THE FARNHAM ANTICLINE, CARBON COUNTY, UTAH.

By Frank R. Clark.

INTRODUCTION.

The Farnham anticline is a small upfold in the south-central part of Carbon County, Utah. (See fig. 1.) It lies about 10 miles southeast of Price, the county seat, and northeast of Farnham Siding on the Denver & Rio Grande Railroad, from which it takes its name. The Midland Trail, an automobile highway from Pueblo, Colo., to Salt Lake City, passes across the north end of the anticline. (See Pl. I.) This anticline has been mapped by Lupton[1] in connection with a coal examination in Castle Valley, but he did not describe its oil possibilities. These possibilities are set forth in the present paper, the data for which were obtained by the writer.

TOPOGRAPHY.

The Farnham anticline is outlined on the west and north by a ridge of sandstone (Dakota sandstone) within which erosion has considerably dissected the soft shale and sandstone (McElmo formation) that crown the anticline. Outside this sandstone ridge is a second ridge or escarpment (Ferron sandstone member of the Mancos shale), which is separated from the first by a narrow shale valley (Mancos shale). Beyond this outer rim, which nearly surrounds the anticline, the surface is flat for many miles. The highest point within a radius of several miles has an elevation of 5,957 feet and lies in sec. 12, T. 15 S., R. 11 E., near the crest of the anticline. The total relative relief in the Farnham district is 600 feet. The nearest permanent water supply is in Price River at the south end of the anticline, but considerable rain water could be caught by damming small drainage channels within the area covered by the anticline.

STRATIGRAPHY.

SURFACE ROCKS.

The surface strata involved in the Farnham anticline are, from the top downward, the Mancos shale (Cretaceous), which crops out on the flanks; the Dakota sandstone (Cretaceous), which rims the anticline on the north and west; and the McElmo formation (Cretaceous ?), which crops out over the crest of the anticline.

[1] Lupton, C. T., Geology and coal resources of Castle Valley in Carbon, Emery, and Sevier counties, Utah: U. S. Geol. Survey Bull. 628, 1916.

The Mancos shale consists of a homogeneous blue-gray to black shale with one prominent sandstone member (Ferron sandstone) that lies about 650 to 700 feet above the base and forms a vertical cliff which nearly surrounds the anticline.

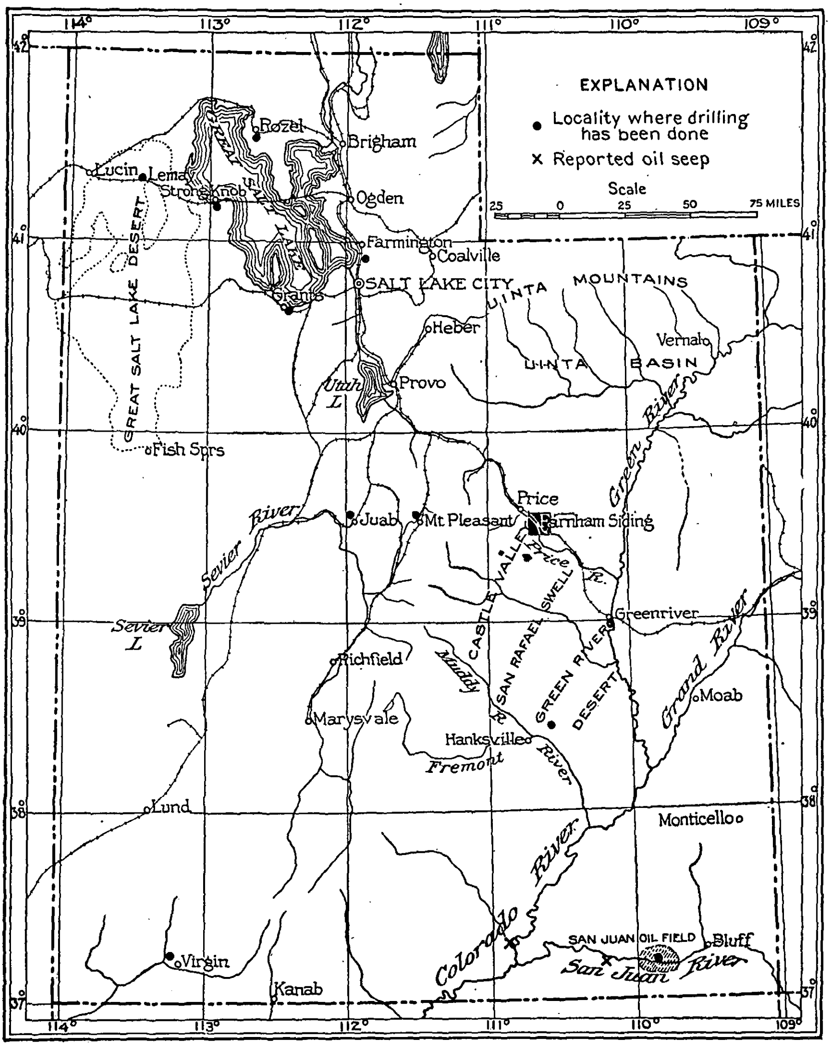
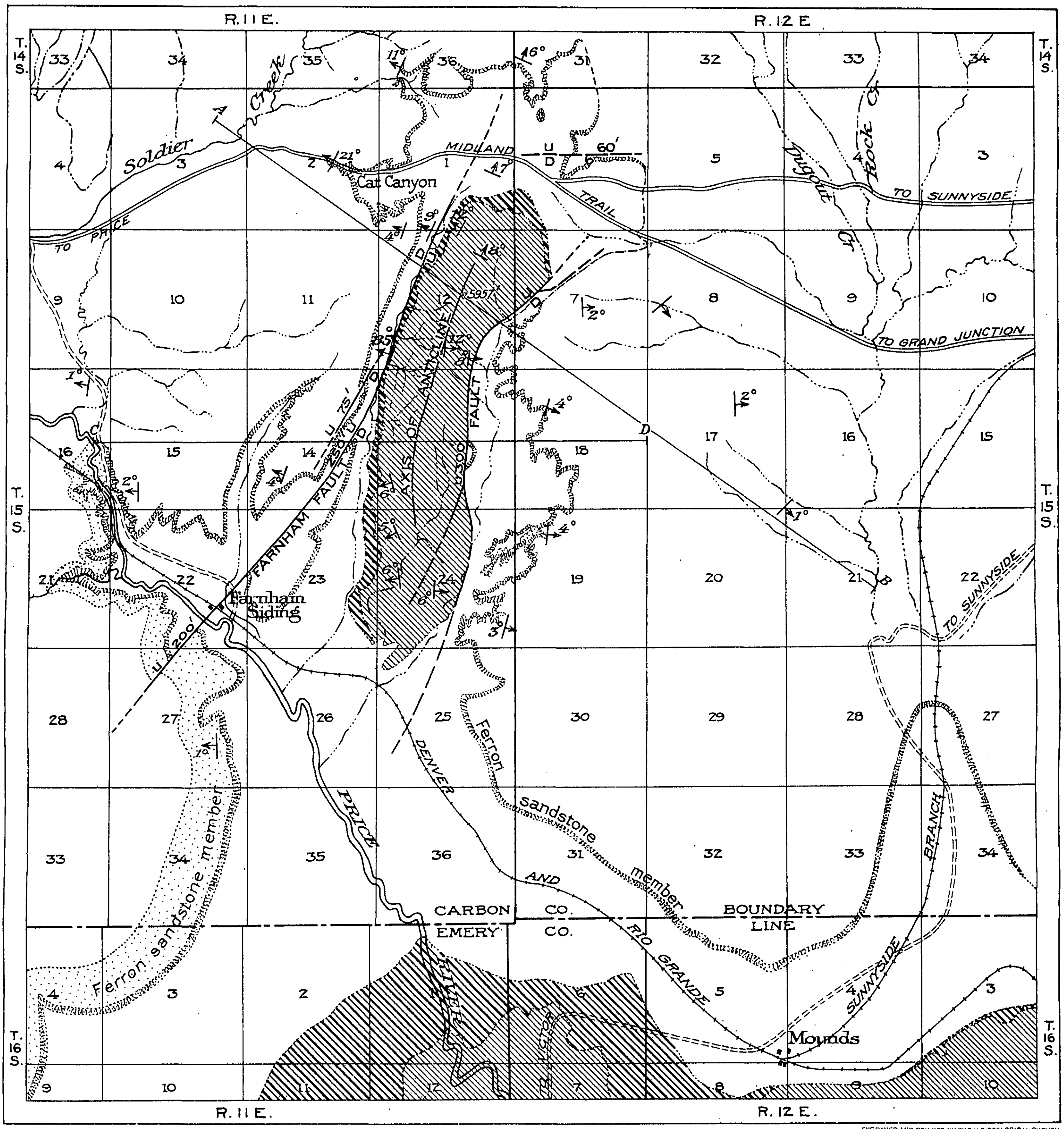
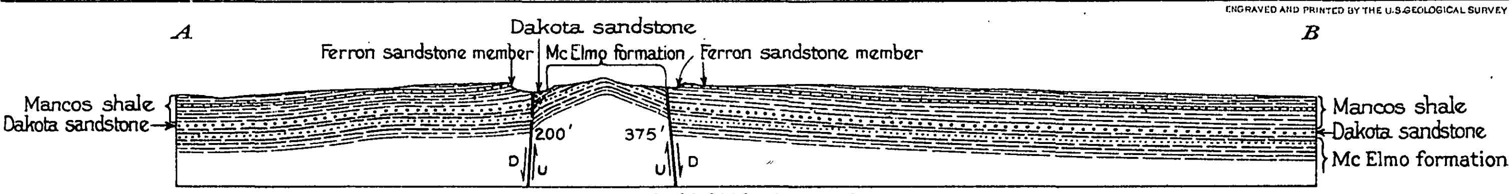


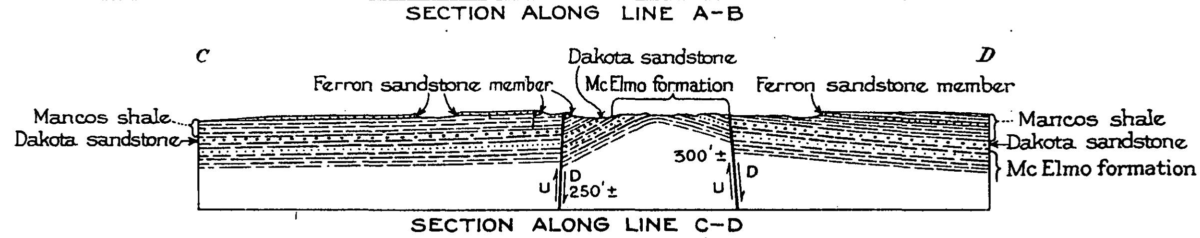
FIGURE 1.—Index map showing location of Farnham anticline and localities that have been prospected for oil and gas in Utah.

The Dakota sandstone is a single bed of hard, dense, gray sandstone, from 5 to 15 feet thick, and in most places extremely conglomeratic.

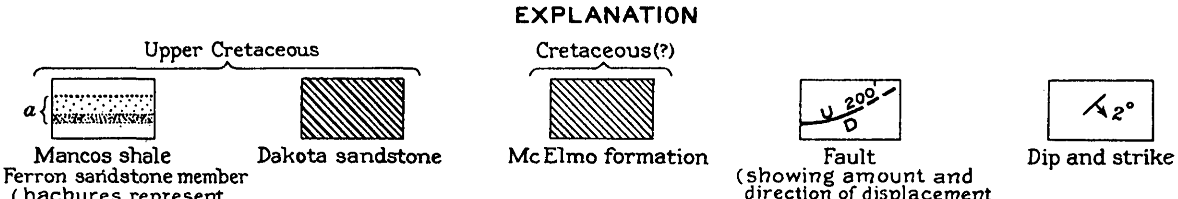
About 400 feet of the top of the McElmo formation is exposed in the Farnham uplift and consists of pink, maroon, and light-green shale, dense sandstone, and conglomerate. The upper portion contains sandstones and conglomerates which are separated by thin beds of shale, and the basal portion contains for the most part variegated shale with some thin bands of calcareous sandstone. (See Pl. II, *A*.)







EXPLANATION



GEOLOGIC MAP OF THE FARNHAM ANTICLINE, CARBON COUNTY, UTAH.

0 1 2 3 MILES

UNEXPOSED ROCKS.

GENERAL FEATURES.

The lowest beds exposed in this area are those in the upper portion of the McElmo formation (Cretaceous ?), but in a comprehensive discussion of the possibilities of oil and gas concentration in the Farnham anticline it is necessary to consider some of the deeper rocks down to the top of the Pennsylvanian (?). Unfortunately the nearest exposures of these rocks that will indicate their nature in the Farnham district are 50 miles away, in the Green River Desert, in Emery and Wayne counties.

A study of the stratigraphic sections in eastern Utah indicates a strong convergence of the strata between the top of the McElmo and the top of the Pennsylvanian toward the Farnham locality. These rocks consist of sandstone, sandy shale, shale, and conglomerate, aggregating from 3,200 to 7,500 feet in thickness. Several of the formations in this series in Wyoming and Utah contain oil seeps or other evidences of petroleum, as shown by the subjoined correlation table. The section of these rocks measured by Emery [1] in the Green River Desert is described below in detail because it is considered to represent conditions at Farnham more nearly than other known sections and to serve as an index of what may be encountered in drilling in this area.

[1] Emery, W. B., The Green River Desert section, Utah: Am. Jour. Sci., 4th ser., vol. 46, pp. 551–577, 1918.

Sections showing occurrence of oil and gas in some of the fields in Wyoming and Utah.[a]

System.	Series.	Virgin River, Utah.[b]	Castle Valley, Utah.[c]	Green River Desert, Utah.[d]	San Juan, Utah.[e]	Northwestern Colorado.[f]	Lander, Wyo.[g]	Central Wyoming.[h]	Douglas, Wyo.[i]
Cretaceous (?).	Lower Cretaceous (?).			McElmo formation. —Unconformity—	[McElmo formation.[j]]	Beckwith.	Morrison.	Morrison (seeps).	Morrison.
Jurassic.	Upper Jurassic.		McElmo.	La Plata group. Navajo sandstone. —Unconformity(?)— Todilto (?) formation. —Unconformity(?)—	La Plata sandstone.	Twin Creek.	Sundance.	Sundance. (seeps).	Sundance.
	(?)	Jurassic.	La Plata. —Unconformity? Vermilion Cliff (seeps).	La Plata group. Wingate sandstone. —Unconformity (?)—		Nugget (seeps).	[Unconformity]	[Unconformity]	[Unconformity]
Triassic.	Upper Triassic.	Triassic.	Triassic.	Chinle formation. —Unconformity (?)—	Dolores shale.	Triassic (?).	Chugwater (red) (oil, seeps).	Chugwater (red)(seeps).	Chugwater (red).
	(?)			Shinarump conglomerate (seeps). —Unconformity— De Chelly sandstone absent.	Moencopie formation. / Oljato sandstone member.				
	Lower Triassic.			Moenkopi formation. —Unconformity (?)—		—Unconformity Lower Triassic.			
Carboniferous.	Permian.	Permian (oil).	Permian.	[?]	[?]	Park City (seeps).	Embar (oil).	Embar (gray and green).	
	Pennsylvanian.	Upper Carboniferous.		Pennsylvanian (?) (seeps)	Goodridge formation (oil, seeps).				Forelle (?). Satanka (?). Casper (seeps).
						Weber and older.		Tensleep (seeps). Amsden.	

[a] This table shows only rocks older than Cretaceous, but in most of the localities represented younger beds were also studied.
[b] Richardson, G. B., Petroleum in southern Utah: U. S. Geol. Survey Bull. 340, p. 343, 1908.
[c] Lupton, C. T., Geology and coal resources of Castle Valley in Carbon, Emory, and Sevier counties, Utah: U. S. Geol. Survey Bull. 628, pp. 20–21, 1916.
[d] Emery, W. B., The Green River Desert section, Utah: Am. Jour. Sci., 4th ser., vol. 46, pp. 551–577, 1918.
[e] Woodruff, E. G., Geology of the San Juan oil field, Utah: U. S. Geol. Survey Bull. 471, p. 76, 1912.
[f] Schultz, A. R., Oil possibilities in and around the Baxter Basin, Rock Springs uplift, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. — (in preparation).
[g] Woodruff, E. G., The Lander oil field, Fremont County, Wyo.: U. S. Geol. Survey Bull. 452, 1911.
[h] Hares, C. J., Anticlines in central Wyoming: U. S. Geol. Survey Bull. 641, pp. 233–279, 1916.
[i] Barnett, V. H., The Douglas oil and gas field, Converse County, Wyo.: U. S. Geol. Survey Bull. 541, pp. 49–88, 1914.
[j] Gregory, H. E., The San Juan oil field, San Juan County, Utah: U. S. Geol. Survey Bull. 431, p. 16, 1911.

CHARACTER IN GREEN RIVER DESERT REGION.

McElmo formation (*Cretaceous?*).—The McElmo formation includes about 750 feet of rocks below the Dakota sandstone and above the Navajo sandstone. It embraces a series of coarse sandstones, conglomerates, and variegated marl-like shale and may be divided into three lithologic units. The upper portion consists of hard sandstone interbedded with small amounts of variegated shale. The middle portion embraces a series of variegated shales with local thin sandstones. The lowest unit is the Salt Wash sandstone member, which consists of coarse sandstone and conglomerate with minor amounts of light shale.

Navajo sandstone (*Jurassic*).—The Navajo sandstone, the highest formation of the La Plata group, includes the rocks between the variegated shale and coarse sandstone and conglomerate of the Salt Wash member of the McElmo and the Todilto (?) formation. In the Green River Desert it has two lithologic units aggregating about 725 feet in thickness. The upper 90 feet is characterized by sandy shale interbedded with dirty gypsum. Below this is a series of thin-bedded sandstone and sandy shale, for the most part brick-red in color, but near the middle there is a conspicuous zone of light-greenish beds. With the greenish beds are associated irregular bunches of quartz which weather into small rounded red balls or lozenges resembling in appearance rubber bath sponges. The lower 300 feet of the Navajo consists of medium-grained massive and much cross-bedded sandstone, held together by calcareous cement.

Todilto (?) formation (*Jurassic*).—The Todilto (?) formation constitutes the middle formation of the La Plata group and comprises a heterogeneous and extremely variable series of shale, sandstone, limestone, and gypsum aggregating from 100 to 300 feet in thickness. Its great variability is the diagnostic character which distinguishes it from the Navajo sandstone above and the Wingate sandstone below.

Wingate sandstone (*Jurassic*).—The Wingate sandstone, the lowest formation in the La Plata group, is the massive cross-bedded sandstone between the Todilto (?) and Chinle formations. It is a remarkably uniform series of extremely massive, very cross-bedded medium to fine grained sandstones, averaging in the Green River Desert about 900 feet in total thickness. The Wingate sandstone may be divided into three parts; the upper and lower parts are more massive and more resistant to weathering than the middle part.

Chinle formation (*Triassic*).—The Chinle formation embraces the 200 to 300 feet of variegated shales and red sandstones between the massive Wingate sandstone and the Shinarump conglomerate. Sandstone predominates in the upper part but gives way to shale below. The sandstone is fine grained, massive, cross-bedded, and of maroon to orange or terra-cotta color. The shale is very argillaceous, rather firmly cemented, hard, friable, and of variegated colors.

Shinarump conglomerate (Triassic).—The Shinarump conglomerate underlies the Chinle formation and unconformably overlies the Moenkopi formation. It is composed of coarse-textured cross-bedded and massive sandstone and conglomerate aggregating 80 to 100 feet in thickness. The conglomerate is of two types, one consisting of waterworn black and brown quartz pebbles, the other of angular yellow and drab limestone and shale pebbles. The Shinarump is in places saturated with petroleum.

Moenkopi formation (Triassic).—The Moenkopi formation includes a series of reddish shales and sandstones aggregating 500 to 600 feet in thickness between the Shinarump conglomerate and the white Pennsylvanian (?) sandstone. It is arenaceous throughout. The upper part consists of alternating red sandstones and shales. About 140 feet above the base near Temple Mountain is a thin layer of very calcareous buff sandstone containing many fossil fragments. The basal 60 to 75 feet consists of white to brownish-buff sandy shale with numerous interbedded thin sandstones of the same color.

Pennsylvanian (?) sandstone.—The Pennsylvanian (?) sandstone was the lowest formation studied by Emery in the Green River Desert, where the upper 50 to 100 feet is exposed. This part consists of gray to white sandstone that is heavily impregnated with oil on the outcrop, and it is probably oil bearing throughout in that region.

COMPARISON WITH GREEN RIVER DESERT AND OTHER SECTIONS.

The rock formations between the McElmo and Pennsylvanian are much thinner in the Green River Desert than in southeastern Utah and northeastern Arizona. The Green River Desert and Castle Valley sections agree closely as to the thickness above the top of the Wingate, but the rocks in Castle Valley referred to by Lupton[1] as the Vermilion Cliff and La Plata sandstones and now known to be equivalent to the Wingate aggregate 400 feet more in thickness. It is possible that Lupton overestimated the thickness of these beds, because his investigation included a detailed study of nothing below the coal-bearing series (Mancos shale). He reports asphaltum seeps about 200 feet below the top of his Vermilion Cliff at a few places.

A reconnaissance study of the strata between the Aspen shale (lower part of Mancos) and the Park City made by Schultz[2] on the flanks of the Uinta Mountains, in northeastern Utah, shows a marked convergence of these beds toward the south and east. The aggregate thickness of these rocks along Duchesne River, near the west end of

[1] Lupton, C. T., Geology and coal resources of Castle Valley in Carbon, Emery, and Sevier counties, Utah: U. S. Geol. Survey Bull. 628, 1916.

[2] Schultz, A. R., personal communication.

the Uinta Mountains, is 7,525 feet, whereas northeast of Vernal, near Little Mountain, they are only about 4,360 feet thick, showing a convergence of over 2,100 feet in a distance of 75 to 80 miles. No information is available as to the thickness of these beds between the Uinta Mountains and Castle Valley and the Green River Desert, but the minimum thickness near the Uinta Mountains is about 1,150 feet greater than the aggregate thickness in the Green River Desert. Schultz reports evidences of petroleum in the Nugget sandstone and in the Park City formation. The above discussion indicates that the Jurassic and Triassic rocks increase in thickness toward the north and south from the Green River Desert, where the minimum thickness may or may not be represented.

STRUCTURE.

GENERAL FEATURES.

The Farnham anticline is a small uplift in a broad, gently northward-dipping monocline which was developed in the movement that produced the San Rafael Swell and Uinta Basin folds. It is about 3 miles long by three-quarters of a mile wide, and has a southward-trending axis through secs. 12, 13, and 24, T. 15 S., R. 11 E. It is purely local, and within a few miles of the crest the rocks resume their normal attitude. The dip of the rocks affected by the anticline rarely exceeds 10° except adjacent to faults, where it ranges from 25° to 85°. (See Pl. I.)

In the vicinity of Cat Canyon, near the center of sec. 2, T. 15 S., R. 11 E., a small northeastward-trending structural terrace roughly paralleling the anticline is suggested. This terrace is indicated in Cat Canyon itself by the comparatively steep dip (21°) of the Ferron sandstone, which flattens to 11° just north of the canyon, in the SW. ¼ sec. 36, T. 14 S., R. 11 E. The terrace probably extends some distance north and south of the canyon, though evidences of it were found only on the north. Toward the east and west the strata flatten to the normal dip of less than 4°.

FAULTS.

Several faults cut the surface strata of the anticline and trend roughly parallel to the axis of the fold. The strike fault east of the axis of the fold (see Pl. I) trends southwest for about 3 miles. Its trace is well defined in secs. 12 and 13, where the variegated McElmo shale abuts against the dark-brown to black Mancos shale. The maximum vertical displacement is 375 feet in sec. 12 and 300 feet in the SE. ¼ sec. 13, and the east block is dropped relative to the west block at each point. The other strike fault (the Farnham), west of the axis of the fold, is of the scissors type, with the hinge or point of zero throw near the southwest corner of sec. 12. It passes through Farnham and trends northeastward for 4 or 5 miles. (See Pl. I.) South of the hinge point the east block has been dropped relative to the west block, and north of that point the west block has been dropped relative to the east block. South of Price River the fault displaces the Ferron sandstone 200 feet,[1] and north of the river, in the eastern part of sec. 14, the Ferron sandstone has been displaced 250 feet. (See Pl. II, *B*.) The shearing action of the fault is suggested in the SW. ¼ sec. 12, where the Dakota sandstone is badly broken and jointed as well as intricately slickensided. North of this point the vertical throw again increases; in the NW. ¼ sec. 12 the displacement is 200 feet, and near the center of sec. 1 it is about 360 feet. The throw rapidly diminishes toward the north, as the Ferron sandstone in sec. 31, T. 14 S., R. 12 E., is not displaced.

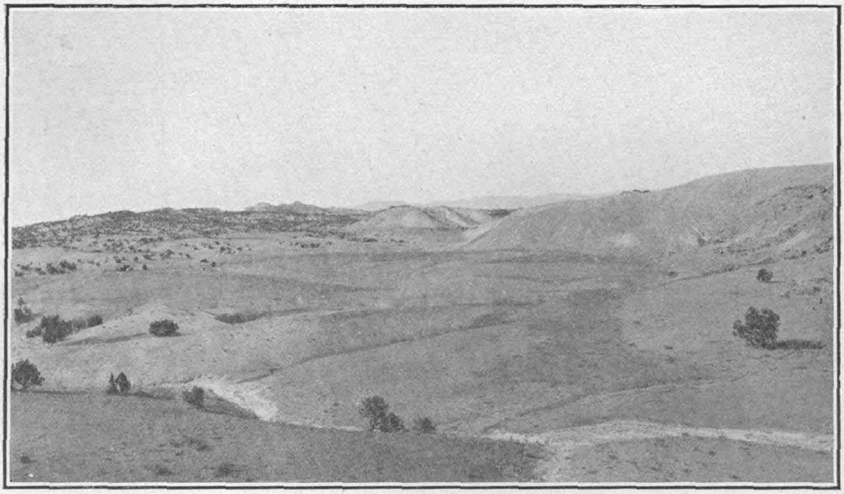
Two small faults or slumps displace the Ferron sandstone in the NE. ¼ sec. 14 and extend for short distances northeastward. The west one shows a maximum displacement of 75 feet, and the east one considerably less, with the downthrown block on the east. These fault traces may join the Farnham fault near its hinge line, or the breaks may be due entirely to slumping. A westward-trending fault displaces the Ferron sandstone near the center of sec. 6, T. 15 S., R. 12 E., where the south block has been dropped 60 feet.

POSSIBLE EFFECT OF FAULTS ON UNEXPOSED ROCKS.

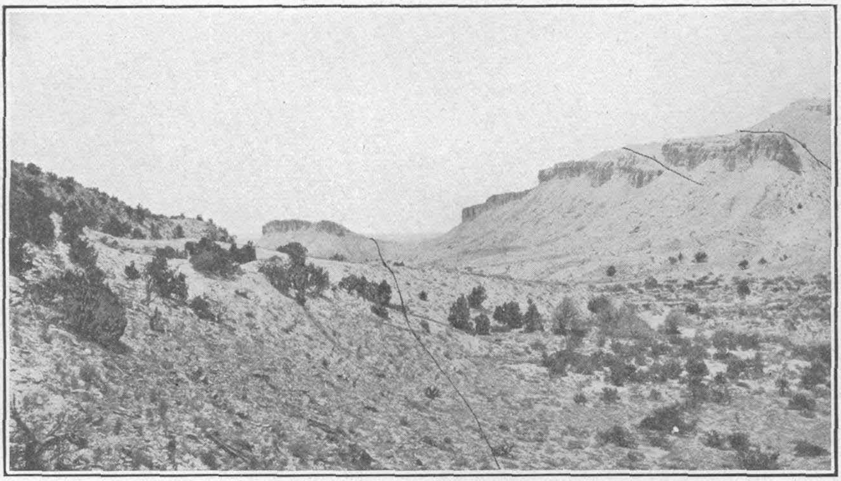
It is impossible to say in advance of drilling what effect the folding and faulting may have had on the attitude of the rocks between the surface and the possible oil and gas bearing strata in the Farnham anticline. The conditions set forth below may be encountered by drilling this fold if the characteristics of the Triassic and Pennsylvanian (?) rocks in the Green River Desert persist northward and if the attitude of the surface rocks continues to a depth of 3,000 to 3,500 feet. In general the most promising location for a test hole on an anticlinal fold is on the crest or near it on the flank that forms the gathering area, but here the normal attitude of the rocks is interrupted by faults that render the location of test holes more uncertain.

A location suggested for a test hole is about 500 feet east of the west quarter corner of sec. 13, T. 15 S., R. 11 E. West of this point the east block of the Farnham fault has been dropped 250 feet—a displacement which, if continuous or accentuated at a depth of 3,300 feet, would offset the top of the Moenkopi formation or the Shinarump conglomerate, both of which are more or less porous, opposite the top of the Pennsylvanian (?) sandstone. If these conditions exist the depth to the possible oil and gas bearing rocks may be reduced by the amount of the displacement of the fault.

[1] The letters on Lupton's Castle Valley map (U. S. Geol. Survey Bull. 628, pl. 12, 1916) indicating the upthrow and downthrow sides are interchanged.



A. STRUCTURE AND CHARACTER OF McELMO FORMATION IN FARNHAM ANTICLINE, CARBON COUNTY, UTAH.



B. FARNHAM FAULT CUTTING FERRON SANDSTONE MEMBER OF MANCOS SHALE AND DAKOTA SANDSTONE.

Another location suggested for a test hole is in the NW. ¼ sec. 12, west of the trace of the Farnham fault and east of the Ferron sandstone escarpment. Here the west block of the Farnham fault has been dropped 200 feet, but any displacement here due to faulting could have had no effect on the depth to the possible oil and gas bearing strata, because the normal succession is uninterrupted. At this point the Pennsylvanian (?) may be expected at a depth of about 3,400 to 3,500 feet. If the surface displacement of the fault is continuous or is accentuated at a depth of 3,500 feet it has probably prevented migration up the dip to the east, and oil or gas might have accumulated on the down-dip (west) side of the fault unless the possible oil-bearing stratum were offset opposite a porous rock east of the fault, so that oil or gas would continue to migrate and would accumulate in or near the crest of the anticline.

OIL AND GAS POSSIBILITIES.

The Farnham anticline is structurally favorable for the accumulation of oil and gas. It is a small uplift in a great northwestward-dipping monocline. The south and east flanks are short compared with the north and west flanks and within a short distance from the crest of the anticline conform to the regional monoclinal dip. If petroleum were present in any of the underlying rocks and were associated with water under pressure it would migrate up the dip. Under such conditions the west and north flanks would afford a good gathering area and oil might be expected to accumulate in the crest of the anticline and on its northwest flank. The Farnham fault, west of the axis of the anticline, may, however, have cut off any migration and petroleum may have accumulated on the west or down-dip side of the fault unless the displacement dies out below the surface or unless the oil and gas bearing stratum is offset and abuts against a higher or lower porous rock on the east side of the fault.

The known occurrences of petroleum in the Rocky Mountain States in rocks older than Cretaceous are few and widely separated. The correlation sections on page 4 show such occurrences in Wyoming and Utah. In Wyoming some wells in the Lander field are producing oil from the base of the Chugwater formation and others from the top of the Embar formation; in central Wyoming oil seeps are reported in the Sundance formation, Chugwater formation, and Tensleep sandstone; and in the Douglas field oil seeps are reported from the top of the Casper formation. In Utah Schultz [1] noted considerable evidence of petroleum in the Nugget sandstone and Park City formation on the south flank of the Uinta Mountains. The Nugget sandstone in many places is highly saturated with asphaltic sub-

[1] Schultz, A. R., personal communication.

stances, and the Park City formation contains cavities filled with asphalt, gilsonite, and related hydrocarbons. In some places the material is soft and waxy, and in others it is hard and brittle. Schultz considers it unlikely that the asphaltic material originated in the Nugget, and states that it may have migrated from the beds beneath, probably the Park City. This suggestion seems improbable, however, because the Nugget and Park City are separated by 1,000 to 1,200 feet of impervious shale.

In southeastern Utah asphaltic saturated sandstones are reported in the Jurassic of Castle Valley;[1] oil is reported in the Permian in the Virgin River field; several sandstones in the Pennsylvanian are oil bearing in the San Juan field; and oil seeps are reported in the Shinarump conglomerate (Triassic) and in the Pennsylvanian (?) in the Green River Desert. The only other known occurrences of petroleum in beds older than Cretaceous in southeastern Utah are several reported oil seeps along Colorado River, probably in rocks of Carboniferous age.

From the above descriptions it seems possible that in eastern Utah the upper Carboniferous and in places the Triassic rocks may yield petroleum in commercial quantities. The Farnham anticline is structurally favorable for the accumulation of oil and gas, and the nearest exposures of Triassic and Pennsylvanian rocks contain oil seeps. These conditions appear to warrant one or more test holes of this fold, though it should be clearly understood that such tests would be purely "wildcatting." Locations for test holes are suggested under the discussion of structure (pp. 8–9).

REVIEW OF OIL AND GAS PROSPECTING IN UTAH.

San Juan field.[2]—Oil occurs in the San Juan field in rocks of upper Pennsylvanian age (Goodridge formation), which contain five reported oil-bearing sands at about the following depths below the top of the Goodridge formation: Baby, 29 feet; Goodridge, 74 feet; Third, 190 feet; Mendenhall, 231 feet; Little Loop, 381 feet. Oil seeps are reported to occur at several localities in the Goodridge formation along San Juan River westward from Goodridge to the boundary of the field. At some places the oil seeps from crevices and at others it saturates the unbroken rock, but the oil impregnation seems to be local and to occur at no definite horizon in the sand. Several wells were drilled no deeper than the Baby sand, but most of them went as far as the Goodridge sand and a few penetrated to a depth of 1,425 feet. Woodruff believes that as all the wells with more than a good showing of oil are in the syncline the area of

[1] Called Vermilion Cliff sandstone and assigned to the Triassic in U. S. Geol. Survey Bull. 628, 1916.

[2] Gregory, H. E., The San Juan oil field, San Juan County, Utah: U. S. Geol. Survey Bull. 431, pp. 11–25, 1911. Woodruff, E. G., Geology of the San Juan oil field, Utah: U. S. Geol. Survey Bull. 471, pp. 16–104, 1912.

basin structure contains most of the oil. In this field during 1916 one dry hole was completed and one well formerly classed as a producer was abandoned. The five other wells in the field reported as capable of producing were closed through lack of marketing facilities.

Green River.[1]—Prospecting for oil near Green River has extended over 20 years, and interest has several times been revived by the increasing demand for petroleum and by the discovery of other oil seeps. Two wells, Levi No. 2 and Collins, have penetrated Lupton's McElmo and entered the underlying La Plata sandstone. The Levi well, in sec. 35, T. 22 S., R. 17 E., was drilled to a depth of 1,500 feet, and the Collins well, in sec. 20, T. 21 S., R. 17 E., to a depth of 2,100 feet. No oil or gas was reported from the Levi well, but gas was reported in the Collins well at 850 feet (in Dakota sandstone) and at 976 feet, gas and salt water at 1,840 feet, and dry gas at 1,980 feet. Rainbow colors on the water accompanied each flow of gas. Most of the other wells in this area were drilled into the McElmo, but a few stopped in the overlying Mancos shale, from which most of the gas was derived.

The results of drilling up to 1912 gave little encouragement for further exploration, because three out of seven wells proved to be dry holes, three encountered traces of oil and small quantities of gas, and one struck "pockets" of gas without oil. The Green River field contains no anticlines or domes favorable for large accumulations of oil or gas.

San Rafael Swell.—Several wells have been drilled for oil or gas southeast of the San Rafael Swell and northeast of Hanksville, near the junction of Fremont and Dirty Devil rivers, in Tps. 26 and 27 S., Rs. 12 and 14 E., in Emery and Wayne counties.[1] A well 600 feet deep was drilled just south of the "Flattops" in sec. 18 or 19 (unsurveyed), T. 26 S., R. 13 E., which possibly passed through Lupton's McElmo formation and penetrated about 35 or 40 feet into the La Plata sandstone but found no oil or gas. The Des Moines Oil Co.'s well near the center of sec. 29, T. 26 S., R. 14 E., had in November, 1912, been sunk to a depth of 2,140 feet but did not obtain oil or gas. It is estimated that the upper 600 feet of this well was in the Navajo and Todilto; from 600 feet to 1,325 feet the drill penetrated the Wingate. Fresh water was encountered at several horizons from 310 feet down. The Mount Vernon Oil Co.'s well, 10 or 12 miles southwest of the Des Moines well, in the NE. ¼ sec. 9, T. 27 S., R. 12 E., probably started in the Navajo and penetrated to a depth of 2,715 feet. Oil is reported to have been found in this well at 2,175, 2,530, and 2,655 feet below the surface, all of which may be in the Pennsylvanian (?), but it is possible that the first show of oil, at

[1] Lupton, C. T., Oil and gas near Green River, Grand County, Utah: U. S. Geol. Survey Bull. 541, pp. 115–133, 1914.

2,175 feet, was in younger rocks. These wells, according to Lupton, are near 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 on the east.

Southwestern Utah.—The rocks exposed in the Virgin River field [1] range in age from Carboniferous to Eocene and so far as known contain oil only in the lower red beds, of probable Permian age. Oil seeps near Virgin, on Virgin River in Washington County, southwestern Utah, have probably been known for many years, but no prospecting by drilling was undertaken there until recently. The first well, in the flood plain of North Creek about 2 miles north of Virgin, was drilled in the summer of 1907 to a depth of 610 feet and struck oil in the Permian (?) rocks at 556 feet. This well yielded oil at the rate of 10 barrels a day and stimulated the drilling of six other wells, none of which produced oil in paying quantities, but it is reported that some oil was found in all the wells. Interest in the Virgin River field has again been revived, but, although some drilling is reported, at the date of writing (September, 1918) there had been no commercial production. The oil has a specific gravity of 0.9225 (22° Baumé), contains some paraffin and a large percentage of asphalt, and is essentially a fuel oil. Richardson believes that the source of the oil is in the underlying Carboniferous limestone, that the oil-bearing rocks occur as lenses rather than as persistent beds, and that oil accumulated in this field only in lenticular beds and not in folds, because the rocks are flat-lying.

Great Salt Lake and Sevier Lake basins.—At many places in the Great Salt Lake and Sevier Lake basins considerable drilling for oil and gas has been done, but, so far as the writer knows, oil has not been encountered in commercial quantities.

Juab Valley.—Several holes have been drilled in Juab Valley, near Juab, in Juab County, but no production of oil has been reported. The rocks exposed in the valley are probably Lake Bonneville beds. Rocks of Eocene age dip westward from Gunnison Plateau beneath the valley floor, but the writer has no knowledge of the local structure of the rocks in the vicinity of the wells.

San Pete Valley.—A hole was drilled in the north end of San Pete Valley near Mount Pleasant, but no information is available regarding the results. The beds that crop out on both sides of the valley are Tertiary.

Shores of Great Salt Lake.—More or less interest and some excitement has for many years attended the drilling for oil and gas along the shores of Great Salt Lake. Oil has not been encountered in paying quantities, but considerable gas was produced by wells about

[1] Richardson, G. B., Petroleum in southern Utah: U. S. Geol. Survey Bull. 340, p. 343, 1908.

12 miles north of Salt Lake City.[1] This drilling has probably been stimulated at various times by the gas bubbling from hot-water springs, by reports regarding "showings" of oil in water wells and springs, and by the occurrence of solid asphalt deposits such as those south of Rozel Hills,[2] on the west side of the Promontory Range, on the north shore of the lake. A well was drilled to a depth of 2,480 feet near the Southern Pacific Railroad track at Lemay, about 80 miles west of Ogden, but found no oil or gas. The drill penetrated, according to reports, 850 feet of clay carrying gypsum, fossiliferous limestone, and brown sandstone. Another well along the same railroad was drilled to a depth of 800 feet at Strong Knob, at the north end of the Lakeside Mountains, about 52 miles west of Ogden, and obtained some gas but no oil. Several shallow wells were drilled south of the Rozel Hills, on the west side of the Promontory Range, to test the extent of asphalt beds, but no wells deep enough to test the oil or gas possibilities of this region are reported. A well about 1 mile southwest of Farmington was drilled to a depth of 2,000 feet in unconsolidated lake beds but found no oil or gas. It is reported that another well is now (September, 1918) being drilled near the site of the old well, but no information is available regarding the results. Several wells drilled a few miles south of Farmington and about 12 miles north of Salt Lake City produced considerable gas.[1] The deepest well was 1,400 feet deep but did not pass through the unconsolidated lake beds. The gas in most of the wells came from depths of 500 to 700 feet below the surface and was piped to Salt Lake City, where it was used for about 19 months, until the wells failed to yield sufficient gas to pay the costs of operation. A deep well has been drilled on the south shore of the lake near Grants station, on the Western Pacific Railroad, and in April, 1916, oil was reported to have been encountered at a depth of 1,900 feet. Many shallow wells have been drilled for water on the east and south sides of the lake, but so far as known these wells have found no oil or gas. Drilling in the Lake Bonneville beds for oil or gas is attended with great uncertainties and is purely wildcatting, because the nature and thickness of the lake beds and the underlying bedrock are not known.

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[1] Richardson, G. B., Natural gas near Salt Lake City, Utah: U. S. Geol. Survey Bull. 260, pp. 480–483, 1905.

[2] Boutwell, J. M., Oil and asphalt prospects in Salt Lake basin, Utah: U. S. Geol. Survey Bull. 260, pp. 468–479, 1905.