This report is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

CONTENTS

ILLUSTRATIONS
(in pocket)

GEOLOGY AND OIL-SHALE RESOURCES OF THE EASTERN PART OF THE PICEANCE CREEK BASIN, RIO BLANCO AND GARFIELD COUNTIES, COLORADO

By D. C. Duncan and Carl Bolser

The Green River formation of Eocene age, which extends over wide areas in western Colorado, northern Utah, and southern Wyoming, contains a thick sequence of marlstone and shale, rich in organic matter. These rocks yield oil by destructive distillation. The Piceance Creek Basin in western Colorado contains the richest and thickest oil shales known in the formation. The oil shales crop out in prominent cliffs around the margins of the basin and underlie the basin in most places under less than 1500 feet of overburden. The deposits have been of interest as a possible source of oil since about 1910, and many published reports (Winchester, 1923) describe the oil shales along the margins of the Basin.

In the Piceance Creek dome, which lies in the northeastern part of the basin (see accompanying maps), several gas test wells have penetrated the complete sequence of oil shale in the Green River formation. This report shows the character and relationship of the oil shales in four of these subsurface sections and in a surface section on the east side of the basin near Rio Blanco.

One split of the samples from the wells obtained by Carl Bolser of the U. S. Bureau of Mines was tested for oil yield at the

STRATIGRAPHY

Rocks of early Tertiary age assigned to the Wasatch and Green River formations are exposed along the margins of the Piceance Creek Basin and overlie a thick sequence of Mesozoic and Paleozoic sedimentary rocks.

Wasatch formation

The Wasatch formation consists of alternating varicolored shale, mudstone, and lenticular sandstone. It ranges from about 3400 to 5200 feet in thickness in measured surface sections around the Piceance Creek Basin and crops out as red and tan slopes below the prominent Roan Cliffs of the Green River formation. The Wasatch formation, as identified in most reports on the area, includes beds of Lower Eocene age. The top of the Wasatch formation was selected for present purposes at the top of the highest red or varicolored shale observed in the section.

Green River formation

In the central part of the Piceance Creek Basin the Green River formation consists mainly of lake deposits of shale and marlstone but includes a basal sandstone member and, at the top, a sequence of marlstone, siltstone, and tuffaceous sandstones. In the Piceance Creek dome the formation totals about 3500 feet in thickness. It conformably overlies the Wasatch formation, and in places the basal sandstones of the

Green River formation interfinger with the redbeds of the Wasatch formation.

The Green River formation has been divided into four members (Bradley, 1931, pp. 9 – 14). These are the basal Douglas Creek member, a sandstone and shale unit; the Garden Gulch member, a slope-forming dark shale and marlstone unit; the Parachute Creek member, a cliff-forming marlstone and oil-shale unit; and at the top the Evacuation Creek member, a tuffaceous siltstone, sandstone, and marlstone unit. These lithologic units are well defined along Parachute Creek Canyon south of this area and can be recognized in the drill sections. The subdivisions are indicated in the accompanying columnar sections. Along the east side of the basin the lower part of the Green River is composed of a near-shore facies of alternating sandstone and shale designated the lower sandy member. This unit interfingers laterally with the Douglas Creek, Garden Gulch, and lower part of Parachute Creek members.

Lower sandy member.—Beds equivalent to the Douglas Creek, Garden Gulch, and lower part of the Parachute Creek members but consisting mostly of a shore facies of sandstone and sandy shale with small amounts of marlstone are exposed along the east side of the Piceance Creek Basin. They have been mapped as the lower sandy member (Duncan and Denson, 1949) in the adjoining area south, and equivalent beds about 1100 feet thick in the Gray Hills to the north have been identified as a shore facies of the Green River formation (Bradley, 1931, p. 14).

Along upper Piceance Creek near Rio Blanco the lower sandy member is about 1875 feet thick. It is exposed in discontinuous slopes and cliffs and contains gray and tan sandstone, sandy shale, and toward the top some barren gray marlstone. The unit contains many oolitic, calcareous sandstone beds some of which contain ostracods. The sandstone beds interfinger westward with marlstone and shale. The change from predominantly sandy nonorganic sediments to shaly organic sediments takes place in an east-west distance of less than 6 miles between outcrop and drill holes (see cross section A-A'). Along the Petrolite Hills northwest of Rio Blanco some sandstones of the lower sandy member are locally saturated with asphalt.

Douglas Creek member.—The Douglas Creek member is the basal part of the Green River formation. It ranges in thickness from about 430 feet to 760 feet in surface sections to the south along Parachute Creek (Duncan and Denson, 1949, sheet 1). In the drill holes on the Piceance Creek dome only the basal 70 to 230 feet of the Green River formation is assignable to the Douglas Creek member. This thin unit, however, is the important gas-bearing zone. It consists of alternating beds of sandstone, dark gray shale, sandy shale, and some gray marlstone. The unit locally contains abundant ostracods, and some of the sandstones are oolitic. Although the gas from the several capped wells of the field is dry, cores of some thin sandstone beds are oil stained.

Garden Gulch member.—Overlying the Douglas Creek member is a series of dark gray, brown, and black shales and marlstone assigned to

the Garden Gulch member. In surface sections along Parachute Creek the unit ranges from 630 to 720 feet in thickness (Duncan and Denson, 1949). Slacking dark gray, brown, and black shale of similar type with small amounts of marlstone comprise most of the cuttings in the lower part of the Green River formation from the wells in the Piceance Creek dome. There the unit ranges from 400 to 1020 feet in thickness. The electric logs show a relatively low resistivity for beds of this zone, as compared with high resistivity of beds in the overlying Parachute Creek member, perhaps mostly due to a low carbonate content of sediments in the Garden Gulch member. In the Piceance Creek dome shales of the Garden Gulch member contain organic matter in quantity sufficient to yield more than 15 gallons of oil per ton over thick stratigraphic intervals. The content of organic matter in this member is considerably more than has been recognized in surface sections.

Parachute Creek member.—The Parachute Creek member is composed mainly of organic marlstone but contains a smaller amount of organic shale and many thin persistent beds of altered tuff. It ranges from about 400 to 1250 feet in thickness in surface sections, where the unit contains most of the important oil-shale zones of the Green River formation. In outcrops along the south and west sides of the basin the member is resistant to weathering and forms the prominent Roan Cliffs; but along the north and east sides where the beds are more steeply tilted the member forms high hills. As recognized in the drill section, the member

ranges from 1155 to 1680 feet in thickness and is characterized by gray, brown, and black marlstone with a small amount of tuffaceous sandstone. Most cuttings are dolomitic. The electric logs reflect the highly dolomitic character of the marlstone and suggest a correlation with the organic content of the marlstone. Notably the greatest resistivity is in the zone of the Mahogany ledge, which contains the beds with the highest oil yield. This rich oil shale zone is identified in the outcrop and well cuttings by the distinctive reddish brown or "mahogany" color of some of the rich oil shale beds included in it. The zone includes a distinctive sandy textured analcitized tuff bed about ½ foot thick, known as the Mahogany marker, which is used as the standard reference bed in detailed correlations of the oil shales of the Mahogany ledge. Although the Mahogany marker could not be identified in well cuttings its approximate position in section is indicated for purposes of correlation, on the accompanying columnar sections. The organic content of the Parachute Creek member is comparable to that of the surface sections southward near Parachute Creek, but the analyses of the drill cuttings do not reflect details of high and low oil yield of thin beds.

Evacuation Creek member.—The Evacuation Creek member forms the upper part of the Green River formation and contains alternating brown weathering siltstone, sandstone, and gray marlstone. This sequence of beds contains mostly siltstone and marlstone near the base but grades

upward to predominantly sandstone and minor marlstone. In some maps and reports (Bradley, 1931, p. 19; Kramer, 1945) the upper part of the sequence in the central part of the basin has been tentatively assigned to the Bridger formation. These upper beds are equivalent, however, to the upper part of the Evacuation Creek member as identified near Parachute Creek. As no convenient horizon in the section was found at which to subdivide the upper part of the sequence penetrated by drilling it is included in the Evacuation Creek member of the Green River formation as identified in this report. The member is about 1000 feet thick as recognized in well cuttings and surface sections.

STRUCTURAL FEATURES

The Piceance Creek Basin includes a central area of gently dipping beds flanked on the east by steeply dipping rocks along the Grand Hogback monocline and on the west by the more gently dipping rocks on the east flank of the Douglas Creek anticline. Several gentle folds trend northwestward across the basin. Paralleling the crests of some folds are zones of nearly vertical faults. The Piceance Creek dome is one of the folds within the basin, and it is cut by a fault zone along which the throw is down to the south. It is believed that the structural development of the Piceance Creek Basin started in Eocene time during accumulation of the Green River formation—near-shore sediments accumulating at the east side of the basin while

the shales rich in organic matter accumulated only a few miles to the west. In general the zones of equal richness of the oil shale parallel the Grand Hogback. The steep tilting of beds on the east side of the basin occurred after deposition of the Green River formation. The smaller northwest-trending folds, such as the Piceance Creek dome, and associated faults were developed also after deposition of the oil shales of the Green River formation. Some movement may have occurred, however, during deposition of the Evacuation Creek member, as local unconformities are recorded in it or in equivalent beds at several places (Bradley, 1931, pp. 19, 20). One such unconformity may be seen along Piceance Creek about 2 miles west of its junction with Fourteen Mile Creek along the south flank of the Piceance Creek dome.

The approximate trend of the trough of the Piceance Creek Basin is N. 20° W., as shown on the left part of the accompanying map. Perhaps the basin trough was in about the same position during deposition of the oil shales. The smaller northwest-trending folds complicate the position of the actual trough line, however, and the line as shown on the map is generalized.

CHARACTERISTICS OF THE OIL-YIELDING ROCKS

Rocks in the Piceance Creek Basin that yield oil include organic marlstone, organic shale, thin layers of altered tuff in the oil shale, beds of asphalt-saturated sandstone, and small amounts of asphaltlike hydrocarbons along the fault and joint planes. Most of the organic matter is in

the shale and marlstone and is in a solid form as kerogen, which converts to heavy oil with destructive distillation. Perhaps the free asphalt or heavy oil of the sandstone and altered-tuff beds was derived from the oil shale.

Inorganic constituents of most of the oil shale are mainly microcrystalline calcium and magnesium carbonate minerals and clay. Such rock is technically marlstone; but some oil shale, particularly in the lower part of the Green River formation, contains little or no carbonate. Such shale is less resistant to weathering and deteriorates on exposure to air. Samples of some of these lower oil-shale beds have a high oil yield.

Analyzed samples of the well cuttings show oil yields ranging from a mere trace to 37 gallons of oil per ton. The specific gravity of the oil shale and the number of cubic feet of oil shale per ton are approximately as follows for selected grades:

Oil yield (gallons per ton)	Specific gravity	Cubic feet per ton
30	2.16	14.8
25		14.3
20	2.32	13.8
15		13.2
10	2.54±	12.6

RESERVES

Oil reserves of the Mahogany ledge, which yields 25 to 30 gallons per ton over an area of approximately 1000 square miles in the

Piceance Creek Basin, have been estimated to total roughly 100 billion barrels (Bolser, 1948, p. 10). The portion of the Mahogany ledge that yields 25 gallons or more per ton is perhaps the only oil-shale zone of present economic interest. A wide range in thickness of the Mahogany ledge in near-outcrop sections was observed south of the map area (Duncan and Denson, 1949). There several core drill holes and surface sections through the zone show a minimum of 11 feet of rich oil shale at the east edge of the Roan Cliffs and as much as 135 feet of rich oil shale along Parachute Creek. Thicker zones with lower oil yield may become of interest if other methods of oil extraction are developed. Reserve data of accompanying table 1 were prepared, therefore, to show the relative amounts of oil available from zones more than 15 feet thick with selected oil yields averaging a)#30 gallons per ton, b)#25 gallons per ton, c)#20 gallons per ton, d)15 gallons per ton, and e) average yield of the entire oil-shale sequence. The average yields were obtained by calculating the maximum continuous sequence of beds that would yield 30, 25, etc., gallons per ton. Some units thus selected include intervals that yield less than the average.

Only the Mahogany ledge contains uniformly rich oil shale across the Piceance Creek dome. Each sampled well penetrated zones 20 feet or more thick that yield about 30 gallons of oil per ton. (See table 1 and cross section A-A'.) In the surface section near Rio Blanco, however, only 10 feet of the unit is estimated to yield 30 gallons or more per ton. The zone lies at depths of about 1200 to 1700 feet below

surface in the Piceance Creek dome. Well 66-5-G, nearest the basin trough, penetrated a lower zone 30 feet thick yielding 30 gallons per ton at a depth of 2200 feet.

By selecting the maximum thickness of beds averaging 25 gallons of oil per ton in the Mahogany ledge, the zone ranges in thickness from 70 to 160 feet in sections penetrated by the drill holes. The zone thins eastward, however, and only about 25 feet of the Mahogany ledge in the surface section near Rio Blanco is estimated to yield 25 gallons of oil per ton.

Surprisingly, a zone 480 feet thick penetrated in Well 66-5-G, at a depth of 2160 to 2640 feet in the lower part of the Green River formation, also yields an average of 25 gallons of oil per ton. This unit is lower stratigraphically than any rich oil-shale units recognized at the surface in other parts of the Piceance Creek Basin. Equivalent beds penetrated by the other test wells do not show the same high oil yield. If this lower zone carried the high oil yield westward to the basin trough, however, an enormous potential oil resource, on the order of 870,000 barrels per acre, could be expected to underlie an area of many square miles in the central part of the basin.

If a lower cutoff point is selected at which oil yield averages 20 gallons per ton, considerably thicker zones of oil shale are included in the sections in Piceance Creek dome. In Well 66-5-G, about 1950 feet of the section, almost the entire oil-shale sequence has an average yield

of 20 gallons of oil per ton; but the wells farther east show decreasing amounts of oil shale of the same quality. Only about 40 feet of beds in the surface section near Rio Blanco is estimated to yield an average of 20 gallons of oil per ton. The well data show a still greater increase in total potential oil yield if an average yield of 15 gallons per ton is selected.

Zones of equal richness and thickness of the oil shale along the east side of the Piceance Creek Basin trend roughly northward parallel to the Grand Hogback. No attempt is made in this report to prepare reserve estimates for this area, as more complete data are required along the north side of the basin before accurate trends of zones of equal richness and thickness can be determined.

GAS FIELD DEVELOPMENT

Of seven wells drilled for gas in the Piceance Creek dome, six wells were completed, and these had initial open-flow tests up to about 10,000,000 cubic feet of gas per day. One well, 24-12-C, was abandoned although initial tests yielded a small flow of gas. The wells are shut in, but the field has been under consideration as a local source of gas to supply nearby towns and industries. Casing-head pressures of most wells in the field are about 800 pounds per square inch.

The gas-producing zone is a sequence of alternating sandstone, shale, and sandy shale ranging in overall thickness from about 12 feet to about 230 feet. The principal productive horizon is a sandstone unit in the lower part of the Douglas Creek member.

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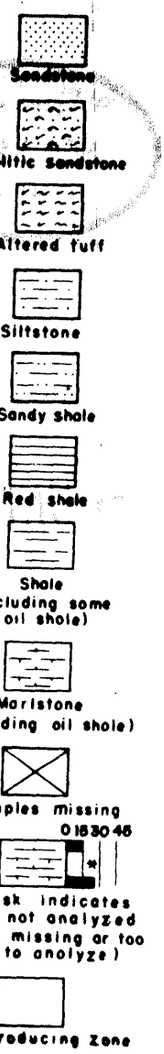
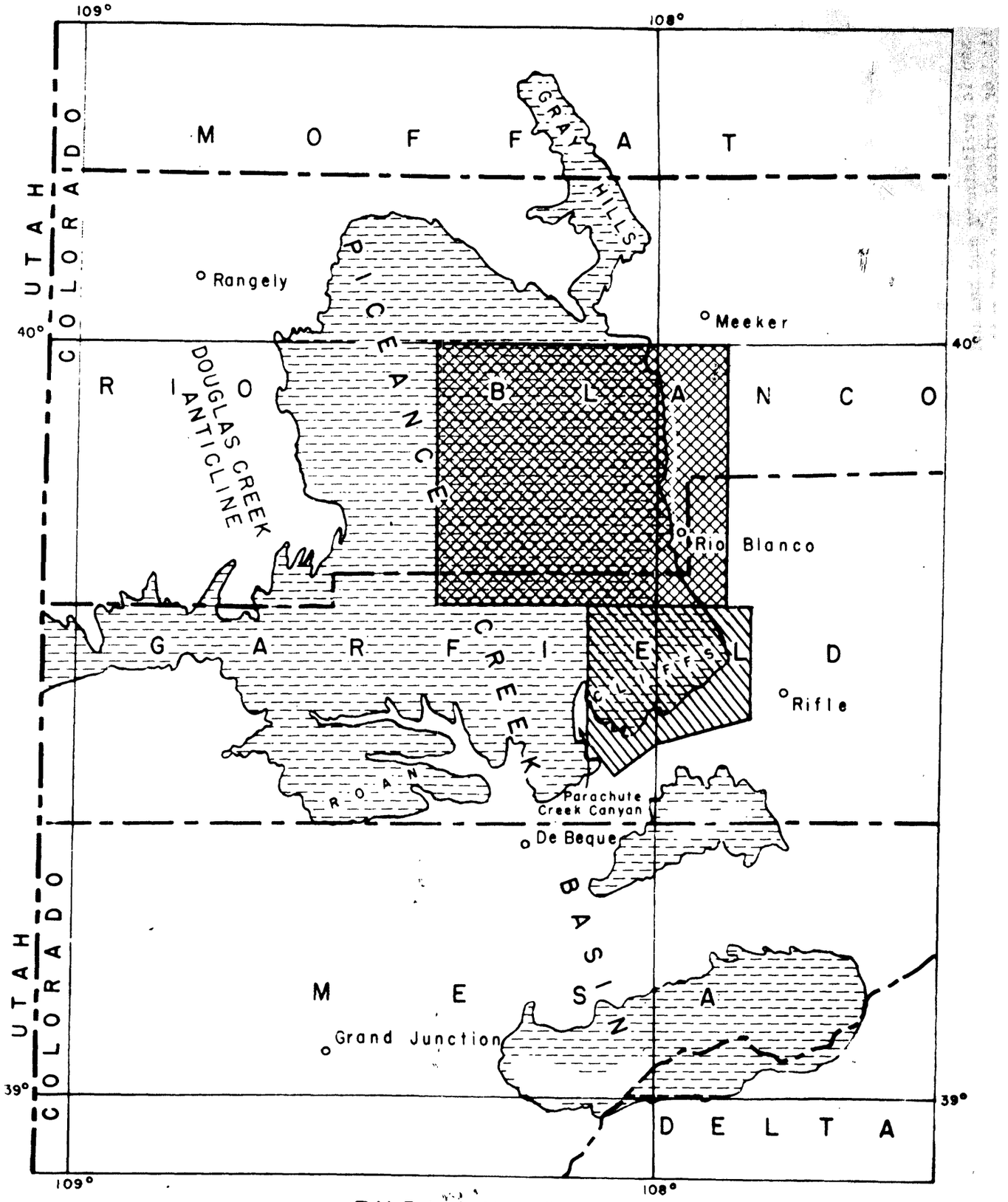
Table 2. Wells drilled for natural gas in the Piceance Creek dome, Rio Blanco County, Colorado

Operator and well name or number	Location	Year completed	Total depth (feet)	Collar elevation (feet)	Top of Parachute Creek member (feet)	Top of Douglas Creek member (feet)	Top of Wasatch formation (feet)
Magnolia Petroleum Co. Fordham No. 1	SWSW sec. 9, T. 2 S., R. 96 W.	1930	5130	7298	?	2655	2885
Magnolia Petroleum Co. Titley No. 1	NWNWSW sec. 15, T. 2 S., R. 96 W.	1932	2988?	7498	750±?	2814?	2978?
Magnolia Petroleum Co. Maddock No. 1	NWNWSE sec. 9, T. 2 S., R. 96 W.	1932	2958	7472	830±	2900?	2958?
General Petroleum Corp. 84-15-G	SESENE sec. 15, T. 2 S., R. 96 W.	1946	12,019	7617	890	3045	3127
General Petroleum Corp. 28-19-G	SESWSW sec. 19, T. 2 S., R. 95 W.	1947	3490	7816	1170	3345	3457
General Petroleum Corp. 24-12-G	SESWNW sec. 12, T. 2 S., R. 96 W.	1947	3700	7779	1223	3514	3681
General Petroleum Corp. 66-5-G	SENWSE sec. 5, T. 2 S., R. 96 W.	1947	3100	7440	910	2990	3057

EXPLANATION OF COLUMNAR SECTIONS





EXPLANATION

Area underlain by Green River formation

Area of this report

Area of Oil & Gas Inv. Preliminary Map 94

0 10 20 30 40 MILES

INDEX MAP