W. An abundant supply of fuel can be obtained from the Mesaverde coals near by. Water sufficient for drilling could scarcely be got from either Seeping Spring Gulch or Stinking Gulch but might be piped from Milk Creek or Morapos Creek.

The Iles dome is the best place for a deep well to test formations below the Dakota. The estimated depths at which the lower formations would be found are as follows: Twin Creek limestone, 3,300 feet; Nugget sandstone, 3,425 feet; Ankareh (?) shale, 4,375 feet; Park City formation, 5,335 feet. The cost of such a well is practically prohibitive, except for a large company financially able to make a test as a venture and for the sake of the geologic information obtainable.

Axial Basin anticline.—If other wells drilled on the Moffat and Iles domes meet with success, attention should be paid to a terrace on the Axial Basin anticline in secs. 19, 29, and 30, T. 5 N., R. 93 W. The shape and position of this terrace as shown on the geologic map are based on poor exposures of the Mancos shale and should be checked by additional study. Such a terrace, although small, might trap oil or gas moving up the flanks of the anticline and also up the plunging axis from the saddle in T. 4 N., R. 92 W. The Dakota should be reached at a depth of approximately 2,300 feet. Water for drilling can probably be obtained from Morgan Gulch.

Bell Rock dome.—Beds near the top of the Williams Fork formation are exposed on the Bell Rock dome. As the Mesaverde group in this vicinity is about 2,950 feet thick the greater part of the Mancos is below drilling depth. The drainage area of the dome is narrow on the east, south, and west but extends for a long distance northward. Numerous sandstones in the Mesaverde and the upper part of the Mancos, capable of serving as reservoirs, would be tested by a 3,500-foot well. The writer is not optimistic, however, about the chances for success, because of the lack of oil indications in the Mesaverde of this region and because of the failure of the Richmond Petroleum Co.'s well on the Wilson Creek dome, in sec. 27, T. 3 N., R. 94 W., which penetrated 500 feet of Mesaverde and 4,300 feet of Mancos shale.

Breeze anticline.—As the top of the Mesaverde group is exposed on the Breeze anticline, that fold offers chances similar to those of the Bell Rock dome. The east-west fault along the crest of the Breeze anticline may have afforded a channel for the upward migration of oil and gas from the lower part of the Mancos, but no seepages have been observed along the fault.

Danforth Hills anticline.—The Danforth Hills anticline is of little promise as a producer of oil and gas. Northwest of Coal Mountain the axis rises rapidly and merges with the southward dip of the rocks on the flank of the Axial Basin anticline; any oil and gas that might have been present would probably have migrated up this plunging axis. The low dome in the southeast corner of T. 4 N., R. 95 W., is slightly more favorable, but rocks in the middle of the Mesaverde group are exposed on the dome, and the lower part of the Mancos is below practicable drilling depth. The failure of the well drilled in similar rocks on the Wilson Creek dome, a few miles farther southeast, is not encouraging.

Elk Springs anticline.—The small dome recently discovered on the southeastward-plunging anticline near Elk Springs is worth a thorough test, as the Frontier (?) and Dakota sandstones are within reasonable drilling depth. It is reported that the Union Oil Co. of California plans to drill a well on this dome, in the NW. ¼ sec. 31, T. 5 N., R. 98 W.

Anticline near Marshall's Spring.—The faulted anticline in the Nugget sandstone northwest of Marshall's Spring is partly covered by unconformable Bridger and Browns Park beds that conceal its extent, but regional relations show that it is a local reversal of the northeastward-dipping Mesozoic and Paleozoic beds on the flank of the Uinta Mountain arch. Its probable small size and ignorance concerning the distance to which the northeastward dips extend under the Tertiary cover of Sand Wash Basin make the writer very doubtful whether this anticline would serve efficiently as a trap for any oil or gas migrating up the regional dip toward the axis of the Uinta Mountain arch. If oil and gas are present and are thus trapped the anticline is well worth drilling, as the Nugget, Ankareh (?), Thaynes (?), Woodside, and Park City formations can be tested by a 2,000-foot hole. The presence of oil is suggested by the saturation of the Dakota sandstone near by and of the Nugget sandstone a few miles farther northwest by oil presumably coming from the Park City. The locality is rather inaccessible, although a sandy secondary road leaves the Sunbeam-Ladore road at Lone Mountain and runs to Marshall's Spring. Fuel in the vicinity is limited to piñon and scrub cedar. Water is very scarce, and Marshall's Spring furnishes hardly enough even for camp use.

Dry Mountain and Powder Wash anticlines.—The Dry Mountain and Powder Wash anticlines seem at present to have little potential value, as thus far tests in the Green River formation have not met with success. Rocks along the crest of the Dry Mountain anticline belong either to the base of the Bridger or the top of the Green River; the thickness of the Tertiary beds is problematic, as the Wasatch is probably either thin or missing. No evidence is at hand as to the age of the rocks beneath the Tertiary beds along this fold. On the crest of the Powder Wash anticline are exposed beds of upper Green River age (Laney shale); the Tipton tongue of the Green River is either very thin or missing.

Vermilion Creek dome.—The broad Vermilion Creek arch is complicated by several minor folds in Wasatch beds, as described on page 305. In this area the Wasatch lies unconformably on rocks which are probably as young as Mesaverde or Mancos but which may be very much older. There is a chance that some of the Wasatch sandstones may contain oil or gas rising from the older rocks, but no local evidence is known to favor this possibility.

RECENT DEVELOPMENTS.

By September, 1924 (after this report was in type), the Iles dome also was proved to be productive by the completion of a well in the NE. 1/4 SW. 1/4 sec. 22, T. 4 N., R. 92 W. (Midwest Refining Co., French No. 1). The Frontier (?) sandstone was reached at 2,310 feet and the Dakota sandstone at 2,616 feet; the well penetrated the Dakota to a depth of 15 feet and gave an initial production estimated to be 1,000 barrels a day of rather heavy oil. A month earlier water had been found in the Dakota sandstone at a depth of 3,366 feet by a well in the SW. 1/4 NW. 1/4 sec. 16, T. 4 N., R. 92 W. (T. S. Hogan, State No. 1), on the edge of the Iles dome.

Oil was being run through a small pipe line from the discovery well on the Moffat dome to a tank farm near Craig, and on August 19 the first shipment, 6 tank cars, was made to a refinery at Florence. Plans for a larger pipe line to a refinery in Wyoming will probably be put into effect if further developments in the field warrant the construction. Some uneasiness was felt, however, because the discovery well had dropped from its initial production to a flow of about 2,000 barrels a day, and because the oil was carrying 10 to 15 per cent of hot fresh water, the source of which was uncertain.

At this time 14 other wells were reported in progress within the area discussed in this report; half of these are on the Moffat dome.

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