OIL AND GAS NEAR GREEN RIVER, GRAND COUNTY, UTAH.

By CHARLES T. LUPTON.

INTRODUCTION.

FIELD WORK.

This paper is based on field work done in November and December, 1912, by M. W. Ball, R. V. A. Mills, and the writer. The area discussed contains about 300 square miles and lies just southeast of the town of Green River, in Grand County, Utah. It is included in Tps. 21, 22, 23, and 24 S., Rs. 16, 17, 18, 19, and 20 E., Salt Lake meridian. (See fig. 4.) Practically all the drilling in this area has been done along and adjacent to the fault zone that crosses the field in a northwest-southeast direction.

The object of the examination was to determine if this area, in which considerable drilling for oil and gas had been done and in which some development work is still going on, contains any reservoirs of oil or gas. The result of the investigation shows that in the area examined in detail there are no anticlines or domes in which large quantities of oil or gas might be expected to collect. It is true that traces of oil and small pockets of gas have been encountered in some of the wells but only in sufficient quantities to afford slight encouragement.

The greater part of the area examined in detail (see Pl. VI, p. 132) was mapped by means of plane table and telescopic alidade, a system of triangulation having been developed from a base line (*A–B*) measured in secs. 26 and 27, T. 22 S., R. 17 E. Practically all of the more nearly level part of the field situated east of the range line separating Rs. 17 and 18 E. and lying north and northeast of the road connecting Green River with Brink Spring was mapped by following section lines and recording observations on the plats.

A flying level line was run from Green River along the Green River-Moab road to the top of the divide in sec. 3, T. 23 S., R. 18 E., separating the drainage system of Salt Wash from that of Tenmile Wash, and another from this road in sec. 25, T. 22 S., R. 17 E., to Levi well

No. 2, in the NE. ¼ NW. ¼ sec. 35 of the same township. During the development of the triangulation system the altitudes of practically all points occupied and many others were determined by means of vertical angles and distances between points. The figures given on the map are not precise but are intended to show relative instead of exact altitudes. It is believed, however, that the altitudes shown

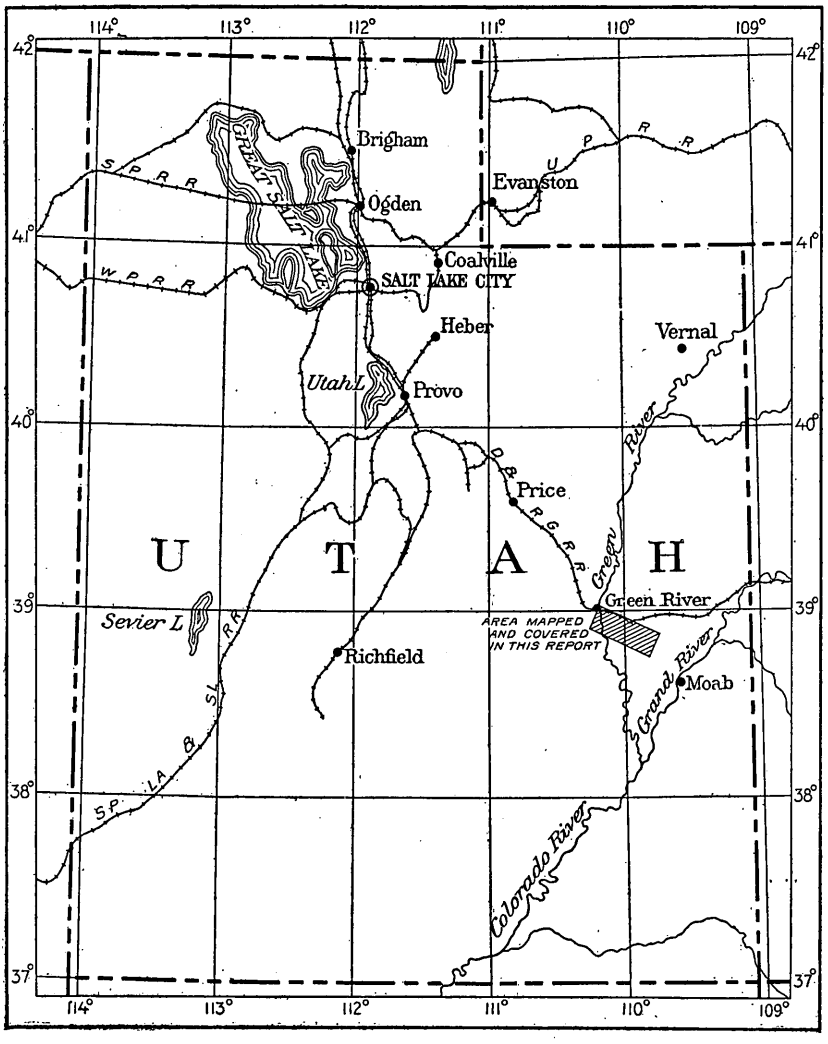


FIGURE 4.—Index map of Utah, showing location of area in Grand County examined in detail.

are within a very few feet of the exact elevations above sea. In the greater part of the area mapped by line riding, altitudes were ascertained approximately by means of the aneroid barometer.

In addition to the detailed work above described, a reconnaissance was made from Green River to Hanksville across the Green River Desert. No detailed mapping was done on this trip, but the stratig-

raphy and structure were studied in a general way. A brief discussion of the observations made at that time, with their bearing on the possible presence of reservoirs for oil or gas, is given under "Conclusions."

The writer desires to acknowledge the courtesy of the managers of the British-American Petroleum Co., who gave the geologic party every means of assistance at their command. Messrs. Frank Cook, William Dixon, Nat Levi, H. H. McFann, George Muller, Charles P. Tasker, and Robert Woodruff, of Green River; W. G. Clark, Knox Patterson, A. M. Rogers, of Moab, and others gave information which has made the historical part of this report possible. Millard and Arthur Massey rendered valuable service as camp assistants.

HISTORY OF DEVELOPMENT OF THE FIELD.

Prospecting for oil in this general region has been carried on at intervals for over 20 years. The presence of asphaltum-saturated sandstone and petroleum seeps at various places in and adjacent to the field suggested to the minds of the more optimistic prospectors the existence of an oil reservoir of commercial importance.

A well situated a short distance south of Elgin, in Grand County, in the SW. ¼ SE. ¼ sec. 15, T. 21 S., R. 16 E., was drilled about 1891 by Bamberger & Millis with an American or Parker rig. The upper 100 feet of this well is in the Mancos shale and the remainder in the Dakota sandstone and McElmo formation. No oil was encountered in the drilling, but a little carbonic acid gas escaped at one or more horizons in the well. A little water, which probably contains some lime, issues from the well and has built up a small deposit around its mouth. As this well furnished no encouragement for further prospecting, no additional efforts to discover oil or gas in this locality were made for 10 years.

About 1900 the increasing demand for petroleum and its products and the discovery of other seeps of asphalt or oil in the region encouraged prospectors again to test the field. In sec. 5, T. 22 S., R. 15 E., in Emery County, just west of the road connecting the Tomlinson ranch, on San Rafael River, with Green River, the California-Utah Oil Co. in 1899 drilled a well by means of a 72-foot standard rig to a depth of 1,600 feet. The upper 800 feet of the hole is in the Mancos shale and the remainder in the Dakota sandstone and the McElmo formation. At a depth of 500 feet, probably near the base of the Ferron sandstone member, water was encountered. Gas, which when ignited blazed 30 feet up in the derrick, was struck at a depth of 1,100 feet. A trace of oil was noted at the same depth by the "rainbow" colors on the surface of the water, which was very alkaline. At 1,600 feet a sand was encountered which, by the "paper

test,"[1] showed a trace of oil. The showing was so poor, however, that drilling was discontinued.

In 1899 and 1900 a well was drilled by P. D. Jones, of Duluth, Minn., to a depth of 1,800 feet, in sec. 13, T. 22 S., R. 22 E., at a place about 2 miles south of White House, a flag station on the Denver & Rio Grande Railroad. Work at this locality extended over a period of 1½ years, owing to the fact that three strings of tools were lost. Two of these are in one hole and the other in another hole 20 feet away. The upper 800 feet of the latter well is in the Mancos shale and the lower 1,000 feet in the Dakota sandstone and McElmo formation. No trace of oil or gas, but much bad water, was encountered. At 1,600 feet water carrying copper in solution is reported to have been struck.

Another well was drilled in 1899 in sec. 15 or sec. 16, T. 20 S., R. 14 E., about 3½ miles southwest of Desert, a flag station on the Denver & Rio Grande Railroad about 13 miles northwest of Green River. The well, it is reported, was drilled by a man named Burns, with a standard rig, to a depth of 1,490 feet. At 1,100 feet a "showing" of oil was encountered and it is reported that about 1 gallon of oil was taken from the receiving tank. Excellent artesian water, which flowed over the top of the casing, was struck at 1,200 feet. The water was cased off at 1,290 feet, but 50 feet deeper another flow was encountered. So much water was present in the well at 1,490 feet that drilling was discontinued. At the present time a strong flow of artesian water issues from the well. It is estimated that the upper 1,100 feet of this well is in the Mancos shale and the lower 390 feet in the Dakota sandstone and McElmo formation.

About 1910, owing to the finding of hitherto unknown oil seeps and rocks saturated with asphaltum and oil at several localities, and also to the increased price of petroleum and its products, interest was again aroused in this field and active prospecting has continued to the present time. During the last three years several wells have been drilled and at present drilling operations are being continued at three localities.

Levi well No. 1, drilled with a Keystone rig No. 5, by the British-American Petroleum Co., is in sec. 25, T. 23 S., R. 18 E. Drilling was begun April 1, 1912, and was discontinued about July 1 of the same year at a depth of 530 feet. A fairly strong flow of water was struck at 350 feet and a little gas with a small quantity of oil is reported to have been encountered near the bottom of the hole. This well is wholly in the McElmo formation. Levi well No. 2, in the NE. ¼ NW. ¼ sec. 35, T. 22 S., R. 17 E., was drilled with a standard rig by the

[1] The "paper test" is applied by putting dry sand on paper and allowing it to remain there for some time. If the sand contains even a slight amount of oil the paper will be stained.

same company to a depth of 1,500 feet. No oil or gas is reported to have been encountered in this hole, which is now clogged owing to the "shooting" of the well in an attempt to loosen the casing, which could not be pulled. The same company, using a Keystone rig, drilled a hole in the SE. ¼ SE. ¼ sec. 26 of this township, to a depth of 425 feet, in an attempt to reach a thin sandstone which, on the face of a cliff 1,700 feet southwest of the well, is partly saturated with petroleum. The horizon of this sandstone should have been encountered at a depth of 140 feet, but as no petroleum-saturated sandstone was struck at on near this depth, it is believed that the bed is lenticular under cover, as it certainly is along the outcrop.

The Klondike well, drilled by the Moab Oil Co. of Utah to a depth of about 700 feet by means of a Keystone rig, is located in the NW. ¼ SW. ¼ sec. 26, T. 23 S., R. 19 E. Three pockets of gas were struck in the well but no water nor oil. The first pocket was encountered at a depth of 75 feet and furnished sufficient gas to light the cook tent and for cooking purposes until it was cased off. The gas, escaping through a ¾-inch pipe, burned with a flame 1½ to 2 feet long. The second flow of gas, much stronger than the first, was struck at 265 feet and lasted undiminished until it was cased off. The third flow, which was the weakest of the three, was encountered 500 feet below the surface and lasted about three weeks, when it was cased off. It is believed that the entire well is in the Mancos shale and that the underlying Dakota sandstone was not penetrated. If it had been reached a flow of water would probably have been encountered.

The Queen or Hagan well, in the SE. ¼ SE. ¼ sec. 18, T. 23 S., R. 19 E., was drilled by means of a Keystone rig to a depth of 920 feet. The upper 410 feet of this well is believed to be in the Mancos shale, the remainder being in the Dakota sandstone and McElmo formation. At a depth of 425 feet fresh water was found in a white sand (probably Dakota), and at 600 feet salt water was encountered. Salt water was again encountered at 870 feet and a "showing" of oil at 910 feet. Drilling was discontinued at 920 feet, the casing pulled, and the well abandoned.

The Collins well, in the NW. ¼ NE. ¼ sec. 20, T. 21 S., R. 17 E., was drilled by the Crescent Oil Co. with a National rig to a depth of 2,100 feet. Drilling began September 12, 1912, and was discontinued about March, 1913, on account of a strong flow of salt water that issued from the top of the well and could not be cased off without considerable difficulty. The well penetrated 850 feet of Mancos shale and then passed through the Dakota sandstone and McElmo formation and 100 to 150 feet into the La Plata sandstone, which, being coarse grained, is an excellent carrier of water. Gas was obtained in white sand (probably Dakota) at 850 feet and again in similar material at

976 feet. Gas associated with salt water was encountered at 1,840 feet and dry gas at 1,980 feet. Rainbow colors on the water accompanied each flow of gas. The same company is reported to have moved its rig about 1½ miles southeast and has begun another well near Solitude, approximately in the NE. ¼ NE. ¼ sec 28 of the same township. It is reported that at 70 feet in this well a good flow of water was encountered and that at 350 feet a pocket of gas was struck which burned for a short time a flame 8 to 10 feet in length.

Oil seeps and rocks saturated with oil and asphaltum are present at several localities in the region. Three of these were visited by the writer and are described briefly below. The most prominent seep known to the writer in the area mapped in detail is near the north boundary of the NE. ¼ sec. 2, T. 22 S., R. 16 E., and is known locally as "Goin's seep." It is situated in a narrow zone of rocks which have been disturbed by a fault whose displacement at this locality is about 450 feet, with downthrow on the south side. Several prospect pits for collecting the oil have been dug where the rocks seem to be most nearly saturated, but at the time the writer was in the field there was not sufficient oil in any of the pits to enable him to collect a sample, though the presence of films of oil on the surface of the water in one or two of the pits, as indicated by the rainbow colors was noted. Sandstone partly saturated with petroleum outcrops on a southwestward-facing cliff in the NE. ¼ sec. 35, T. 22 S., R. 17 E. This is the lenticular sandstone that the British-American Petroleum Co. attempted to reach by means of the 425-foot hole. A small lentil of sandstone in the SW. ¼ NW. ¼ sec. 35, T. 22 S., R. 16 E., is partly saturated with petroleum.

Two wells are now being drilled on the west side of Green River outside of the area examined in detail. One of these, located near the center of sec. 29, T. 26 S., R. 14 E., just southwest of "Flattops," is being drilled by the Des Moines Oil Co. At present the drill has penetrated to a depth of 2,140 feet, the upper 600 feet of which is in the McElmo formation, the part from 600 to 1,325 feet in the La Plata sandstone, and the part below 1,325 feet probably all in what has been referred to by Gilbert[1] in the Henry Mountain section as the Vermilion Cliff group. At a depth of about 310 feet a strong flow of good water was encountered which has reduced the expense of drilling considerably, as previous to this time water for all purposes had to be hauled about 10 miles. About 150 feet lower another good flow of water was struck; in fact, from about 310 feet down fresh water was encountered at several horizons. This locality was visited on a reconnaissance trip in November, 1912. From observa-

[1] Gilbert, G. K., Geology of the Henry Mountains: U. S. Geog. and Geol. Survey Rocky Mtn. Region, pp. 6-7, 1877.

tions made at that time it seems probable that the well is situated just north of the axis of a broad, nearly flat east-west anticline which connects the San Rafael Swell on the west with another reported anticline occupying a position near the junction of Grand and Green rivers.

About 10 or 12 miles southwest of the Des Moines Oil Co.'s well, above discussed, in the NE. ¼ sec. 9, T. 27 S., R. 12 E., another well is being drilled by the Mount Vernon Oil Co. This locality was not visited by the writer, as development work had not begun at the close of the field season. It is reported that at first a 600-foot hole was drilled for water and that another a few feet distant is now being drilled for oil. The drill penetrated to a depth of 820 feet in the early part of June. An 84-foot standard rig is used by this company and undoubtedly a thorough test for oil and gas will be made.

TOPOGRAPHY.

The country in the vicinity of Green River, shown in Plate VI (p. 132), lies at the base and south of the Book Cliffs, which form a continuous precipitous escarpment 1,500 to 2,000 feet high, extending from western Colorado as far west as the Wasatch Plateau. Part of the region in Utah lying south of this escarpment and east of the San Rafael Swell constitutes the Green River Desert, of which the area under discussion forms a part. There are excellent exposures of the strata in this region, for the wind and water remove the rock as rapidly as it is disintegrated. Except in a very few places the strata outcrop in nearly vertical scarps that range from a few feet up to 300 or 400 feet in height, wherever hard strata protect the softer underlying rocks. The surface between the escarpments, where the rocks are homogeneous, like the Mancos shale, is a comparatively smooth plain cut into badlands near the stream courses. The plains type of topography predominates north of the road extending southeastward from Green River to Brink Spring, in the SE. ¼ sec. 10, T. 24 S., R. 19 E., whereas the more rugged topography characterizes that part of the area south of the road above mentioned and east of Green River. Dip slopes, usually of small extent, are numerous in the rugged part of the field.

Green River, the only perennial stream, flows along the west side of the field in a canyon whose walls range from a few feet up to 200 or 300 feet in height. Little Grand, Salt, Red, and White washes also have cut canyon-like valleys. Badland topography occurs in many places adjacent to the streams. Salt Wash flows for the greater part of its course on a down-faulted block of McElmo rocks, which forms a conspicuous break in the rugged topography in T. 22 S., Rs. 16 and 17 E., and T. 23 S., R. 17 E.

The relief of the surface in this field is approximately 1,000 feet, the lowest point being on Green River in sec. 31, T. 23 S., R. 17 E., which is approximately 3,990 feet above sea level, and the highest point being in the NE. ¼ NW. ¼ sec. 19, T. 23 S., R. 18 E., where the altitude is about 4,990 feet.

WATER SUPPLY.

The climate is semiarid, as shown by the mean annual rainfall, which in the vicinity of the town of Green River is about 6½ inches. The most important water supply in the field is Green River, which forms the western boundary of the area and carries a plentiful amount of water the year round. Plans have been made to divert some of the water from the river to irrigate large tracts of land on each side of it, in addition to that already under irrigation. Little Grand, Salt, Red, and White washes, which are the principal tributaries, joining Green River from the east, are intermittent streams throughout the greater parts of their courses. In the vicinity of springs, however, the water flows on the surface for some distance, and then sinks into the sand to reappear as other springs or seeps farther down the valley.

In the NE. ¼ SW. ¼ sec. 27, T. 22 S., R. 17 E., about a mile northwest of Levi well No. 2, there is a fairly strong spring which, on account of its slightly saline and alkaline character, is known locally as Salt Spring. In the bed of Little Grand Wash, in sec. 8 of the same township, there is another fairly good spring. A spring of good water in the SE. ¼ NE. ¼ sec. 17, T. 22 S., R. 18 E., on a northern tributary of Little Grand Creek just west of the traction road connecting Floy or Little Grand with some manganese claims near the river, constitutes the only water supply in the township. In the S. ½ sec. 25, T. 22 S., R. 16 E., two or three salt springs furnish sufficient water to make the lower course of Salt Wash a perennial stream. Brink Spring, situated on a fault in the SE. ¼ sec. 10, T. 24 S., R. 19 E., has a strong flow of excellent water. Four to five miles slightly south of east from Brink Spring there are two good springs. One of these is in a stream bed just north of the Court House Cattle Co's ranch and the other at Court House stage station, about a mile farther northeast. A water hole of considerable size is situated in the SW. ¼ sec. 15, T. 23 S., R. 18 E.

At several places where the massive sandstone beds in the lower part of the McElmo formation outcrop in almost flat surfaces, holes, formed principally by wind erosion, collect rain water and retain it for relatively long periods of time, thus affording excellent temporary local supplies of water.

The wells drilled in the field to date, with the exception of the Klondike well in the NW. ¼ SW. ¼ sec. 26, T. 23 S., R. 19 E., have all

encountered some water. Artesian water was struck in the well southwest of Desert station, in T. 20 S., R. 14 E., and in the Elgin well, in the SW. ¼ SE. ¼ sec. 15, T. 21 S., R. 16 E., as noted in the description of these wells under "History of development of the field," the former furnishing fresh and the latter salt water.

LAND SURVEYS.

The land surveys in parts of this field are remarkably good. Where section lines were followed in mapping practically all the corners were found, but where the triangulation method of mapping was employed only a sufficient number of corners were located to check the triangulation work. For this reason little can be said regarding the surveys in that part of the field where the triangulation method was used. From retracements of exteriors made in the more recent work for the General Land Office it is believed that the chaining in the earlier work was long, so that the old lines are slightly longer than is indicated on the original township plats.

STRATIGRAPHY.

GENERAL SECTION.

The rocks exposed in the Green River field belong to the Cretaceous and Jurassic systems. The Mancos shale and Dakota sandstone represent the former, and the La Plata sandstone and probably the McElmo formation represent the latter, although it is not yet definitely determined whether the McElmo is Jurassic or Cretaceous. Rocks of Cretaceous age in this field were mapped in a reconnaissance way by Richardson[1] in 1906. The underlying formation which, in the present report, is mapped as McElmo, was considered by Richardson[2] to be equivalent in part to the Morrison formation.

The following summary gives a general description of the rocks exposed in the Green River field:

[1] Richardson, G. B., Reconnaissance of the Book Cliffs coal field between Grand River, Colorado, and Sunnyside, Utah: U. S. Geol. Survey Bull. 371, Pl. I, 1908.

[2] Idem, Pl. III, p. 14.

General section of rocks outcropping in the Green River field, Utah.

System.	Formation.	Member.	Description of strata.	Thickness (feet).	Economic value.
Cretaceous.	Mancos shale.		Yellow to bluish drab sandy shale; the upper part is very sandy and contains beds and lenses of sandstone; the middle and lower parts are mainly shale.	About 2,500 (after Richardson).	
		Ferron sandstone member.	This sandstone contains in places concretions which are fossiliferous. It forms a hogback through the field.	50-100.	Possibly this sandstone is a reservoir for the gas that has been obtained in some of the wells.
			Bluish drab sandy shale; sandy material is most plentiful near the base and top of this part of the formation.	About 400.	
	Dakota sandstone.		Yellowish-gray sandstone with thin beds of shale alternating. Sandstones, coarse, soft, and in places very conglomeratic.	0-40.	Contains a little coal in places, but none was observed in this field.
			——Unconformity.——		
Jurassic (?).	McElmo formation.		Gray conglomerate, variegated sandy shale, and clay, and a few feet of limestone about 175 feet from the top. Some of the sandstone is quartzitic.	325-350.	A few lenses of sandstone contain pockets of gas. Other lenses are partly saturated with petroleum.
		Salt Wash sandstone member.	Gray conglomeratic sandstone which outcrops in cliffs. The sandstone in places is lenticular, soft, and friable.	150-175.	Water-bearing in places. Probably contains a little gas and a trace of oil.
			Red sandstone, thin-bedded above and massive below.	About 700.	Gypsum and manganese in the upper part.
Jurassic.	La Plata sandstone.		Very cross-bedded coarse gray sandstone.	Estimated 700.	Water-bearing in many places.

JURASSIC SYSTEM.

LA PLATA SANDSTONE.

The La Plata sandstone consists of a cross-bedded coarse-grained, very massive gray sandstone, the base of which was not observed in the Green River field. It is believed, however, that the thickness of the formation in this locality is about the same as in the vicinity of the San Rafael Swell, where it is 700 or 800 feet. In places this sandstone is stained from the overlying red sandstone and sandy shale of the McElmo formation. The La Plata sandstone, first described by Cross[1] as "seldom more than 100 feet" in thickness at the type locality, is much thicker in this field, as noted above. This sandstone, being coarse grained and massive, is an excellent reservoir for water, and, as stated under "History of development of the field," it is believed that the salt water encountered in the Collins well, in sec. 20, T. 21 S., R. 17 E., is derived from its upper part.

JURASSIC (?) SYSTEM.

M'ELMO FORMATION.

General occurrence and character.—Overlying the La Plata sandstone with apparent conformity is the McElmo formation, which, according to Cross,[1] should include all the rocks between the Dakota sandstone above and the La Plata sandstone below. At the west side of the San Rafael Swell, east of Emery, marine fossils of Jurassic age were collected about 15 feet above what was taken to be the base of the McElmo formation, but this bed may belong with the underlying formation. Bones were also noted in a conglomerate about 500 feet below the top of the formation in the same area. On account of lack of time little attention was given during the field examination to the collecting of fossils. A detailed section of the greater part of the formation was measured in the NW. ¼ sec. 19, T. 23 S., R. 18 E., and is given on page 126.

[1] Cross, Whitman, Description of the Telluride quadrangle, Colorado: U. S. Geol. Survey Geol. Atlas, Telluride folio (No. 57), p. 3, 1909.

Section of part of McElmo formation measured in the NW. ¼ sec. 19, T. 23 S., R. 18 E. Salt Lake meridian, Utah.

	Ft.	in.
Sandstone, gray; weathers brown; contains clay-ball concretions in places	8	
Clay, bluish gray; contains a little limestone about 5 feet below top	28	6
Clay, brick-red, gray, and purplish, sandy; contains several thin beds of gray to white sandstone	116	
Sandstone, gray; weathers brown; indurated at base, conglomeratic and quartzitic in places, lenticular	5	
Clay, brick-red, sandy	52	
Sandstone, brick-red, massive	14	
Clay, brick-red, sandy	12	
Salt Wash sandstone member:		
Sandstone, gray, conglomeratic; contains some interbedded gray sandy shale (Ft. 58)		
Sandstone, reddish, calcareous (Ft. 17)		
Sandstone, gray to white, soft, cross-bedded in places (Ft. 10)		
Sandstone, red and gray, soft, calcareous (Ft. 42)		
Sandstone, gray to white, soft, massive; contains a little argillaceous material (Ft. 37)		
	164	
Sandstone, grayish brown, interbedded with gray and reddish calcareous and argillaceous sandstone	27	
Sandstone, white; weathers reddish brown	12	
Sandstone, red with streaks of green, calcareous	20	
Sandstone, grayish brown, with calcareous layers	50	
Sandstone, brown	2	
Sandstone, calcareous	5	
Sandstone, grayish brown, medium bedded	4	
Sandstone, red below and gray above, very calcareous; contains many small nodules	40	
Sandstone, brick-red, thin and medium bedded. This sandstone is believed to be calcareous. It bears manganese ore in the upper part	128	
Sandstone, red, massive	400±	
	1,087	6

A section of the upper part of the McElmo formation measured in secs. 26, 34, and 35, T. 22 S., R. 17 E., near Levi well No. 2, shows that the formation is about 100 feet thicker than is indicated by the section given above. Most of the part omitted from the above section consists of alternating beds of sandstone and sandy shale of various colors capped by a conglomeratic quartzitic sandstone about 20 feet thick. The east end of the base line (*B*, Pl. VI), in the SE. ¼ SW. ¼ sec. 26, just north of Levi well No. 2, is on this sandstone.

The upper part of this formation was regarded by Richardson [1] as probably equivalent to the Morrison formation, as a number of

[1] Richardson, G. B., Reconnaissance of the Book Cliffs coal field between Grand River, Colorado, and Sunnyside, Utah: U. S. Geol. Survey Bull. 371, p. 14, Pl. III, 1909.

dinosaur bones were found in that part of the formation near Grand Junction, Colo.,[1] some distance east of the area under discussion. These rocks in the Green River field are similar lithologically to the Morrison formation at its type locality and to the same formation in Wyoming, where the writer has had opportunity to observe it. The McElmo formation, described first by Cross,[2] is 400 to 500 feet thinner at the type locality than in the area under discussion. The upper 350 feet of the McElmo formation in the Green River field consists of variegated sandstone, sandy shale, shale, limestone, and about 150 feet of conglomeratic sandstone beds (Salt Wash sandstone member), which occur principally near the base of this portion of the section. The middle part of the formation consists of 300 to 400 feet of red, mainly thin-bedded sandstone and sandy shale which, in its upper part, contains in places considerable gypsum. As much as 60 feet of gypsum was measured at one place. At places where the gypsum is not present manganese in the form of pyrolusite may be found at about the same horizon—in fact, the Colorado Fuel & Iron Co. mined considerable of this mineral in the southern part of the area under discussion and hauled it to the railroad to be shipped east. At present, however, mining operations have been discontinued. The lower 400 feet or more of the formation is made up of massive red sandstone. At several horizons in the formation there are lentils of sandstone that in places are partly saturated with petroleum. Two of these outcrop at the surface in this field and have been described above under "History of development of the field." Some gas has also been encountered in the wells in this formation.

Salt Wash sandstone member.—A gray coarse-grained sandstone, conglomeratic in places, occurs in the Green River field about 350 feet below the top of the McElmo formation. It probably corresponds to the lower conglomerate of the "Henrys Fork group" of Powell's section [3] on the north flank of the Uinta Mountains and of Gilbert's section [4] in the Henry Mountains. This sandstone was used as a datum plane on which altitudes were determined, and is shown on the map by hachures in the unpatterned area. The writer proposes the name Salt Wash sandstone member of the McElmo formation for this sandstone.

[1] Riggs, E. S., The dinosaur beds of the Grand River valley, Colorado: Field Columbian Mus. Geol. Ser., vol. 1, 1901.

[2] Loc. cit.

[3] Powell, J. W., Report on the geology of the eastern portion of the Uinta Mountains and a region of the country adjacent thereto: U. S. Geol. and Geog. Survey Terr., 2d div., p. 157, 1876.

[4] Gilbert, G. K., Geology of the Henry Mountains: U. S. Geog. and Geol. Survey Rocky Mtn. Region, p. 4, 1877.

CRETACEOUS SYSTEM.

DAKOTA SANDSTONE.

The Dakota sandstone unconformably overlies the McElmo formation and in this region is variable in thickness. Richardson,[1] who examined this and adjacent formations from Grand River, Colo., to Sunnyside, Utah, found it to be cut out entirely in the vicinity of Elgin, though reaching a maximum of 200 feet in other places. In the Green River field it consists of 40 feet or less of yellowish-gray to white coarse-grained sandstone which in places is conglomeratic. Thin beds of coal have been found in this sandstone in the vicinity of Fruita and Grand Junction, Colo., and along the east side of Castle Valley to the west, but no carbonaceous material was observed in the Green River field.

The Dakota sandstone is a water bearer in places in this region and is believed to contain the pocket of gas encountered at a depth of 850 feet in the Collins well, in sec. 20, T. 21 S., R. 17 E. In the area under consideration no part of the formation is known to be saturated with oil or asphaltum, as are some of the sandstone beds in the underlying formation.

MANCOS SHALE.

General character.—The Mancos shale consists of about 3,000 feet of bluish-drab shale, very sandy near the top and the base. Approximately 1,400 feet of the Mancos is exposed in the area under consideration. About 400 feet above the base occur sandy beds 50 to 100 feet thick, which are known as the Ferron sandstone member. (See below.) The rocks underlying and overlying the Ferron sandstone member are similar in appearance. They contain sandy beds which undoubtedly form the pockets for the gas encountered in the Klondike well and at 350 feet in the Collins well. The greater part of the small amount of gas encountered in the field was struck in the Mancos shale.

Ferron sandstone member.—The portion of the formation distinguished as the Ferron sandstone member contains sand and sandy material and is more resistant than the overlying and underlying rocks, and for that reason it outcrops in a hogback which extends the full length of the field. In the southeastern and eastern parts it is represented by two small hogbacks near each other, which suggests that the sandy material brought in at the time these rocks were laid down was more plentiful than farther west and northwest, where but one hogback is present. This sandy member of the Mancos shale can be definitely correlated with alternating sandstone, shale, and coal

[1] Richardson, G. B., Reconnaissance of the Book Cliffs coal field, between Grand River, Colo., and Sunnyside, Utah: U. S. Geol. Survey Bull. 371, pp. 12, 14, Pl. III, 1909.

beds in the vicinity and south of Ferron, in Castle Valley, from which the member takes its name. A complete description of the sandstone at its type locality is given in another report in this bulletin.

STRUCTURE.

The structure in general in the western part of the field is that of a gently northeastward-dipping monocline, which, owing to the presence of a comparatively narrow, somewhat broken anticline extending northwest and southeast and lying mainly east and southeast of the area mapped, develops gradually toward the east into a flat syncline. From rather meager data collected in the extreme eastern part of the field it is believed that considerable strike faulting has disturbed the rocks on both sides of the anticline. In the southwestern part of the area mapped there are numerous variations in the general northeast dip of the strata, which are discussed below in detail. A prominent fault zone crosses the field in a northwest-southeast direction. Its direct bearing on the possible presence of an oil reservoir is fully discussed under "Conclusions." Another important fault zone, smaller than the one just mentioned, crosses Green River in the southern part of T. 21 S., R. 16 E., and extends a few miles into the area mapped.

The details of the structure are shown by dip symbols and fault lines on the map which accompanies this report (Pl. VI). The mapping of the outcrops of the formations, together with the hachured line representing the outcrop of the Salt Wash sandstone member of the McElmo formation, furnishes additional aid in interpreting the structure of the rocks.

The dips measured on the Dakota sandstone are characteristic of the overlying Mancos shale and the underlying McElmo formation. Hence a discussion of the structure of this sandstone applies equally well to the adjacent formations near the outcrop of the Dakota. Beginning near the town of Green River, where the dip is about 4°, and following the outcrop to the southeast, the dips increase to as much as 6° in sec. 25, T. 21 S., R. 16 E. This dip is constant for about 2 miles, then drops to 5° just north of the fault in sec. 32, T. 21 S., R. 17 E. South and southeast of the fault, through T. 22 S., Rs. 16, 17, and 18 E., and the northern part of T. 23 S., R. 18 E., the dips range from 4° to 5° NE. The outcrop of the Dakota is obscured by faults southeast of the northern part of sec. 10, T. 23 S., R. 18 E., for about 5 miles. Dips on the Ferron sandstone member of the Mancos shale show that the beds flatten gradually to 2° at the extreme southeast exposure of this sandstone, in the hogback in secs. 1 and 2, T. 24 S., R. 19 E., near the end of the syncline. At this locality the Dakota is again recognizable as the outcrop swings away from the fault and extends to the north and northwest along the east

flank of the syncline above referred to. To the north and northwest the dips increase to as much as 9° SW. in sec. 12, T. 23 S., R. 19 E., just north of the State road connecting Thompson and Moab. The stratigraphically lower rocks along the east flank of the syncline dip more steeply than the Dakota.

South of the principal fault zone near the river, in secs. 26, 34, 35, and 36, T. 22 S., R. 16 E., and secs. 1, 2, and 3, T. 23 S., R. 16 E., variations in the dips suggest the presence of a small dome whose center is near the northwest corner of sec. 1. In secs. 7 and 8, T. 23 S., R. 17 E., other variations in structure give indications of a small dome, the center of which is near the east quarter corner of sec. 7. Irregular dips are numerous in secs. 15, 16, 17, 18, 19, 20, and 21 of the same township and indicate that the structure is undulating, with a fairly well defined dome of small extent in secs. 15, 16, 21, and 22. The southeastern part of this dome could not be determined on account of lack of exposures, as drifted sand covers the rocks in the White Wash. The center of the dome is probably in the SW. ¼ sec. 15. Adjacent to the main fault zone in secs. 11 and 12, T. 23 S., R. 18 E., the dips are very irregular and show a very small dome which is due partly to faulting, as the northernmost fault of the principal zone terminates near this place.

The faults are discussed below in order from north to south. As shown on Plate VI a fault extends through secs. 33, 34, 35, and 36, T. 21 S., R. 16 E., and secs. 31, 32, 33, and part of 34 (where it disappears), T. 21 S., R. 17 E., and carries the outcrop of the Mancos shale about 3 miles west of its position north of the fault. Its extent to the west is not definitely known but is probably not greater than to the east of the river. The maximum displacement of this fault, the downthrow of which is on the south side, is about 450 feet. Goin's oil seep, near the north boundary of the NE. ¼ sec. 2, T. 22 S., R. 16 E., and a former spring, now marked by a calcareous deposit, near the northeast corner of the same section are closely related genetically to the disturbed strata adjacent to the fault in that the disturbed rock, being more porous, furnished an outlet to the surface for the oil and calcareous material.

Block faults prevail in the western two-thirds of the field along the main zone of disturbance, whereas a single fault is the result of the earth movement in the eastern part. In sec. 26, T. 22 S., R. 16 E., and sec. 1, T. 23 S., R. 17 E., as many as four faults cut the rocks along Salt Wash in a distance of three-fourths of a mile, but throughout the remainder (and longer part) of that stream only two faults, a little less than half a mile apart, are present. The rocks between the two principal faults have been dropped as much as 500 feet, and the strata on the north side of the zone are about 300 feet higher than the corresponding strata to the south of the disturbed belt. This

condition is well illustrated by the stratigraphic section shown on Plate VI. The other downfaulted block, extending through secs. 1 and 2, T. 23 S., R. 17 E., and secs. 3, 4, 5, 6, 8, 9, 10, 11, 14, and 15, T. 23 S., R. 18 E., carries the outcrop of the lower part of the Mancos shale about 3 miles west of its normal position. This block has a maximum displacement of about 400 feet.

Both of the principal down-faulted blocks have a synclinal structure, which is due to the bending up of the strata caused by dragging along the fault planes. This is especially noticeable along Salt Wash, in the western part of the field. Southeast of Tenmile Wash the disturbance has taken place for the most part along a single fault plane, the strata to the north of the fault showing more evidence of the effect of dragging than those to the south, as indicated by dip symbols on Plate VI. At Brink Spring, in sec. 10, T. 24 S., R. 19 E., the displacement is about 1,200 feet, the downthrow being on the north side of the fault. The La Plata sandstone, capped with a few outliers of the McElmo formation, forms the surface rocks south of the fault in this locality. The location of this fault east and southeast of a point about a mile southeast of Brink Spring is only approximate. Although conditions to the southeast were not studied in detail, it is believed that the amount of displacement increases in that direction.

In addition to the larger faults described above, there appears to be in sec. 1, T. 22 S., R. 16 E., about 1 mile southeast of Goin's oil seep, a short minor fault of slight throw.

THEORY OF OIL ACCUMULATION.

Oil operators are desirous of finding anticlines or domes if the rocks are saturated with water ("wet") and synclines or basins if the strata are "dry" or comparatively so. Generally, wherever the rocks contain water and oil disseminated throughout the pores of the mass, there is a tendency for the water, being the heavier, to collect below and thus force the oil to occupy a position above it. If the rocks are thoroughly saturated there will be a general migration of the globules of oil upward through the strata until they reach the surface of the earth or until their progress is stopped by the presence of rocks like clay, shale, and dense sandstone, which are almost impervious to oil. If the porous stratum and the impervious cover are flat lying probably there will be no large accumulations of oil, but if they are inclined slightly the oil will continue to migrate up the rise at or near the base of the impervious stratum until it reaches the upper limit of water saturation or the surface of the earth and escapes in an oil spring or seep. If the structure of the impervious stratum is that of a dome or anticline the oil will collect in the porous rock underlying the impervious cap in the top of the anticline and remain there until it can escape to the surface through natural

or artificial openings, such as fault planes or drill holes. If the rocks are "dry" the disseminated oil particles, acted upon only by the force of gravity, tend to migrate downward. If the structure is that of a syncline or basin underlain by an impervious stratum, the oil will collect in the depression.

In the above discussion the simplest condition—that in which the rock containing the oil is a homogeneous sandstone overlain or underlain by a stratum impervious to oil—is assumed. It is believed that where the conditions are more complex, as where the oil is included in a shale or a compact fine-grained sandstone containing lentils of coarser sandy material, and the rocks are fairly well saturated with water, the oil will be forced into the lentils of rock whose pore spaces are larger, owing to the differential capillary attraction of water and oil. The presence of oil-saturated sandstone lentils in the more compact, finer-grained sandstones in the McElmo formation of the Green River field may be explained by this theory.

CONCLUSIONS.

The results obtained from drilling seven wells in this field, as indicated in the following table, have furnished but little encouragement for further exploration.

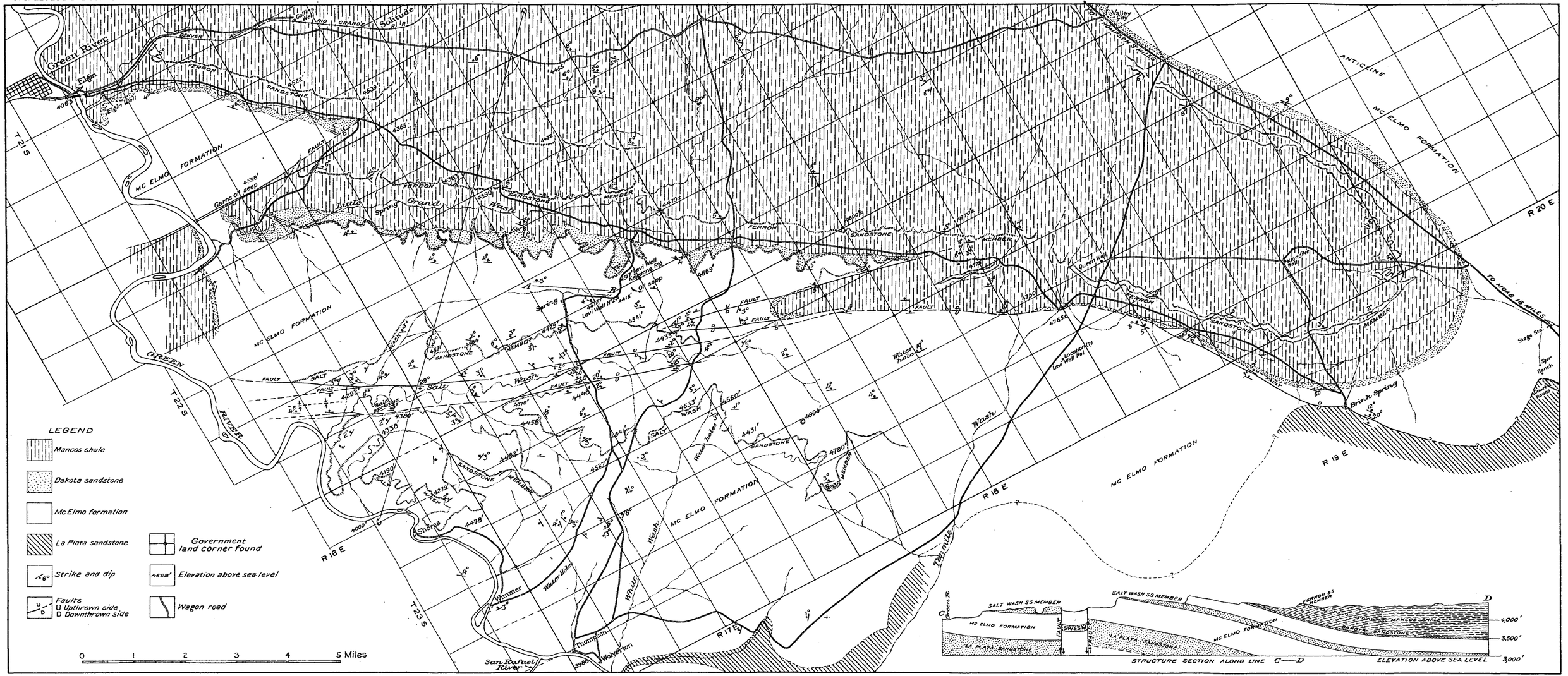
Wells drilled for oil or gas in the Green River field, Utah.

Name of well.	Location.	Depth.	Oil.	Gas.	"Dry."
		Feet.			
Elgin	Sec. 15, T. 21 S., R. 16 E.	1,000			×
Levi No. 1	Sec. 25, T. 23 S., R. 18 E.	530	Trace.	×	
Levi No. 2	Sec. 35, T. 22 S., R. 17 E.	1,500			×
Levi (Keystone)	Sec. 26, T. 22 S., R. 17 E.	425			×
Klondike	Sec. 26, T. 23 S., R. 19 E.	700		×	
Queen	Sec. 18, T. 23 S., R. 19 E.	920	Trace.	×	
Collins	Sec. 20, T. 21 S., R. 17 E.	2,100	Trace.	×	

Three of the wells have proved to be dry holes according to the most reliable reports obtainable, three encountered traces of oil and small quantities of gas, and one struck "pockets" of gas without oil.

Levi well No. 2 and the Collins well, which were drilled to depths of 1,500 and 2,100 feet, respectively, passed entirely through the McElmo formation and penetrated the upper part of the La Plata sandstone, proving conclusively that the McElmo contains no persistent oil-bearing stratum, although it may contain numerous small lenses of sandstone that may be partly or wholly saturated with petroleum. As stated under "History of development of the field," lentils of petroleum-saturated sandstone outcrop, and it is reasonable to assume that there may be others beneath the surface.

The pockets of gas encountered in the wells are for the most part in the Mancos shale, although the Collins well, in sec. 20, T. 21 S., R. 17 E., found pockets of gas in the McElmo formation also.



MAP OF AREA EXAMINED FOR OIL AND GAS SOUTHEAST OF GREEN RIVER, IN GRAND COUNTY, UTAH

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

Structurally the area mapped in detail contains no anticlines or domes of importance in which large quantities of oil or gas could have collected. On the other hand, the eastern part of the field in the vicinity of the Klondike well includes some anticlines, but they are not believed to be especially favorable on account of the presence of probable faults on each side of the upfolds. Additional field work in the locality will definitely determine the character of the structure. The monoclinal character of the greater part of the remainder of the field is not promising, as discussed under "Theory of oil accumulation."

The small domes discussed under "Structure" and situated east of Green River, in Tps. 22 and 23 S., Rs. 16 and 17 E., are in the writer's opinion the most favorable places to drill for oil in this field. The favorable structure, however, does not mean that oil will certainly be encountered at these localities.

Faults and fault zones are usually unfavorable structures for the accumulation of oil or gas, because the rocks adjacent to the breaks in the strata are somewhat crushed and for that reason are rendered more porous, allowing an easy passageway to the surface for the oil, gas, or water that may be seeking an upward outlet. It is believed that the petroleum-saturated condition of the rocks in the vicinity of Goin's seep, situated near the north boundary of sec. 2, T. 22 S., R. 16 E., is due to the fault having cut a lentil of oil-saturated sandstone at some depth beneath the surface. The conditions along the faults and fault zones that cut the strata in the Green River field suggest either that the petroleum-saturated sandstone lentils cut by faults are comparatively few, or that if they are numerous the amount of oil they contain is small, not saturating the rocks at the surface.

From the evidence already obtained by drilling in this field and from the presence of gas in the Mancos shale in other fields, it seems safe to predict that a little gas will probably be encountered in every well drilled in the Mancos shale. It seems equally probable, considering the structure of the field, that gas in large quantities will not be found.

As stated under "History of development of the field," two wells are being drilled 45 to 50 miles southwest of Green River. The structure in this general region, to judge from the meager evidence collected on a reconnaissance trip, seems to be favorable for the accumulation of oil and gas in what appeared to be a broad, flat anticline extending in an east-west direction. It should be reiterated that the presence of favorable structure does not mean that oil or gas will be found in commercial quantities. Favorable structure is a necessary condition but not the only one. The underlying strata must contain oil or gas disseminated through them, or the reservoirs, however ideal they may be, are of no importance.

PETROLEUM NEAR DAYTON, NEW MEXICO.

By G. B. Richardson.

Introduction.—Interest in the possible occurrence of a commercially important quantity of petroleum in the Pecos Valley has been revived by the discovery, near Dayton, N. Mex., of oil in a well drilled for water. This well is reported to have a capacity of about 25 barrels of oil a day. Several companies have been organized, and in March, 1913, three standard rigs were in the field prepared to test

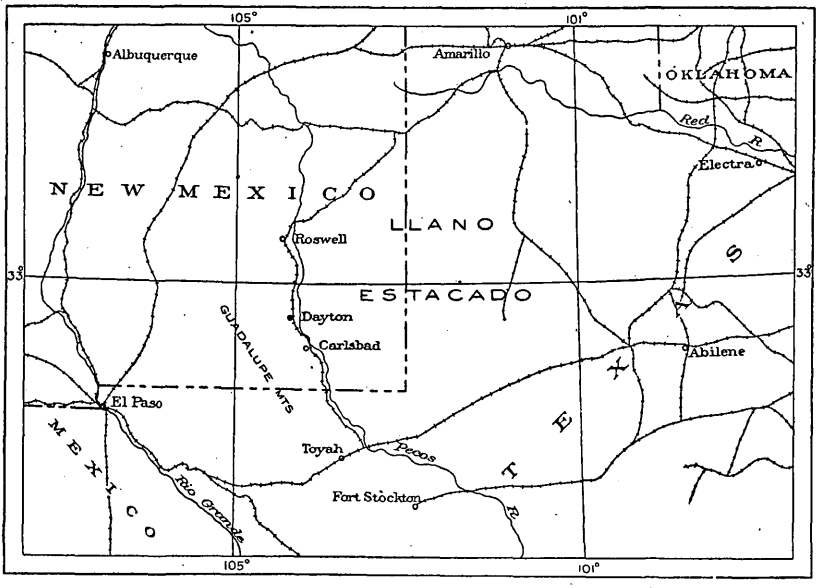


FIGURE 5.—Sketch map showing location of Dayton, N. Mex.

the area in the vicinity of Dayton. Although detailed geologic work has not yet been done in this region, and little is known about the field, the following statement, based on data obtained during a short visit in March, 1913, has been prepared in response to numerous requests for information.

Development.—Several hundred wells have been sunk for water in the Roswell artesian area,[1] in which Dayton is located. These range

[1] Fisher, C. A., Preliminary report on the geology and underground waters of the Roswell artesian area, New Mexico: U. S. Geol. Survey Water-Supply Paper 158, 1906.

from a few hundred to about a thousand feet in depth, and in the vicinity of Artesia and Dayton there are a number of wells which individually flow more than 1,000 gallons a minute. The water is obtained from a porous limestone member of the group of Permian red beds of the Pecos Valley and, as the oil occurs below the water-bearing bed, the casing off of this great flow will be a serious matter, but the first problem is to determine whether or not there is in this locality an important quantity of oil.

Traces of oil and gas have been found in a number of wells in this vicinity, and in 1909–10 local excitement was caused by the discovery of these substances in unusual quantity. Natural gas was struck in the Platt well, in the SW. ¼ sec. 26, T. 18 S., R. 26 E., 1½ miles southeast of Dayton. This well is reported to be 869 feet deep, the flow of water being encountered at 790 feet. Accurate measurement of the quantity of gas produced has not been made, although the pressure is said to have been great enough to break a 300-pound gage. In March, 1913, the gas, after being shut off for some time, was turned on, escaping with a roar and burning with a flame several feet high. Oil was not found in this well.

Another well, the Old Williams, now known as the Belt well, in the NW. ¼ sec. 25, T. 18 S., R. 26 E., 2½ miles east of Dayton, was driven to a depth of 1,002 feet (reported by some to be 1,340 feet) and encountered one flow of water at 783 feet and another at 820 feet. A small quantity of gas and oil flowed from the well with the water and at first was allowed to escape, but recently, by allowing the flow to enter a series of settling tanks and drawing off the water from below and the oil from above, a reported yield of about a barrel of oil a day has been obtained.

The best yield of petroleum yet obtained in the Pecos Valley is from the old Hammond, now known as the Brown well, in the NE. ¼ sec. 15, T. 18 S., R. 26 E., 2¼ miles northeast of Dayton. This well was sunk in 1909 to a depth of 950 feet. A flow of water was encountered at 660 feet, a little gas at 762 feet, and oil between 911 and 926 feet. An attempt was made to case off the flow of water, and in the summer of 1911 a yield, continuing for several months, of 6 to 10 barrels of oil a day was reported. In 1912 this well was acquired by Charles S. Brown, of Artesia, who succeeded in increasing the yield of oil and in cutting off more water, but the attempt to case off the water has been only partly successful. In March, 1913, Mr. Brown stated that he pumped approximately 800 barrels of liquid a day from this well, including about 25 barrels of oil. The oil is separated from the water by a series of settling tanks and is sold for fuel and for smudging orchards.

Not long after oil was found in the Old Hammond well a local association known as the Giant Gas & Oil Co. was organized, and

in 1910 it sank a well close by, in the NE. ¼ sec. 15, T. 18 S., R. 26 E. This well is reported to have been put down 1,118 feet without finding either gas or oil. From lack of money the well was not drilled deeper, but as oil had been found between 911 and 926 feet in the adjacent well the test was thought to be fair. Nevertheless continued interest in the possibilities of the Dayton field has been maintained, and recently it was determined to test the area by sinking wells considerably deeper. Two companies were therefore organized, the Pecos Valley Oil & Gas Co., which is drilling a well in the SE. ¼ sec. 15, T. 18 S., R. 26 E., and the Dayton Petroleum Co., in the NW. ¼ sec. 23, T. 18 S., R. 26 E., both sites being between the Brown and Belt wells referred to above. Another test well said to be located in the SE. ¼ sec. 35, T. 19 S., R. 24 E., 12 miles southwest of Dayton, was started by the Seven Rivers Oil & Gas Co., which intended to sink it to a considerable depth, but in the spring of 1913 it was reported to be temporarily stopped at a depth of about 600 feet on account of lack of funds.

Quality of the oil.—Samples of oil from the Brown and Belt wells, collected by the writer in March, 1913, were analyzed by David T. Day with the following results:

Analyses of petroleum from the vicinity of Dayton, N. Mex.

	Belt well.	Brown well.
Color	Brown.	Brown.
Specific gravity	0.8974 at 26° B.	0.9097 at 23.9° B.
Distillation:		
Gasoline	None.	None.
Begins to boil at	170° C.	160° C.
Boiling below 300° C. (kerosene) per cent	33	29
Specific gravity of above fraction	0.7903	0.8041
Residue per cent	65.6	69.3
Specific gravity of residue	0.9223	0.7396
Total per cent	98.6	98.3
Asphalt do	2.0	0.35
Sulphur do	1.0	2.3

These tests show that the oil is similar to that of the Beaumont field in Texas. It is a fuel oil which furnishes little or no gasoline but from which a fair yield of kerosene can be obtained.

Geology.—Although detailed geologic work has not yet been done in southeastern New Mexico, general conditions are known as a result of several reconnaissance surveys.

In this part of New Mexico Pecos River flows in a broad, open valley lying between the Llano Estacado on the east and the Guadalupe and Sacramento mountains on the west. The rocks are sedimentary and the general dip is eastward, decreasing from 5° or 10° in the mountains nearly to horizontality on the plains. The rocks of the mountains consist of at least 10,000 feet of limestone and subordinate sandstone, which are succeeded by the red beds that directly underlie the Pecos Valley. These rocks are of Carboniferous age, the lowermost

being Pennsylvanian and the uppermost Permian. East of the river the red beds are overlain by Triassic and Tertiary strata, which for present purposes are unimportant. The bituminous limestones and sandstones which underlie the red beds constitute the probable source of the petroleum.

The greater part of the Pecos Valley is occupied by unconsolidated Quaternary deposits, consisting of gravel, sand, and clay, which are separable into river alluvium and material derived from the disintegration of the rocks of the mountains and transported as wash toward the river. These unconsolidated materials, as indicated by logs of wells, vary in thickness, reaching a maximum of a few hundred feet, and occupy a large area, in places having a width of 25 miles. The bedrock is therefore concealed beneath the valley and details of its character and structure are unknown.

The red beds of the Pecos Valley, which directly underlie the unconsolidated materials and outcrop on the highlands east and west of the river, consist of a complex group of lenticular beds of red sandstone and shale, magnesian limestone, and gypsum. Satisfactory measurements of the thickness of these beds have not been made, although they are locally known to be more than 1,600 feet thick. But the thickness varies greatly because the red beds are not confined between definite horizons, the red color extending irregularly across the strike in accordance with varying conditions of deposition. The red beds of the Pecos Valley, on the evidence of fossil shells and stratigraphic position, are believed to be of Permian age and are correlated with the well-known Permian red beds of north-central Texas and Oklahoma, which outcrop east of the Llano Estacado.

An idea of the composition of the red beds is indicated by the log of the Williams or Belt well, as reported by the driller.

Log of the Williams or Belt well, in the NW. ¼ sec. 25, T. 18 S., R. 26 E.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Soil	8	8	Concrete	50	750
Gumbo	7	15	Sand, red	8	758
Gravel	10	25	Hard rock	12	770
Gypsum, soft	60	85	Shale	13	783
Sand	65	150	Water rock	7	790
Gypsum	10	160	Shale, red	18	808
Sand, white	47	207	Water rock	12	820
Sand, red	6	213	Hard rock	15	835
Concrete	5	218	Sand, red	8	843
Sand, red	4	222	Sandstone	10	853
Shale, red	6	228	Hard rock	42	895
Gypsum, rock	12	240	Gypsum	5	900
Gumbo	10	250	Black sulphur rock	10	910
Sand, red	45	395	Clay, blue	2	912
Clay, blue	10	405	Sandstone	23	935
Shale, red	15	420	Limestone	11	946
Concrete	90	510	Sandstone, white	32	978
Sand, red	30	540	Hard brown rock	11	989
Hard rock	50	590	Light-brown rock	5	994
Shale	40	630	Sandstone, white	2	996
Water rock	50	680	Dark-brown rock	4	1,000
Clay, blue	20	700	Light-brown rock	2	1,002

Beneath the red beds of the Pecos Valley is a great mass of limestone with interbedded lenses of sandstone, having an estimated thickness of 10,000 feet, which outcrops in the Guadalupe and Sacramento mountains and dips eastward toward Pecos River at a low angle. This limestone in turn is underlain by a lower zone of red beds exposed on the western escarpment of the Sacramento Mountains, 90 miles west of Pecos River. Both the lower red beds and part of the overlying limestone and sandstone are of Pennsylvanian age.

Petroleum.—The petroleum in the vicinity of Dayton occurs at or near the base of the red beds of the Pecos Valley, beneath the water-bearing stratum of porous limestone that furnishes the artesian supply. Presumably the oil originated in the bituminous limestones and sandstones which outcrop in the mountains west of the Pecos Valley and underlie the red beds.

It is of interest that the oil in the Electra field, Texas, east of the Llano Estacado, occurs in a similar stratigraphic position. The significance of this similarity, however, is diminished by the fact that the fossils from the rocks below the Permian red beds of the Pecos Valley are different, according to G. H. Girty, from those occurring in the strata beneath the Permian red beds of north-central Texas, the difference indicating separate basins of deposition. Apparently the occurrence of oil in these two areas east and west of the Llano Estacado is distinct.

It should be noted also that the Dayton oil is quite different from the petroleum of the Electra field, Texas, which is reported by Udden and Phillips as a "high-grade light oil excellently adapted to refinery use."

The recent drilling in the vicinity of Dayton is but one of several attempts to find oil in the Pecos Valley between Roswell, N. Mex., and Fort Stockton, Tex. In this area indications of the presence of petroleum, such as rocks charged with bituminous matter, small oil seeps, and local occurrences of oil in water wells, have long been known. Although the hope of finding petroleum in paying quantity has thus been stimulated, so far experience has been disappointing. Among the prospect wells that have been sunk are some more than 2,000 feet deep in the vicinity of Toyah, Tex., and one almost 3,000 feet deep near Roswell, N. Mex., all of which were failures.

It should be realized that prospecting for oil in Pecos Valley is unusually difficult because of the widespread cover of unconsolidated deposits that conceals the structure of the underlying rocks, which in many fields is a controlling factor in the accumulation of oil. In the Roswell artesian area, however, an important clue to the structure may be obtained from the logs of water wells—in spite of the fact

that logs of variable red beds are usually of little value—because apparently the main flow of water comes from a definite horizon. Study of well logs in this area is facilitated by the systematic records that are required by State law. Apparently this clue has not been utilized.

It should also be realized that petroleum is of widespread distribution and that a considerable accumulation is not necessarily implied by anything thus far known in Pecos Valley. As yet there is no basis for a conclusion one way or the other as to whether a commercially important oil pool exists anywhere in Pecos Valley. It is, nevertheless, most desirable that a thorough test be made in the vicinity of Dayton, where more oil has been found than elsewhere in the valley.