OIL SHALE OF THE UINTA BASIN, NORTHEASTERN UTAH.

By Dean E. Winchester.

INTRODUCTION.

The oil shale in northeastern Utah was examined at three or four widely separated localities in 1913 with rather discouraging results.[1] Two years later the study was begun in more detail by the writer near Watson,[2] and in view of the encouraging findings of this work a party under the direction of the writer during the field season of 1916 studied the zone of oil shale along the south side of the Uinta Basin from Watson west to Soldier Summit. This work included rough mapping of the outcrop of the rich shale zone, together with the testing of numerous samples to determine the approximate value of the shale as a future source of shale oil. In so far as they apply to that part of the Uinta Basin lying in Utah, data obtained during the previous investigations are repeated here so that the basin may be studied as a unit. The writer was assisted in the field by W. B. Wilson and John N. Massey, each of whom had participated in the work of 1915. The apparatus described in detail in Bulletin 641 was used to make the field distillations of the shale.

The reconnaissance studies of the Uinta Basin have proved the existence along its entire southern margin of a bed or beds of oil shale of minable thickness and as rich as or richer than those mined in Scotland at the present time. Previous examinations by members of the Geological Survey have revealed the fact that at practically all points along the north side of the basin, the Green River formation (containing the oil shale) is concealed beneath younger rocks which overlie the oil-shale beds unconformably, so that the area within the Uinta Basin underlain by oil shale can not be determined without extensive prospecting with the drill. However, evidence at hand seems to indicate that the oil shale may be present beneath a great part of the basin, and it is estimated that

[1] Woodruff, E. G., and Day, D. T., Oil shale of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 581, pp. 1-20, 1914.

[2] Winchester, D. E., Oil shale in northwestern Colorado and adjacent areas: U. S. Geol. Survey Bull. 641, pp. 139-198, 1916.

the Utah portion of the basin alone contains sufficient shale to produce 42,800,000,000 barrels of crude shale oil, with perhaps 500,000,000 tons of ammonium sulphate as a by-product.

GEOGRAPHY.

The Uinta Basin is a topographic as well as a structural basin, bounded on the north by the Uinta Mountain uplift, on the south by the southward-facing Roan Cliffs, on the west by the Wasatch Mountains, and on the east by the Rangely dome and related structural features in northwestern Colorado. The oil shales of the Green River formation are exposed along the south side of the basin but are covered by younger rocks along the north side. The map (Pl. XII, in pocket) shows only an area 40 miles wide and 125 miles long on the south side of the Uinta Basin where it was possible to study the shales.

The area examined is one of extensive northward-sloping plateaus cut by many vertical-walled canyons. (See structure section on map, Pl. XII.) The Roan Cliffs, along the southern margin of the basin, south of the outcrop of the oil shale, attain at many places altitudes of more than 9,000 feet above sea level, whereas the valley of Green River, which crosses the area from north to south, is less than 5,000 feet above sea level, the maximum topographic relief of the basin thus being at least 4,000 feet. Green River, which rises far to the north in Wyoming, flows southward, crossing the area examined about 45 miles west of the east line of the State, and is joined near Ouray by White and Duchesne rivers. East of Green River the streams draining the area north of the Roan Cliffs flow northward, joining either White River or Green River; west of Green River most of the canyons lead directly to Green River in a general easterly direction. Willow, Hill, Bitter, and Evacuation creeks occupy narrow canyons in Uinta County east of Green River, and each contains water along its entire course, except Bitter Creek, which is usually dry below the mouth of Sweetwater Creek. South of Ninemile Creek Green River enters Desolation Canyon (see Pl. VI, *A*, p. 31) and flows in a general southward direction between nearly vertical walls which increase in height toward the south, so that in the region of the Roan Cliffs they rise 3,000 feet above the river.

The main line of the Denver & Rio Grande Railroad skirts the Roan Cliffs on the south, and although it is only a short distance from the limit of the oil-shale beds the railroad is accessible only by roundabout routes except in the western part of the field, where the shale crops out in the highlands near the track. The main line of the railroad comes within the area shown on the map west of Colton, but a branch line runs to Sunnyside, in T. 14 S., R. 14 E., and the north end of the Uintah Railway, which connects with the Denver & Rio Grande Railroad at Mack, Colo., is at Watson, near the Colorado-Utah State line.

Wagon roads are nearly as scarce as railroads. A toll road is maintained between Watson, on the Uintah Railway, and Ouray and Vernal, in the interior of the basin, and there are two other well-kept roads connecting the interior of the basin with the Denver & Rio Grande Railroad, to the south. The one from Myton south to the head of Gate Canyon and up Ninemile Canyon to Whitmore Park and thence down Soldier Creek to Price is the older but is at present less used than the road from Duchesne southwestward up Indian Canyon and then down Willow Creek to Helper. Both routes are used by auto stages, but in 1916 the contract for carrying mail to the basin towns was in the hands of the company using the Duchesne and Helper route. During part of the year considerable travel from the interior of the basin goes westward past Strawberry Valley to Salt Lake City. However, snow prevents the use of this route in the winter season.

Except along these three principal roads the trail made by one vehicle is usually almost obliterated by wind and weather before another has cause to follow. The few ranchers who live in the valleys of Hill and Willow creeks get mail twice a week from Ouray by special messenger, usually on horseback, although there is a passable wagon road down each of these streams.

Sheep and cattle raising is the principal industry of the region, although there are small farms along the valleys of Ninemile, Argyle, Willow, and Hill creeks and also along White River near Soldier Summit. North of the area shown on the map, in the interior of the Uinta Basin, is some of the richest agricultural land of the State. The mining of gilsonite and elaterite near Watson, Fort Duchesne, Myton, and Duchesne provides employment for a considerable force of miners, and the coal mines at Sunnyside, Castlegate, and Kenilworth are points of great activity.

GEOLOGY.

PRINCIPAL FEATURES.

The field work on which the present report is based provided no opportunity for careful study of rocks other than those associated directly with the oil shale, but it was possible to make some observations of geologic phenomena in the adjacent rocks which appear worthy of record.

The Tertiary rocks that occupy the interior of the Uinta Basin have been subdivided into four formations—the Wasatch, Green River, Bridger, and Uinta—the division being based on stratigraphic and paleontologic evidence. The Wasatch, the oldest of these formations, consists of coarse sandstones, highly colored shales, and conglomerates, with here and there thin lenses of coal. The Green River, which contains the oil shales, overlies the Wasatch and underlies the Bridger. It includes evenly and thinly bedded gray and white calcareous shale, with some sandstone, oolite, and limestone. The Bridger and Uinta formations comprise irregularly bedded somber-colored clay shale and ferruginous sandstone, and are distinguished from each other largely by their different fossil content, each formation being very fossiliferous.

Hydrocarbon materials have been found in all four formations, although bedded deposits (asphaltic sandstone and oil shale) are known only in the Wasatch and Green River. Veins of gilsonite, elaterite, ozokerite, and other related hydrocarbons cut all the Tertiary formations of the Uinta Basin.

WASATCH AND GREEN RIVER FORMATIONS.

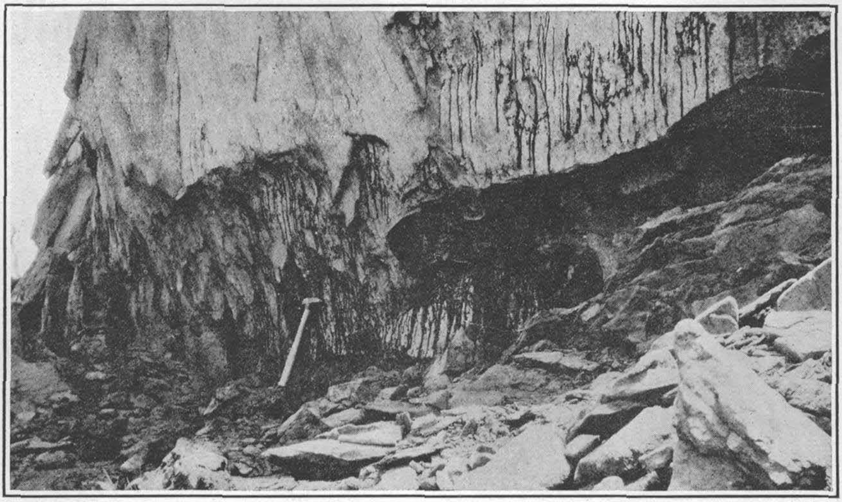
The older part of the Tertiary section in the Uinta Basin is represented by a series of conglomerates, conglomeratic sandstones, shale, oolite, limestone, and oil shale, the lower part of which is undoubtedly of Wasatch age, and the upper part, containing the beds of oil shale, is of Green River age. The correlation of the middle part of this series on lithologic evidence is very difficult, especially over broad areas, inasmuch as the individual beds are not persistent and are variable in character and fossil evidence is lacking. The base of the Wasatch formation has been mapped in several areas around the margin of the basin in Colorado and Utah,[1] and a zone of rich oil shale occurring in the Green River formation has been examined and mapped across the south and east sides of the basin,[2] but the line between the two formations has never been studied. A comparison of the materials in this stratigraphic interval as exhibited in sections studied in northwestern Colorado and northeastern Utah leads to the conclusion that deposition was uninterrupted throughout the time represented by the two formations, although the conditions of deposition varied from place to place.

At De Beque, Colo., Woodruff [3] included in the Green River formation 1,250 feet of gray shale and sandstone below the rich oil-shale zone, and referred to the Wasatch formation more than 4,000 feet of beds, including much red and green shale, with some thin beds of coal.

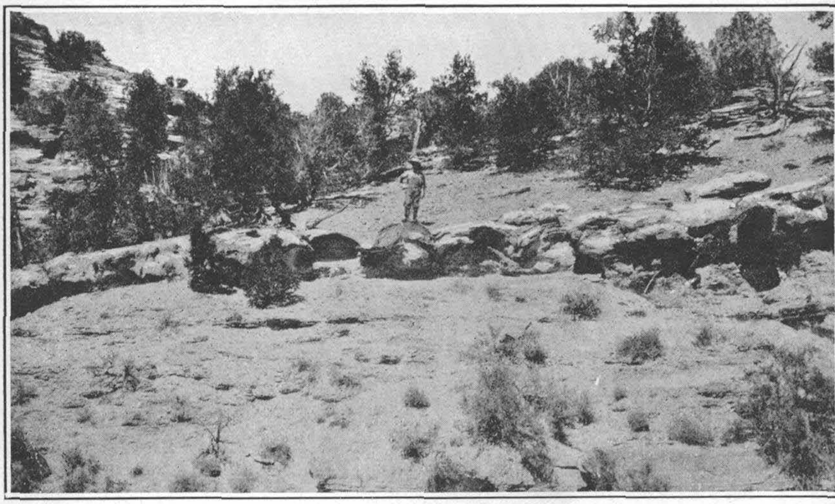
[1] Clark, F. R., Coal fields of the Sunnyside and Wellington quadrangles, Utah: U. S. Geol. Survey Bull.—(in preparation). Hancock, E. T., Coal resources of the Meeker quadrangle, Colo.: U. S. Geol. Survey Bull. — (in preparation). Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, 1910. Richardson, G. B., Reconnaissance of the Book Cliffs coal field, Utah: U. S. Geol. Survey Bull. 371, 1909.

[2] Winchester, D. E., Oil shale in northwestern Colorado and adjacent areas: U. S. Geol. Survey Bull. 641, pp. 139–198, 1916.

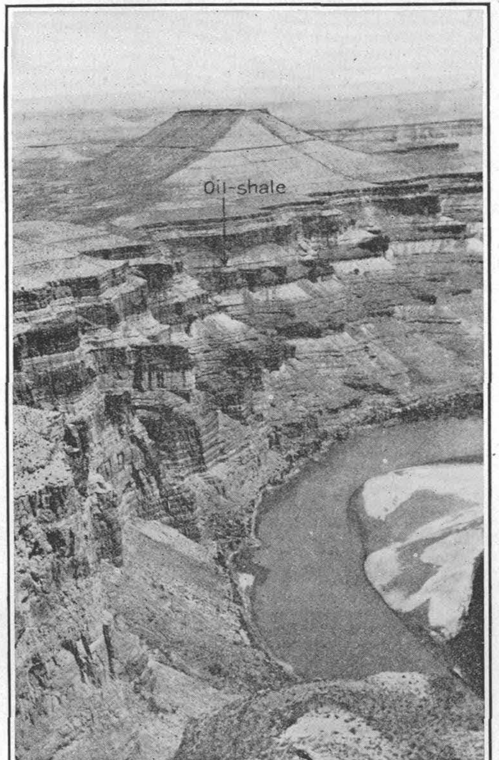
[3] Woodruff, E. G., Geology and petroleum resources of the De Beque oil field, Colo.: U. S. Geol. Survey Bull. 531, p. 57, 1913. Woodruff, E. G., and Day, D. T., Oil shale of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 581, pp. 14, 15, 1914.



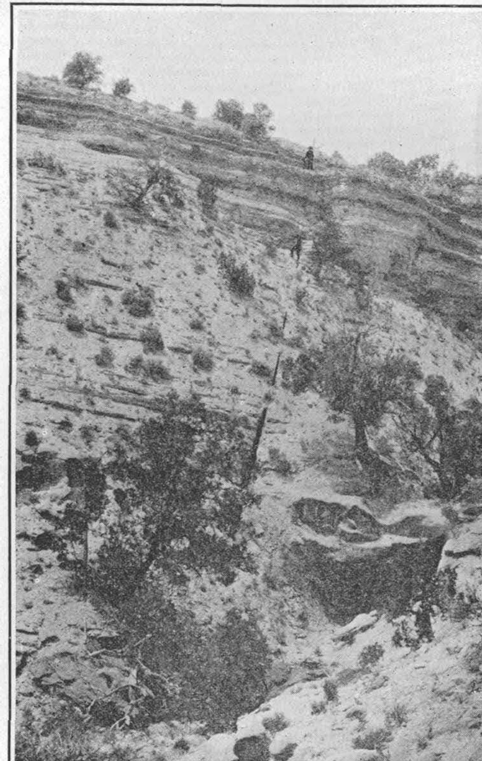
A. ASPHALTIC SANDSTONE NEAR WATSON, UTAH.



B. CONCRETIONARY SANDSTONE, UINTA COUNTY, UTAH.



A. DESOLATION CANYON OF GREEN RIVER, UTAH.



A. GILSONITE VEIN BELOW OIL SHALE NEAR WATSON, UTAH.

Northeast of Watson, Utah, in Hells Hole Canyon (see map, Pl. XII, in pocket), the writer[1] included in the Green River formation 700 feet of gray shale and sandstone below the oil shale. Below this there was a great thickness of red and varicolored shale and coarse sandstone. Only a few miles from this section, at the Old Black Dragon mine, southwest of Dragon, Utah, the 600 feet of rocks immediately below the oil shale includes, according to Woodruff,[2] a large proportion of oolite and pisolite, with but little shale. Woodruff reports "petroliferous sandstone from which asphalt seeps," in beds classified by him as Wasatch, and the writer observed in sec. 9, T. 12 S., R. 25 E., sandstones saturated with asphalt (Pl. V, *A*) in the Green River formation only a few feet below the oil-shale zone. A peculiar bed of concretionary oolite (Pl. V, *B*) about 50 feet below the oil shale extends westward from Dragon beyond Bitter Creek to Willow Creek, a distance of nearly 50 miles.

In Desolation Canyon of Green River (see Pl. VI, *A*) the rocks below the oil shale include many thick beds of reddish-brown sandstone, and farther west, near Sunnyside, Clark,[3] in a detailed study of the geology of the Sunnyside quadrangle, has found it impossible to subdivide the 4,500 feet of rocks between the oil shale and the base of the Wasatch formation, although beds of asphalt-saturated sandstone, which locally compose nearly the whole of 1,500 feet of rocks beneath the oil shale, are not present in the lower part of the series.

Along Ninemile and Argyle creeks (Pl. VII, *A*) above their junction there is a predominance of white shale in the rocks below the principal oil-shale zone, and a second series of oil-shale beds occurs nearly 1,000 feet below. The lower shale zone was not observed east of locality 169,[4] in sec. 12, T. 12 S., R. 13 E., but to the west, in Kyune Canyon, along White River, and near Old Tucker the zone contains several beds of fairly rich oil shale.

In Kyune Canyon near Colton thin beds of good bituminous coal are interbedded with the oil shale of the lower zone, and in White River canyon north of Soldier Summit there are beds of limestone between the lower shale zone and the more persistent upper oil-shale beds. East of Ephraim, Utah, about 50 miles south of Soldier Summit, on the top of the Wasatch Plateau, there is several hundred feet of massive fossiliferous limestone above the lower oil-shale zone.

In Soldier Fork canyon west of Narrows there is beneath the lower shale zone a great thickness of coarse boulder-bed conglomerate which probably represents the Wasatch formation. If these boulder beds are

[1] Winchester, D. E., Oil shale in northwestern Colorado and adjacent areas: U. S. Geol. Survey Bull. 641, pp. 183-186, 1916.

[2] Woodruff, E. G., and Day, D. T., op. cit., pp. 16, 17.

[3] Clark, F. R., op. cit.

[4] Locality numbers given in the test correspond to those used on the map (Pl. XII).

correctly correlated they certainly indicate that the source of material contained in the Wasatch formation must have been very close to the west edge of the area here mapped. In contrast to this, the overlying Green River shales are very fine grained and thin bedded near Old Tucker, as well as across the entire southern rim of the basin, indicating that the material for these beds had been transported a much greater distance. The irregularity in bedding and the coarseness of the beds in the lower part of the series indicate changing local conditions during their deposition, whereas the remarkable persistence and uniformly thin-bedded and fine-grained character of the oil shale indicate stability of conditions. The oil-shale beds were laid down in a great fresh-water lake, the waters of which must have been fairly deep, because much of the fossil material contained in the beds represents a very low order of plant life, which could not have withstood the grinding action of such waves as would have occurred on a lake as extensive as the Uinta Basin (175 miles east to west by 50 miles north to south).

The fossils of the Green River formation include remains of algae and other low forms of plant life, parts of higher plants (pollen grains, a few leaves, etc.), scales (see Pls. VIII and IX) and skeletons of fish, fresh-water shells, insect remains, and bird remains. The plant specimens are largely microscopic in size.

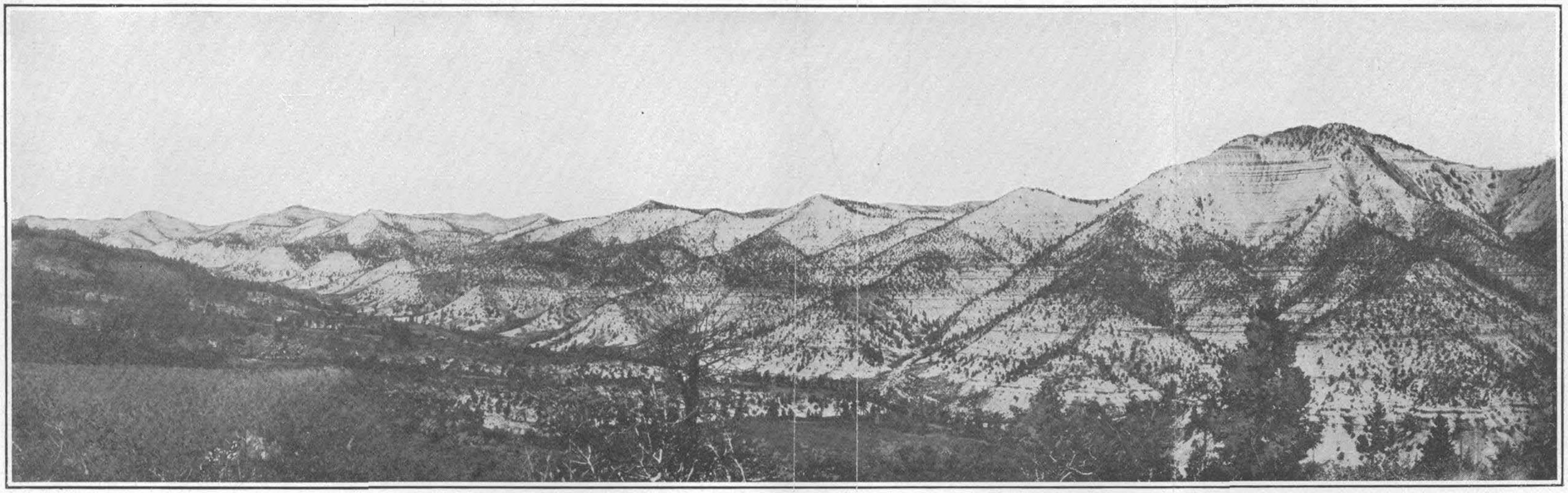
During the field work detailed stratigraphic sections of parts of the Green River formation were measured at points several miles apart along the outcrop of the oil shale, where samples were taken for distillation tests. It was not possible to make careful study of the rocks except at these widely separated localities, hence the correlation of individual beds is not attempted. The examination was sufficient, however, to justify the statement that the principal zone of rich oil shale is the same along the entire southern rim of the basin.

The detailed sections are given below. The beds of shale that are known by testing or are estimated to yield 15 gallons of oil or more to the ton of shale are indicated by heavy type in the sections.

Sections of Green River formation.

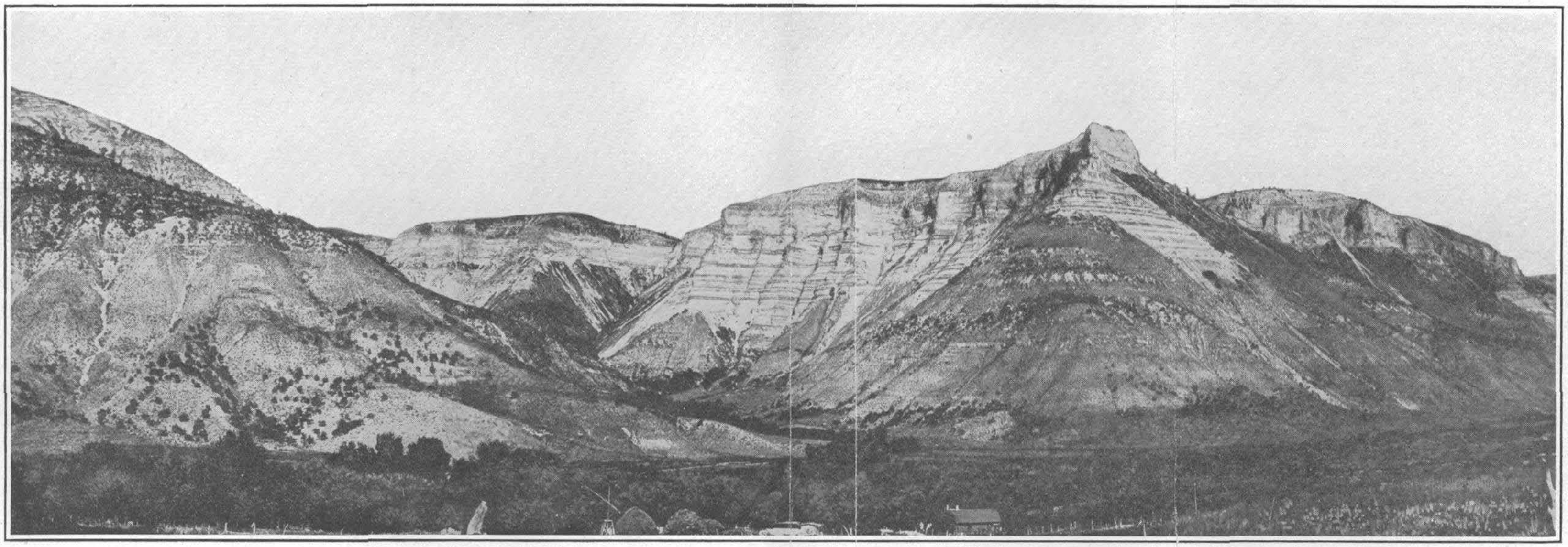
North side of Hells Hole Canyon, sec. 22, T. 10 S., R. 25 E.

		Ft.	in.
Shale, platy, sandy, lean to barren		15	0
Shale, mostly lean, with rich beds too thin to sample		11	0
Shale, thin, platy	(sample 91; 29 gallons).	1	11
Shale, hard, rich		3	2
Shale, lean		2	1
Sandstone, persistent			5
Shale, lean, platy, containing one 6-inch bed of rich shale		6	5
Shale, hard, very rich		3	2
Shale, very sandy, lean			11
Shale, hard, rich (sample 90; 45 gallons)		4	8
Shale, hard	(sample 89; 17 gallons).	1	3
Shale, soft		1	4
Shale, hard, rich		1	5



A. GREEN RIVER FORMATION ON NORTH SIDE OF ARGYLE CANYON, UTAH.

Oil-shale bed is dark band near middle.



B. GREEN RIVER FORMATION ON WEST SIDE OF PARACHUTE CREEK, COLO.

Cliff is largely rich oil shale.

Sections of Green River formation—Continued.

		Ft.	in.
Shale, lean to barren		1	9
Shale, rich (A)	(sample 86, of whole bed, 37 gallons; sample 87, of parts of bed marked "A," 54 gallons; sample 88, of parts of bed marked "B," 25 gallons).		1
Shale, soft (B)			1½
Shale, rich (A)			3½
Shale, soft (B)			3½
Shale, rich (A)			½
Shale, soft (B)			1
Shale, rich (A)			5
Shale, soft (B)			7
Sandstone (discarded)			1
Shale, soft (B)			6
Shale, rich (A)			1
Shale, soft (B)			2
Shale, rich (A)			½
Shale, soft (B)			5
Shale, rich (A)			1½
Shale, lean		1	8
Shale, hard, rich (sample 85; 22 gallons)		1	8
Shale, lean mostly, with rich layers too thin to sample		7	6
Shale, hard, rich (sample 84; 21 gallons)		7	8
Shale, hard, lean to rich, cliff forming		7	4
Sandstone, asphaltic			3
Sandstone, coarse			1½
Shale, hard	(sample 83; 8 gallons).	1	0
Sandstone			1
Shale, hard, rich		2	11
Shale, hard, richest in upper 2 feet (sample 82; 20 gallons)		6	0
Sandstone, asphaltic, variable in thickness (same as 22-inch asphaltic sandstone in Temple Switch section; see p. 183)		1	4
Shale, hard, rich (sample 81; 24 gallons)		1	11
Sandstone			1
Shale, sandy, platy, lean to barren		28	0
Shale, rich			3
Shale, lean to barren, sandy		2	4
Shale, rich			2
Shale, lean to barren		2	6
Sandstone			1
Shale, gray, lean to barren		18	6
Shale, hard, rich			2
Shale, gray, lean to barren		2	10
Shale, alternating hard and soft layers	(sample 80; 33 gallons).	2	4
Shale, soft		1	0
Shale, alternating hard and soft layers		1	3
Shale, lean		5	0
Shale, rich			1
Shale, papery, or sandy and platy, lean		34	0
Shale, rich			10
Shale, sandy, platy, lean to barren		37	0
Shale, rich			10
Shale, barren			6
Shale, hard, rich			1
Shale, platy, barren		5	0
Shale, hard, rich			2
Shale, for the most part gray and lean, but a few rich layers less than 1 inch thick		85	0

	Ft.	in.
Shale, papery, lean	8	0
Shale, platy, lean	3	6
Shale, hard, rich		3
Shale, sandy, barren	3	0
Shale, hard, rich		2
Shale, thin, platy, lean to barren	30	0
Oolite		5
Shale, papery, lean	3	8
Shale, hard, rich		1½
Shale, barren		6
Shale, hard, rich		2
Shale, thin, platy, barren	16	0
Oolite		4
Shale, thin, platy, barren	1	2
Sandstone		7
Shale, thin, platy, barren	16	0
Cherty layers, distorted, concretionary	1	0
Oolite, conglomerate at base	2	4
Shale, gray and drab, barren	2	4
Sandstone		8
Shale, gray and drab, barren	1	10
Sandstone, concretionary	3	6
Shale, gray and drab, barren	20	0
Sandstone, with oolitic bands	4	0
Oolite	3	9
Shale, gray and drab, barren	23	0
Oolite, top distorted and sandy	3	0
Sandstone, oolitic	5	0
Shale, gray	28	0
Sandstone, shaly	15	0
Sandstone, massive	4	0
Shale, barren, gray, sandy	18	6
Oolite	3	6
Shale, barren, gray, sandy	10	0
Oolite	2	0
Sandstone	2	0
Shale, barren, gray, sandy	65	0
Oolite	1	0
Sandstone	3	0
Shale, gray, lean to barren	19	0
Oolite		6
Sandstone, twisted and deformed	1	10
Oolite	6	6
Shale, gray to drab, barren	19	0
Sandstone, massive, yellow	12	6
Shale, gray	5	0
Oolitic sandstone	4	0
Shale, sandy	13	0
Sandstone, massive, yellow, cross-bedded	10	6
Shales, gray and drab, barren	45	0
Sandstone, mostly yellow and massive, but with two somewhat shaly zones	41	0
Shale, sandy, barren	21	0
Shale, rich		6
Shale, gray and drab, barren	35	0
Sandstone and barren, sandy shale	37	0
Shale, largely masked, mostly drab, papery, with sandy zones; not sufficiently cemented to form ledges	95	0
Sandstone, coarse, yellow	1	10
Shale, lean to barren, papery	7	0
Sandstone, yellowish		6
Shale, soft, sandy (sample 79; 1 gallon)	4	1

Sections of Green River formation—Continued.

	Ft.	in.
Sandstone		3
Shale, masked, but for the most part a barren greenish shale	26	0
Sandstone, yellowish brown, poorly cemented	10	0
Shales, red and green (Wasatch).		
	1,047	5

Sec. 24, T. 11 S., R. 25 E. (part of oil-shale zone).

		Ft.	in.
Sandstone			8
Shale, lean, sandy		20	0
Shale, rich			3
Shale, lean		6	0
Shale, rich		1	6
Shale, lean to barren		6	6
Sandstone			5
Shale, lean		4	6
Shale, rich			8
Shale, lean		4	0
Shale, rich			10
Shale, lean, papery		1	6
Shale, rich	(sample 78; 48 gallons).	3	6
Shale, soft			2
Shale, rich			4
Shale, soft		1	7
Shale, rich			8
Shale, lean		2	0
Shale, rich		1	0
Shale, rich, and papery shale		4	0
Shale, medium rich		3	0
Shale, rich, hard			2
Shale, lean		4	0
Shale, medium rich		9	0
Shale, lean		4	0
Sandstone, ferruginous			5
Shale, lean to barren		4	6
Shale, hard, rich			6
Shale, lean to barren		5	0
Sandstone, coarse, asphaltic (same as 22-inch asphaltic sandstone in Temple Switch section; see p. 135)		1	1
		91	9

North side of Saddle Post Canyon, sec. 22, T. 11 S., R. 25 E. (part of oil-shale zone).

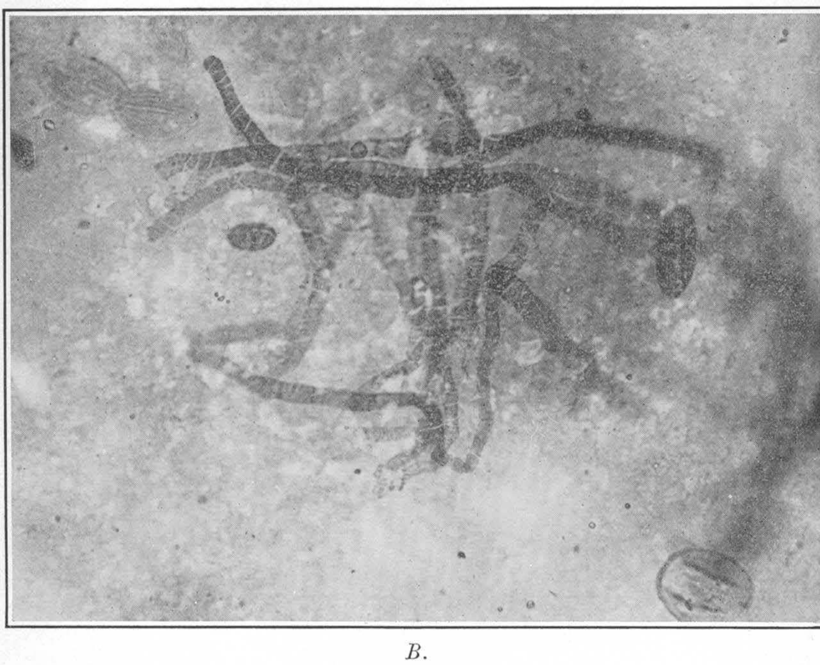
		Ft.	in.
Shale, hard, rich, weathers papery	(sample 76; 31 gallons).	2	11
Shale, rather soft, white on surface, platy		1	7
Shale, hard, rich	(sample 75; 35 gallons).		10
Shale, white, platy			9
Shale, hard, rich			9
Shale, lean to rich; weathers papery		1	6
Shale, lean; weathers white and platy		1	3
Shale, rich; weathers papery			6½
Shale, lean; weathers white and platy		2	4
Shale, hard, rich			10
Shale, lean		12	0
Shale, hard, rich			4
Shale, lean, platy		4	8

	Ft.	in.
Sandstone, persistent, quartzitic (identical with 5-inch sandstone in Temple Switch section; see p. 183)		5
	30	8½

Evacuation Creek between Temple Switch and Dragon.

		Ft.	in.
Shale, thin bedded, lean to barren		40	0
Shale, hard, dark (estimated yield, 20 gallons)		1	0
Shale, lean to barren, thin bedded; a few rich layers less than 1 inch thick (Diptera larvae)		155	0
Sandstone		1	0
Shale, platy, lean to barren; two or three rich beds about 1 inch thick		36	0
Shale, thin bedded, rich		1	0
Shale, lean		6	0
Sandstone, persistent			5
Shale, lean, thin bedded		4	0
Shale, hard, dark brown, rich	(sample 68; 31 gallons).	1	10
Shale, hard, light brown, rich		2	1
Shale, hard, dark brown, rich			6
Shale, sandy (not in sample)			2
Shale, hard, dark brown, rich			3
Shale, hard, light brown, rich			10
Shale, hard, dark brown, rich			8
Shale, dark, tough	(sample 67, from richest part of upper bench; 90 gallons. Sample 65, from whole bed at surface; 32 gallons).	1	4
Shale, dark, platy		1	5
Shale, hard, dark, rich			2½
Shale, soft, dark brown			3
Shale, hard, dark, rich			3
Shale, soft, dark brown			5
Shale, hard, dark, rich	(sample 66, from whole bed 1½ feet back from outcrop; 55 gallons).		3½
Shale, soft, dark brown			10
Shale, hard, dark, rich		1	6
Shale, thin bedded, platy	(sample 64; 15 gallons).	4	2
Shale, rather lean and papery		2	0
Shale, hard, dark brown to black (sample 63; 32 gallons)		4	3
Shale, hard, lean, some thin sandstone layers		3	10
Shale, hard, rich (samples 58 and 62; 23 and 18 gallons, respectively)		3	11
Shale, minutely banded, some rich layers (sample 61; 10 gallons)		6	7
Shale, lean to barren, with two bands of small dark sandstone lenses		4	0

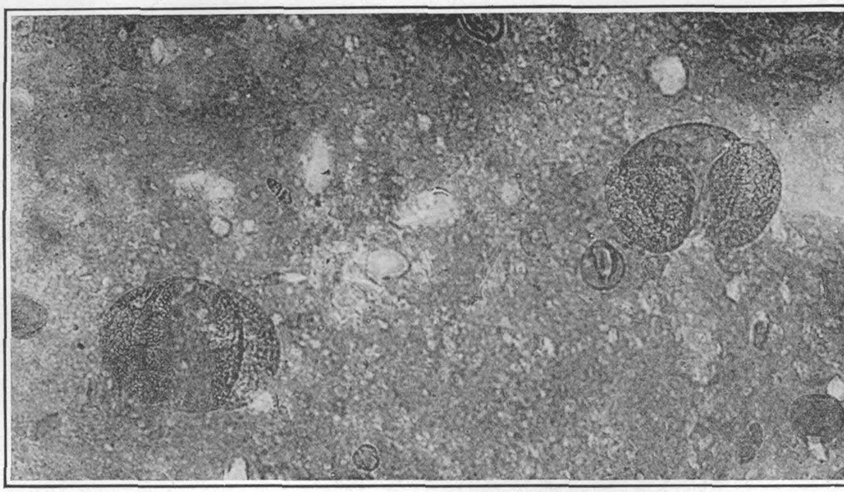
A.



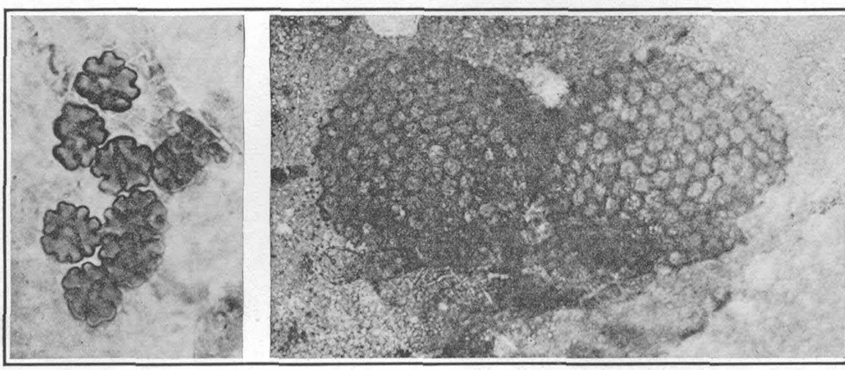
B.

FOSSIL VEGETABLE MATTER OF OIL SHALE OF GREEN RIVER FORMATION (GENERAL VIEWS).

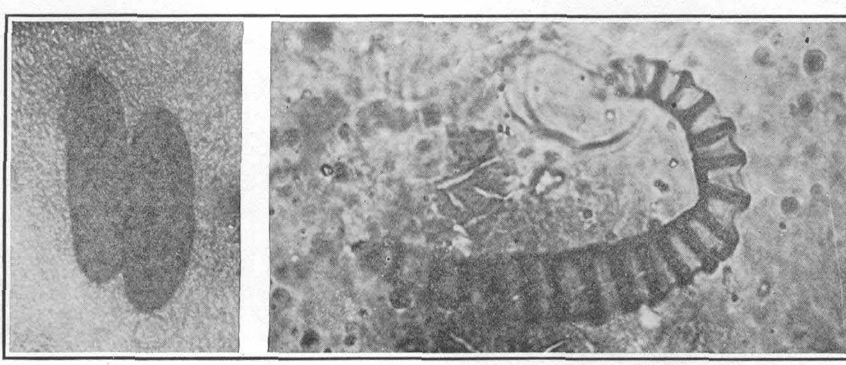
From thin sections prepared by C. A. Davis. *A*, Magnified 410 diameters; *B*, magnified 215 diameters.



A.



B.



C.

FOSSIL VEGETABLE MATTER OF OIL SHALE OF GREEN RIVER FORMATION (DETAILED VIEWS).

From thin sections prepared by C. A. Davis. *A*, Pollen, magnified 245 diameters; *B*, left, yellow-green algæ, magnified 740 diameters; right, (?), magnified 120 diameters; *C*, left, spores, magnified 200 diameters; right, fern annulus, magnified 685 diameters.

Sections of Green River formation—Continued.

		Ft.	in.
Sandstone, hard, quartzitic, persistent			5
Shale, sandy, barren; thin beds of sandstone		3	1
Shale, brown and black, rich	(sample 60; 12 gallons).		7
Shale, hard; weathers green		1	7
Shale, sandy; weathers greenish gray; lean to barren		2	0
Shale, hard (sample 59; 9 gallons)		1	0
Sandstone, rough, coarse, containing asphalt; top and bottom surfaces irregular, with shale conforming to the irregularities		1	10
Shale		7	0
Sandstone, persistent			3
Shale, lean, sandy, gray to reddish, with several thin layers of sandstone		13	8
Shale, hard, rich	(sample 74; 32 gallons).	2	0
Shale, soft		2	0
Shale, hard, rich		1	9
Sandstone			3
Shale, hard	(sample 73; 6 gallons).		3½
Sandstone (not included in sample)			1½
Shale, hard		1	7
Sandstone, persistent (not included in sample)			2
Shale, hard			11
Shale, clayey			5
Shale, hard, mostly lean, with thin beds of richer shale		1	6
Sandstone, persistent			3
Shale, hard, rich	(sample 72; 7 gallons).	2	9
Sandstone			1
Shale, hard, rich			11
Sandstone			¼
Shale, hard, rich		2	6
Sandstone			2
Shale, hard, dark (sample 71; 7 gallons)		7	0
Sandstone, persistent			6
Shale, hard, rich to lean	(sample 70; 14 gallons).		
Horizon of sandstone lenses, none of which came where sample was taken.		3	3
Shale, hard, rich		2	6
Sandstone			1
Shale, probably, lean	(sample 69; 19 gallons).		7
Sandstone, bearing gypsum (not included in sample)			5
Shale, hard, dark, rich; some gypsum near top		1	10
Shale, with considerable gypsum			4
Shale, very dark brown, rich			5
Sandstone, brownish, shaly		23	0
Shale, papery, lean		1	6
Shale, rich; weathers blue			6
Shale, sandy, and barren shaly sandstone		10	0
Shale, rich, papery			6
Shale, sandy, barren		17	6
Sandstone, brown, massive			11
Shale, lean to barren		2	6
Sandstone, massive, ledge making		5	0
Sandstone, brownish, shaly		50	0
Shale, forming ledge, lean to rich		4	6
Shale, papery, lean to barren		4	0
Shale, hard, rich			3
Shale, sandy, lean to barren; two or three sandstone ledges less than 1 foot thick		43	0
Shale, papery; numerous thin blue rich bands		7	0
Shale, barren, with several brownish sandstone layers 2 to 4 inches thick		20	0
Shale; weathers bluish; rich, ledge forming		1	0
Shale; weathers bluish; barren		2	7
Sandstone, light brown		1	0
Shale; weathers bluish; barren		1	5
Sandstone, light brown		4	0
Shale; weathers bluish; barren		1	6
Sandstone, light brown			8
Shale; weathers bluish; barren		1	3
Sandstone, massive		2	6
Sandstone, gray, shaly		3	0
Sandstone, yellowish brown, not well cemented		48	0
Shale, gray		35	0
Sandstone		4	0
Shale, gray		7	0
Sandstone		2	0
Shale, drab		13	0
Oolite		6	0
Shale, drab		42	0
Oolite		2	4
Shale, gray		4	0
Oolite		3	10
Shale, gray		14	6
Sandstone, massive, cross-bedded		14	0
Shale, drab		6	0
Sandstone, massive		8	6
Shale, gray and drab		28	0
Sandstone, resistant			10
Shale, drab		4	0
Sandstone, massive		23	0
Shale, drab		11	0
Sandstone, poorly cemented		4	6
Shale, drab to green		17	0
Oolite, much distorted		2	8
Shale, gray		1	0
Oolite, much distorted		8	6
Shale, sandy		19	0
Oolite		3	0
Sandstone, massive		7	0
Oolite		1	2
Sandstone, massive for the most part; some oolitic members near base		61	0
Shale, drab; upper surface very irregular		4	0
Sandstone, massive		8	0

Sections of Green River formation—Continued.

	Ft.	in.
Sandstone, shaly	18	0
Shale, gray, sandy	7	0
Sandstone, yellow, massive	5	6
Shale, gray, sandy	17	0
Sandstone, massive	3	0
Shale, drab	2	0
Sandstone, massive	14	0
Shale, drab to dark, sandy and concretionary	5	6
Shale, platy, gray and drab	11	0
Oolite		6
Sandstone, finely cross-bedded, poorly cemented	5	0
Oolite		10
Sandstone, massive	2	0
Shale, drab, sandy	3	10
Sandstone, massive	1	6
Shale, drab	3	3
Sandstone, massive	3	0
Shale, gray and drab	102	0
Sandstone, minutely cross-bedded		8
Shale, gray and drab	97	0
Oolitic sandstone, forming ledge; lower 4 inches conglomeratic and may well be considered basal member at Green River	1	4
Sandstone, yellow, poorly cemented	28	0
Shales, red and green, undoubtedly Wasatch.		
	1,306	10½

South side of ridge in sec. 4, T. 12 S., R. 25 E.

	Ft.	in.
Shale, lean	30+	
Shale, rich		10
Shale, rich (sample 136; 43 gallons)	3	0
Sandstone, brown, resistant		2
Shale, fairly rich	1	6
Shale, rich, papery (sample 135; 26 gallons)	3	8
Shale, lean	2	4
Shale, rich (sample 134; 30 gallons)	4	4
Shale, platy, fairly rich (sample 133; 15 gallons)	6	2
Shale, lean	3	6
Sandstone, brown, resistant		5
Shale, lean	5	2
Sandstone, asphaltic, coarse	1	8
Shale, lean	8	0
Sandstone, yellow		10
Shale, sandy, lean	33	0
Sandstone, massive, yellow (This bed to the west is locally saturated with asphalt.)	20+	
	124	7

Spring branch of Bitter Creek, about sec. 17, T. 13 S., R. 24 E.

		Ft.	in.
Shale, lean to barren mostly, but with two or three rich bands, each about 3 or 4 inches thick		35+	
Shale, papery (sample 144; 50 gallons)		4	2
Shale, black, rich	(sample 143; 23 gallons).	2	0
Shale, thin, platy		1	8
Shale, black, very rich	(sample 142; 21 gallons.)		10
Shale, thin, platy		2	3
Shale, hard, rich, black	(sample 141; 31 gallons).	1	11
Shale, thin bedded, platy		1	7
Shale, hard, rich, black			9
Shale, thin bedded, platy	(sample 140; 14 gallons).	2	6
Shale, hard, rich, black		1	2
Shale, lean		4	6
Shale, rich, hard (sample 139; 15½ gallons)		4	5
Shale, lean		1	2
Shale, thin bedded (sample 138; 11 gallons)		2	4
Shale, thin bedded	(sample 137; 2½ gallons).		8
Sandstone			½
Shale, thin bedded		3	11
Shale, lean		2	6
Shale, rich			6
Shale, lean		3	6
Shale, hard, rich			3
Shale, sandy, and a few thin beds of sandstone, lean to barren		31	0
Sandstone, conglomeratic; weathers hackly		2	0
Shale, sandy, barren		16	0
Sandstone, forming weak ledge		4	0
Shale, platy, barren		18	6
Sandstone, oolitic, massive, and somewhat conglomeratic		9	0
Shale, barren and sandy, with some thin platy sandstone		47	0
Sandstone, much contorted and containing large concretionary bodies		3	0
		214	1½

Bitter Creek, about sec. 33, T. 12 S., R. 23 E.

		Ft.	in.
Shale, hard	(sample 146; 38 gallons).	1	3
Shale, hard, rich, thin, platy		1	10
Sandstone (not sampled)			1
Shale, hard, rich		2	1
Shale, hard, rich (sample 145; 43 gallons)		5	9
		11	0

Willow Creek, about sec. 29, T. 12 S., R. 21 E.

		Ft.	in.
Shale, lean to barren with four or five rich beds not more than 6 inches thick		40+	
Shale, papery, forming ledge (sample 150; 28 gallons)		4	0
Sandstone			2
Shale, rich beds alternating with sandy lean layers (sample 149; 10 gallons)		4	10
Shale, rich	(sample 148; 19 gallons).	1	11
Sandstone			½
Shale		1	0
Shale, mostly platy (sample 147; 15 gallons)		5	2
		57	1½

Sections of Green River formation—Continued.

East side of Hill Creek, sec. 7, T. 13 S., R. 20 E.

		Ft.	in.
Shale, lean to barren (estimated)		10	0
Sandstone, yellow (estimated)		10	0
Shale, lean to barren (estimated)		15	0
Shale, rich			6
Shale, lean to barren (estimated)		6	0
Sandstone, yellow (estimated)		20	0
Shale, lean, grading to shale, sandy, barren		4	0
Shale, black, rich (sample 153; 20 gallons)		1	0
Shale, lean		2	0
Shale, brown, lean	(sample 152; 14 gallons).	1	2
Shale, black, hard, rich		1	3
Shale, barren			8
Shale, black, hard, rich (sample 151; 36 gallons)		4	11
		76	6

Spring east of Tabyago Canyon, sec. 16, T. 13 S., R. 19 E.

		Ft.	in.
Shale, papery	(sample 156; 31 gallons).	3	6
Shale, massive		2	10
Shale, lean to barren		2	6
Shale, with sandstone concretions			4
Shale, lean	(sample 155; 18 gallons).	1	11
Shale, rich		1	9
Shale, papery, lean		2	0
Shale, papery, rich			9
Shale, sandy		3	0
Shale, lean		1	11
Sandstone			2
Shale		1	7
Shale (sample 154; 9 gallons)		6	0
Sandstone		1	11
Shale (estimated, 10–15 gallons)		3	4
		33	6

South of Ninemile Creek, sec. 32, T. 11 S., R. 18 E.

		Ft.	in.
Shale papery	(sample 160; 23 gallons).	1	6
Shale, hard		1	10
Shale, hard		5	10
Sandstone			1
Shale, hard (sample 158; 43 gallons)		3	8
Shale, barren, sandy		28	0
Shale, hard	(sample 157; 22 gallons).		9
Shale, papery		1	2
Shale, lean		8	0
Shale, hard, rich			10
		51	8

South side of Horse Bench, sec. 14, T. 12 S., R. 17 E.

		Ft.	in.
Sandstone and shale (estimated)		50	0
Shale, lean (estimated)		50	0
Shale, papery (sample 163; 15 gallons)		3	3
Shale, lean with some rich beds (estimated)		75	0
Sandstone		25	0
Shale, lean with thin beds of rich shale		20	0
Sandstone, yellow, massive		4	0
Shale, lean		6	0
Shale, rich (sample 162; 31½ gallons)		5	2
Sandstone, green		30	0
Shale, lean		3	0
Shale, rich	(sample 161; 16 gallons).	1	8
Sandstone, yellow [1]			1
Shale, moderately rich		1	7
Sandstone, green [1]			1
Shale, lean			4
Sandstone, green [1]			1
Shale, lean			8
Shale, rich		2	8
Shale, lean, papery		3	0
Shale, fairly rich		1	0
Shale, lean.			
		282	7

Rock Canyon, 9 miles east of Willow Springs, about sec. 34, T. 14 S., R. 16 E.

		Ft.	in.
Shale, lean.			
Shale, hard, rich	(sample 164; 32 gallons).		5
Shale, soft, brown, medium			8
Shale, hard, rich		1	3
Shale, thin bedded, rich			7
Shale, hard, medium			11
Shale, lean.			
		3	10

East side of Water Canyon, sec. 22, T. 11 S., R. 15 E.

		Ft.	in.
Shale, rich (sample 167; 24 gallons)		3	10
Shale, lean		7	0
Shale, brown	(sample 166; 13½ gallons).	1	0
Shale, rich		1	8
Shale, lean to barren		18	0
Shale, dark brown (sample 165; 29½ gallons)		3	2
		34	8

Pete Canyon, sec. 19, T. 11 S., R. 15 E.

	Ft.	in.
Shale, rich (sample 168; 26 gallons)	5	2
Sandstone		1
Shale, barren	20+	
	25	3

[1] Not sampled.

Sections of Green River formation—Continued.

North side of Avintaquin Creek, sec. 26, T. 6 S., R. 8 W.

	Ft.	in.
Shale and sandstone to top of hill; upper 200 feet is yellow sandy material but contains in upper 100 feet 2 thin beds (2 inches) of rich oil shale	500+	
Shale, thin bedded, rich (estimated 30 gallons)	1	0
Shale and sandstone	75	0
Shale, rich (estimated 25 gallons)		10
Shale, lean	7	0
Shale, rich (estimated 20 gallons)		5
Shale, barren, and sandstone	300	0
Sandstone	10	0
Shale, barren (some lean) and sandstone, shaly	260	0
Sandstone, white	2	0
Shale, lean (estimated 10 gallons)	4	0
Shale, barren, and thin beds of sandstone	45	0
Shale, thin bedded (estimated 15 gallons)	1	2
Shale, barren	13	0
Shale, thin bedded, rich (estimated 25 gallons)	1	0
Shale, lean	3	0
Shale, thin bedded, rich (estimated 25 gallons)		7
Sandstone, shaly	15	0
Sandstone, massive, coarse	2	0
Shale, lean to barren	35	0
Shale, richer than sample 171	3	0
Shale, barren, and sandstone	12	0
Shale, sandy	1	0
Shale, very lean	17	0
Shale, thin bedded, rich (estimated 30 gallons)	1	2
Shale, lean	8	0
Shale, thin bedded, rich (sample 171; 32 gallons)	4	0
Sandstone		2
Shale, lean	6	0
Shale, rich (estimated 20 gallons)		7
Shale, lean	10	0
Shale, thin bedded, rich (sample 170; 26 gallons)	2	8
Shale, lean (estimated less than 10 gallons)	2	0
Shale, rich (estimated 25 gallons)		6
Shale, lean (estimated less than 10 gallons)	6	0
Shale, thin bedded, rich (estimated 25 gallons)		9
Talus to creek, mostly shale	75	0
	1,425+	

Broadway prospect, Doans Gulch, 6 miles north of Soldier Summit.

	Ft.	in.
Shale, thin bedded	2	3
Covered	20	0
Shale, thin bedded (sample 173, lower 6 feet 6 inches; 19 gallons)	12	6
Sandstone		4
Shale, brown } (sample 172; 11 gallons at face of drift opening).	3	9
Shale, hard, brown } (sample 172; 11 gallons at face of drift opening).	1	10
Shale, thin bedded } (sample 172; 11 gallons at face of drift opening).	1	6
Shale like above	2	0
Talus slope.		
	44	2

Kyune Canyon, 4 miles northwest of Colton, about sec. 17, T. 11 S., R. 9 E. (lower shale zone).

	Ft.	in.
Shale, mostly platy (sample 175; 15 gallons)	2	8
Shale, lean and barren	22	0
Shale, platy } (sample 174; 11 gallons).	4	4
Shale, hard, rich } (sample 174; 11 gallons).		8
Coal		10
Shale, with thin beds of oil shale	35	0
Coal		3
Shale, lean		2
Coal		2½
Shale, lean to barren	2	9
Sandstone, massive	4	3
Shale, barren	2	6
Sandstone		6
Shale, mostly barren, with thin rich bands	40	0
	126	61½

Left Fork of White River, 2 miles north of Soldier Summit, about sec. 18, T. 10 S., R. 8 E. (lower part of formation).

	Ft.	in.
Shale, barren, estimated	300	0
Shale, hard, hackly (sample 179; 8 gallons)	3	9
Shale, mostly barren, with two ledges like sample 176	103	0
Shale, part papery, part platy (estimated less than 15 gallons)	7	0
Shale, not well exposed	140	0
Shale, papery (estimated 15 gallons+)	1	3
Shale, barren	4	6
Shale, not well exposed (estimated 15 gallons)	3	8
Shale, barren	4	0
Sandstone	1	0
Shale, barren	11	0
Sandstone	1	10
Shale, barren	3	6
Shale, papery, dirty	3	0
Shale, papery, dirty } (sample 178; 24 gallons).	1	10
Shale, hard } (sample 178; 24 gallons).		3
Shale, soft } (sample 178; 24 gallons).	2	6
Shale, hard } (sample 178; 24 gallons).	2	4
Shale, twisted and contorted	2	0
Sandstone		3
Shale, good as any in sample 178	1	8
Mostly masked but probably barren shales with a few sandstones	155	0
Shale, medium rich		6
Mostly masked but probably barren shales with a few beds of sandstone	276	0

Sections of Green River formation—Continued.

	Ft.	in.
Shale, soft (sample 177; 7 gallons)		8
Shale, hard (sample 177; 7 gallons)	3	6
Shale, barren	12	0
Masked, estimated	25	0
Shales, bearing some oil alternating with sandstones; no minable units	32	0
Sandstone		7
Shale, lean to barren		10
Sandstone		5
Shale, possibly rich	8	0
Sandstone		2½
Shale, dirty	11	0
Sandstone		6
Shale, lean		3
Sandstone		5
Shale, lean		6
Shale, soft, dirty (sample 176; 12 gallons)		10
Sandstone, cherty (not sampled) (sample 176; 12 gallons)		9
Shale, soft (sample 176; 12 gallons)		3
Sandstone, cherty (not sampled) (sample 176; 12 gallons)		3½
Shale, hard (sample 176; 12 gallons)		4
Shale, soft (sample 176; 12 gallons)		5
Shale, rather massive, very fossiliferous (sample 176; 12 gallons)	1	3
Shale, soft (sample 176; 12 gallons)		5
Shale, rather massive, very fossiliferous (sample 176; 12 gallons)	1	9
Shale, lean, platy	10	0
	1,124	2

Along Denver & Rio Grande Railroad near Old Tucker, sec. 24, T. 10 S., R. 6 E.

	Ft.	in.
Shale, massive but not flexible (possibly 15 gallons)	2	8
Shale, lean	4	0
Shale, massive but not flexible (possibly 15 gallons)	8	0
Shale, lean, gray	28	0
Shale, massive, ledge forming, dark colored but not flexible (probably 15 gallons or more)	2	8
Shale, barren	33	0
Shale, light brown	4	4
Shale, barren	21	0
Sandstone		10
Shale, barren	3	4
Shale, light brown	2	9
Shale, barren	8	0
Shale, light brown, forming small ledge (sample 183; 5 gallons)	2	8
Shale, gray, barren	9	0
Sandstone, massive	3	10
Shale, gray, barren	25	0
Shale, thin plates (sample 182; 14 gallons)	3	6
Sandstone		2
Shale, lean to barren	27	0
Shale, dark to light brown (sample 181; 12 gallons)	4	0
Shale, lean	1	4
Limestone, very fossiliferous		6
Shale, bluish and grayish (probably none as rich as 15 gallons)	110	0
Sandstone	5	0
Shale, lean, bluish	6	2
Sandstone	4	6
Shale, lean	10	0
Sandstone	2	6
Shale, hard, brownish gray (sample 180; 8 gallons)	3	1
	337	8

BRIDGER AND UINTA FORMATIONS.

The somber-colored clay shales and coarse sandstones that occupy the interior of the Uinta Basin have been subdivided into two formations—the Bridger and Uinta—on the basis of their fossils. Along the southern margin of the basin the older of the two (the Bridger) rests on the Green River formation without angular unconformity, but along the north side of the basin it overlaps older formations, entirely obscuring the Green River and in most places covering the outcrop of the Wasatch beds. So far as known neither of these formations includes bituminous beds, either oil shale or saturated sandstones.

The southern limit of the Bridger formation was observed at several places during the field work, and the approximate limit of that formation is shown on the map (Pl. XII, in pocket).

GEOLOGIC STRUCTURE.

The Uinta Basin is a broad, shallow syncline whose axis trends in a general easterly direction and lies near the north side. The beds dip very gently (1°–2°) toward the center of the basin along its southern margin, more steeply around the west end, and at even greater angles on the north side, along the Uinta Mountains. So far as known the only exception to this general structure is near the head of Hill Creek, where there is evidence of a low dome that causes the outcrop of the oil-shale beds to bend considerably toward the south.

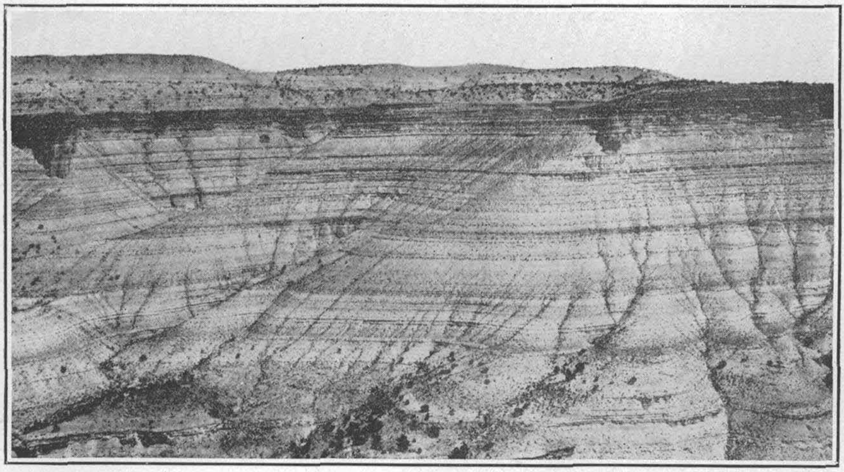
The deformation by which the basin was formed occurred after the deposition of the Green River formation, which contains the oil shale, but before that of the succeeding Bridger formation. There have been other earth movements, however, even since the youngest sedimentary formation (Uinta) of the basin was deposited, as is shown by the presence of great cracks or fissures filled with hydrocarbon material. The origin of these cracks is a disputed question, but the fact that there is neither vertical nor lateral displacement along the fissures and also the fact that their direction bears no consistent relation to the strike of the beds suggest that the cracks are the products of tension, produced perhaps by cooling or drying of the sediments. Where the fissures cut formations that are largely sandstone they present clean-cut walls, but where they cut the beds of oil shale (Pl. VI, *B*, p. 31), as near Watson, there is no break filled with hydrocarbon, but the movement was apparently taken up by the shale without fractures.

The deformation of the oil-shale beds of the Uinta Basin is not sufficient, except in very small areas, to hinder materially the mining of the beds of shale by methods used in mining horizontal coal beds, and in many places the surface of the land has the same attitude as the underlying beds and the overburden to the rich shale beds is thin, so that steam-shovel mining can be practiced without difficulty.

THE OIL SHALE.

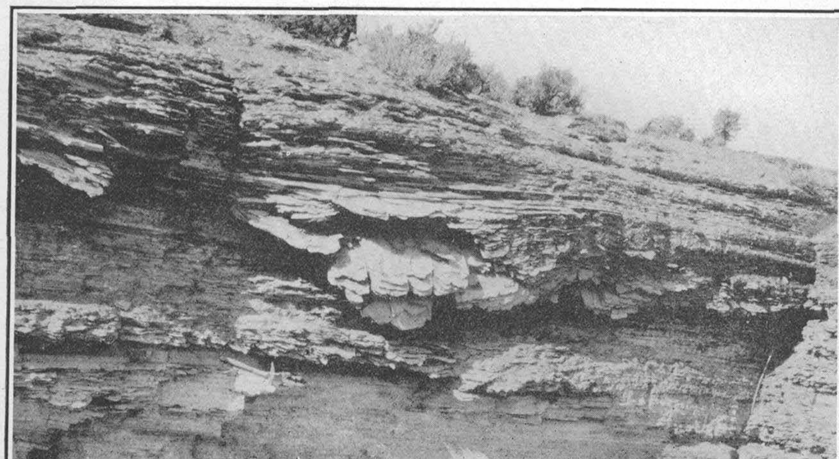
GENERAL CHARACTER.

Good oil shale is black or brownish black except upon weathered surfaces, where it is bluish white or white. It is fine grained, slightly calcareous, and as a rule free from grit. It is tough and in thin-bedded deposits remarkably flexible. (See Pl. X, *B*.) The flexibility of oil shale distinguishes it from ordinary carbonaceous shale, which is brittle. Although oil shale is made up of thin laminae, this is not apparent in some specimens until after the rock has been heated and the oil driven off. Freshly broken oil shale gives off a peculiar odor similar to that of crude petroleum, although the shale contains little oil as such or bituminous matter that is soluble in ether, chloroform, carbon bisulphide, or other solvents of bitumen. Experiments by the writer have shown that from a sample of shale which yielded by distillation oil equivalent to about 14 per cent



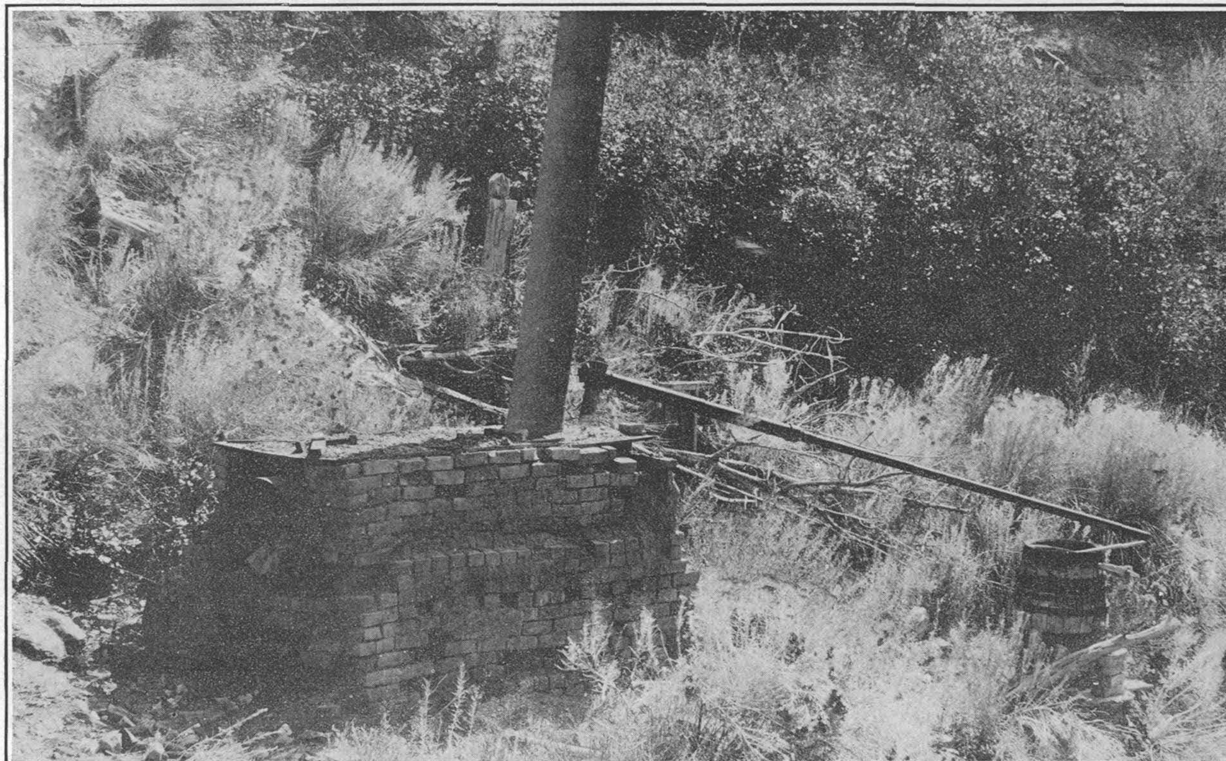
A. OIL SHALE NORTHEAST OF WATSON, UTAH.

Shows thin bedding in this part of the Green River formation. Darker bands are richest beds. About 600 feet of rock exposed.



B. THIN-BEDDED OIL SHALE.

Shows flexibility of rich shale.



ABANDONED SHALE RETORT NEAR JUAB, UTAH.

of its weight it is possible to extract with carbon bisulphide oil at the rate of only about 1 per cent of the original shale—in other words, less than 10 per cent of the oil that can be distilled off is extractable with carbon bisulphide. Oil shale contains a large amount of carbonaceous matter (largely remains of lower plants, including the algae), which is probably the ultimate source of the products of distillation. Thin splinters of oil shale will burn with a very sooty flame and give off an asphaltic odor when ignited with a match. Oil shale is heavier than coal, having an average specific gravity of about 1.60,[1] and the richer shales are lighter in weight than the leaner ones. Analyses of oil shale of the Green River formation[2] show an average ash content of about 60 per cent; six samples having an average yield of 41 gallons of oil to the ton of shale (8.4 to 86.8 gallons) contained an average of 59.83 per cent of ash (45.73 to 79.0 per cent). As the ash content in good coal is less than 10 per cent, oil shale can not be profitably used directly for fuel. The shale to be used must be mined like coal, then crushed and distilled in huge retorts, giving off crude shale oil, ammonia, and fuel gas as the valuable products.

RESULTS OF TESTS.

During the field work samples of the shale were taken at numerous places where the Green River formation crops out along the south side of the Uinta Basin in Utah. Most of the samples represent beds of shale including good oil shale having a minable thickness, but several samples taken for study represent thin beds of rich shale and thick beds of lean shale. The distillation tests were made with the crude apparatus described in a previous report,[3] and the results are only approximate, but they afford a rough estimate of the value of the shale as a source of oil. The variations in temperature obtained in the small field apparatus probably affect the quality more than the quantity of the oil. Distillation without the injection of steam probably makes the quantity of ammonium sulphate produced much less than may be obtained in commercial practice, in which steam will be injected into the heated retorts; therefore the results of the ammonium sulphate determinations are much less complete and reliable than the oil determinations. In the field the uncondensed inflammable gas was not measured, but former tests of similar shale show that the distillation of oil shale will produce a large amount of combustible gas that may be used for fuel. According to Cadell[4]

[1] Woodruff, E. G., and Day, D. T., Oil shale of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 581, p. 3, 1914.

[2] Winchester, D. E., Oil shale in northwestern Colorado and adjacent areas: U. S. Geol. Survey Bull. 641, pp. 152-153, 161, 1916.

[3] Idem. pp. 148-150.

[4] Cadell, H. M., Scottish shale industry: Petroleum World, vol. 10, p. 230, 1913.

the gas produced in the distillation of oil shale in Scotland is sufficient to furnish all the heat necessary for the retorting of the shale.

An examination of the following table of results of distillation shows that a minable thickness of good shale is present at nearly every place examined along the south side of the Uinta Basin in Utah:

Results of distillation of shale from Uinta Basin, Utah.

Sample No.	Locality.			Thickness of bed sampled.		Gravity of oil at 60° F.[a]		Yield of oil per ton of shale.	Yield of ammonium sulphate per ton of shale.[a]
	Sec.	T.	R.	*Ft.*	*in.*	Specific.	Baumé.	*Gallons.*	*Pounds.*
58	17	11 S.	25 E.	3	11	0.8989	25.74	23	5.04
59	17	11 S.	25 E.	1	0	.9327	20.10	9	4.59
60	17	11 S.	25 E.	2	2	.9019	25.22	12	4.38
61	17	11 S.	25 E.	6	7	.9041	24.85	10	3.92
62	20	11 S.	25 E.	3	6	.8983	25.85	18	5.37
63	20	11 S.	25 E.	4	3	.8998	25.59	32	6.96
64	20	11 S.	25 E.	6	2	.8870	27.83	15	4.09
65	20	11 S.	25 E.	6	6	.9090	24.01	32	5.45
66	20	11 S.	25 E.	6	6	.9052	24.66	55	....
67	20	11 S.	25 E.		6	.8745	30.09	90	6.89
68	20	11 S.	25 E.	6	2	.9112	23.64	31	6.99
69	20	11 S.	25 E.	3	7	.9021	25.19	19	5.04
70	20	11 S.	25 E.	5	9	.9260	21.18	14	4.98
71	20	11 S.	25 E.	7	0	.9098	23.88	7	3.48
72	20	11 S.	25 E.	6	3½	.8775	29.54	7	2.25
73	20	11 S.	25 E.	4	8½	.9263	21.13	6	2.61
74	20	11 S.	25 E.	5	9	.8887	27.53	32	7.05
75	22	11 S.	25 E.	2	4	.9036	24.93	35	5.14
76	22	11 S.	25 E.	4	6	.9034	24.97	31	5.20
77	27	11 S.	25 E.	6	10	.8727	30.42	37	7.81
78	24	11 S.	25 E.	6	3	.8833	28.49	48	9.76
79	27	10 S.	25 E.	4	1	....	....	1	2.11
80	15	10 S.	25 E.	4	7	.9094	23.94	33	5.87
81	15	10 S.	25 E.	1	11	.9073	24.30	24	6.72
82	15	10 S.	25 E.	6	0	.9163	22.78	20	6.49
83	15	10 S.	25 E.	4	0	.8975	25.98	8	5.32
84	15	10 S.	25 E.	7	8	.8966	26.14	21	3.77
85	15	10 S.	25 E.	1	8	.8879	27.67	22	5.39
86	15	10 S.	25 E.	3	2½	.8934	26.70	37	6.52
87	15	10 S.	25 E.	1	½	.8866	27.90	54	5.51
88	15	10 S.	25 E.	2	2	.8914	27.05	25	4.05
89	15	10 S.	25 E.	4	0	.9059	24.54	17	5.48
90	15	10 S.	25 E.	4	8	.8976	25.97	45	9.22
91	15	10 S.	25 E.	5	1	.8953	26.37	29	5.35
133	4	12 S.	25 E.	6	2	.8920	26.95	15	2.80
134	4	12 S.	25 E.	4	4	.9138	23.20	30	6.98
135	4	12 S.	25 E.	3	8	.9091	24.01	26	4.17
136	4	12 S.	25 E.	3	0	.9085	24.10	43	6.49
137 [b]	Unsurveyed			4	7½	....	....	2.5	1.72+
138 [b]	do			2	4	.9200	22.17	11	1.70+
139 [b]	do			4	5	.8990	25.72	15.5	2.04+
140 [b]	do			3	8	.8990	25.72	14	3.05+
141 [b]	do			4	3	.8986	25.79	31	3.43
142 [b]	do			3	1	.8960	26.25	21	2.82
143 [b]	do			3	8	.9200	22.17	23	4.08
144 [b]	do			4	2	.9060	24.52	50	8.68
145 [c]	do			5	9	.8912	27.09	43	5.24
146 [c]	do			5	3	....	....	38	5.06
147 [d]	do			5	2	.8840	28.37	15	2.66
148 [d]	do			2	11½	.9250	21.35	19	1.81
149 [d]	do			4	10	.9180	22.50	10	2.16
150 [d]	do			4	0	.8912	27.09	28	5.57
151	7	13 S.	20 E.	4	11	.8929	26.79	36	4.46
152	7	13 S.	20 E.	2	5	....	....	14	3.48
153	7	13 S.	20 E.	1	0	.9050	24.69	20	15.92
154	16	13 S.	19 E.	6	0	.9110	23.67	9	2.49
155	16	13 S.	19 E.	6	5	.8890	27.48	18	2.06
156	16	13 S.	19 E.	3	6	.8850	28.19	31	3.48
157	32	11 S.	18 E.	1	11	.8917	27.00	22+	3.97
158	32	11 S.	18 E.	3	8	.9090	24.01	43	6.41
159	32	11 S.	18 E.	5	10	.8838	28.40	40	6.91

[a] Determinations by Bureau of Mines (C. R. Bopp, chemist).
[b] Bitter Creek, 12 miles southwest of Dragon.
[c] Bitter Creek, 15 miles west of Dragon.
[d] Willow Creek, 28 miles west of Dragon.

Results of distillation of shale from Uinta Basin, Utah—Continued.

Sample No.	Locality.			Thickness of bed sampled.		Gravity of oil at 60° F.		Yield of oil per ton of shale.	Yield of ammonium sulphate per ton of shale.
	Sec.	T.	R.	*Ft.*	*in.*	Specific.	Baumé.		
							Degrees.	*Gallons.*	*Pounds.*
160	32	11 S.	18 E.	3	4	0.8780	29.45	23	2.80
161	14	12 S.	17 E.	6	11	.8850	28.19	16	2.85
162	14	12 S.	17 E.	5	2	....	....	31.5	4.97
163	14	12 S.	17 E.	3	3	.8890	27.48	15	3.76
164[a]	Unsurveyed			3	10	.8974	26.00	32	3.55
165	22	11 S.	15 E.	3	2	....	....	29.5	6.71
166	22	11 S.	15 E.	2	8	....	....	13.5	1.49
167	22	11 S.	15 E.	3	10	....	....	24	3.92
168	19	11 S.	15 E.	5	2	.8866	27.90	26	3.86
169	12	12 S.	13 E.	....		.8800	29.09	10	2.23
170	26	6 S.	8 W.	2	8	....	....	26	8.79
171	26	6 S.	8 W.	4	0	....	....	32	4.96
172[b]	Unsurveyed			7	1	.9150	23.00	11	0.29
173[b]	do			12	6	.8830	28.55	19	4.39
174[c]	do			5	0	.8890	27.48	11	3.56
175[c]	do			2	8	.8980	25.90	15	6.65
176[d]	do			5	3	.8640	32.03	12	4.04
177[d]	do			4	2	.9100	23.84	7	3.11
178[d]	do			6	11	.9050	24.69	24	12.21
179[d]	do			3	9	.9220	21.84	8	10.10
180	24	10 S.	6 E.	3	1	.8900	27.30	8	2.71
181	24	10 S.	6 E.	4	0	.8780	29.45	12	....
182	24	10 S.	6 E.	3	6	.8590	32.98	14	....
183	24	10 S.	6 E.	2	8	.8740	28.18	5	....
3	23	10 S.	6 E.	3	0	.8965	26.2	11.9	6.5

[a] Rock Canyon, 15 miles east of Sunnyside.
[b] Doans Gulch, 6 miles north of Soldier Summit.
[c] Kyune Canyon, 4 miles east of Colton.
[d] Left Fork of White River 2 miles north of Soldier Summit.

THE SHALE OIL.

PROPERTIES AND VALUE.

Most oils obtained from the distillation of shale are reddish brown and at ordinary temperatures range from a thin liquid to a semisolid vaseline-like product. The specific gravity of shale oil obtained in the field apparatus ranges from 0.859 (32.98° Baumé) to 0.9327 (20.10° Baumé) and averages 0.8966 (26.14° Baumé). It is probable that a large part of the difference in the shale oil from different shales is due to variations in the temperature of distillation. Fractionation of shale oil gives the following products:[1] Gasoline (distillate to 150° C.), 7 to 12 per cent; kerosene (150°–300° C.), 28.5 to 49 per cent; asphalt, 0.47 to 4.10 per cent; paraffin, 1.63 to 9.21 per cent; sulphur, 0.41 to 1.42 per cent; nitrogen, 0.887 to 2.198 per cent.

The large percentage of nitrogen noted above may be greatly lessened in commercial practice, in which steam will probably be injected into the retorts during the distillation.

The refining of shale oil is a rather complicated process, as the oil must be distilled many times in order to separate successfully the different ingredients, which have varying degrees of volatility and

[1] Winchester, D. E., Oil shale in northwestern Colorado and adjacent areas: U. S. Geol. Survey Bull. 641, p. 156, 1916.

specific gravity. A small amount of "shale spirit" may be obtained from the permanent gas derived from the original distillation, but most of the valuable hydrocarbon products will be produced from the shale oil itself. The diagram reproduced in figure 19, compiled by H. M. Cadell and printed in his recent work "The story of the Forth," shows the products of the various stages of distillation roughly in proportion to the amount of the product and illustrates briefly the complexity of the refining industry as well as the variety of products derived from the oil shale of Scotland. Although the products of the American oil-shale industry will doubtless be different from those

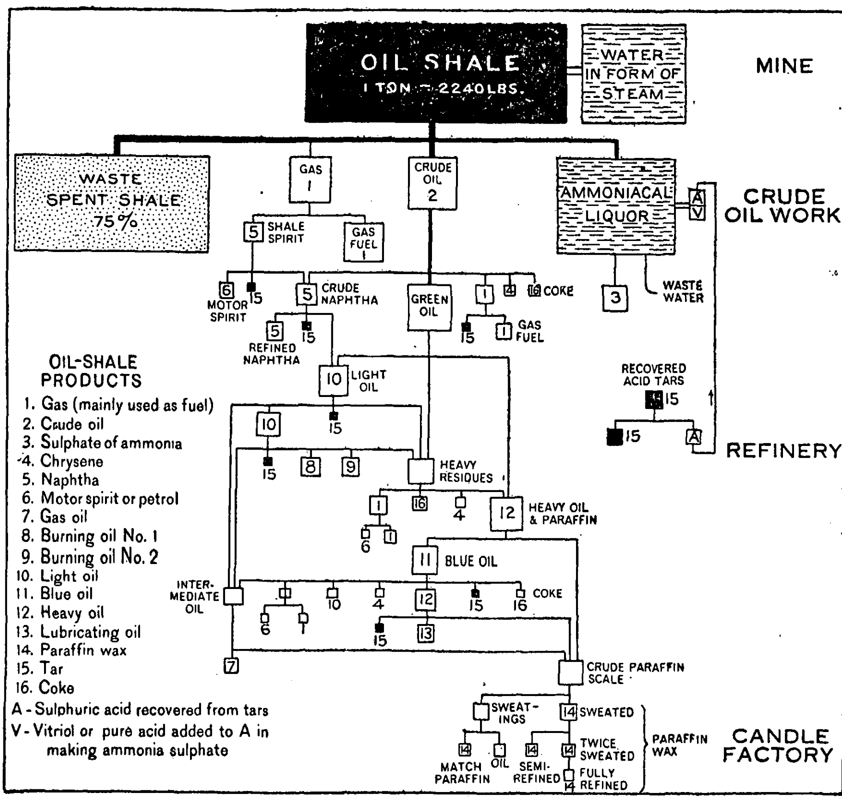


FIGURE 19.—Diagram illustrating processes of manufacture in the Scottish mineral-oil industry.

obtained in Scotland, where the profit is derived largely from liquid and solid products, and also different from those of New South Wales, where the "shale" is used largely in the manufacture of gas, the variety of the American products may be large. It is quite probable that products of especial value will be discovered during the chemical research which should precede and accompany the development of an oil-shale industry in the United States.

The oil shale of this country has until recently received very little attention, chiefly because petroleum has been abundant. Before petroleum was discovered in Pennsylvania the Mormons distilled oil from shale near Juab, Utah, where the ruins of an old still can yet be seen (Pl. XI). Many attempts have been made to distill cannel coal, and a few experiments have been made with the Devonian black shale of the East, but no shale-oil industry has been established in America. According to Baskerville[1] there were 55 shale-oil companies in the United States in 1860. "Many of the companies were of small capacity, and most of them were not more than fairly started when the discovery of petroleum paralyzed the industry." Recently, however, the great increase in the demand for gasoline and fuel oil and the failure to discover large new oil fields have caused interested companies and geologists to turn to the oil shales, and already several small experimental plants are in process of construction, and there appears a good chance that others will follow.

ORIGIN.

Although the oil shales of different countries and areas vary considerably in character and composition and the oil obtained by the distillation of oil shale may not all be derived from the same source, there seems to be ample proof that the oil from the oil shale of the Green River formation is largely obtained by the destructive distillation of the partly bituminized vegetable matter contained in the shale. It has been argued by some authors[2] that the oil is not indigenous to the shale from which it can be distilled but was formed elsewhere and then migrated to the shale, where it has become adsorbed and inspissated, so that it can not be extracted by solvents of petroleum but must be obtained by destructive distillation. According to Cunningham-Craig the oil originated in the coal beds of underlying formations; Coste is inclined to attribute the oil to inorganic sources.

Steuart[3] has suggested that "kerogen" (the oil-yielding substance of oil shale) has been produced from organic matter by the action of microbes under special circumstances, the products being dependent on the microbe, or that "kerogen" may be the remains of certain kinds of vegetable matter, perhaps little altered, the product being dependent on the kind of original organic material. It is the present writer's opinion that to the type of original material is due, at least in large part, the transformation into oil-yielding substance rather than into coal.

[1] Baskerville, Charles, Economic possibilities of American oil shales: Eng. and Min. Jour., vol. 88, pp. 149-154, 195-199, 1909.

[2] Cunningham-Craig, E. H., Origin of oil shale: Roy. Soc. Edinburgh Proc., vol. 36, pp. 44-86, 1916. Coste, Eugene, Oil shales of Elko, Nev.: Am. Inst. Min. Eng. Bull., pp. 1403-1404, 1914.

[3] Steuart, D. R., The chemistry of the oil shales: The oil shales of the Lothians, 2d ed., pt. 3, p. 164, Scotland Geol. Survey Mem., 1912.

An examination of the shales of the Green River formation has shown that invariably the shale showing the larger percentage of vegetable débris will yield the most oil and vice versa, and that shale beds occurring between beds of rich oil shale may be equally compact and fine grained and yet yield no oil on distillation. There appears to be no reason why oil migrating into the shales should not penetrate all alike, and the oil might be expected to follow the beds of least resistance—that is, the coarser beds of sandstone which are interbedded with the shales. It is true that there are beds of sandstone which are locally saturated with asphalt, but there are also persistent beds of sandstone adjacent to rich oil-shale beds and even lenses of sandstone completely surrounded by good oil shale which show no signs of oil or asphalt. It seems certain that if the oil had migrated into the shale such porous sands would contain at least small quantities of oil that might be obtained by distillation.

That oil as such is present in the Green River oil shale is proved by the odor of petroleum given off by rock that is freshly broken and also by the fact that some oil may be dissolved out of the richer shales by ether, carbon bisulphide, etc., and it is possible that an even larger percentage has existed as oil but is now inspissated and has been adsorbed by the shale particles. The fact that after treatment with carbon bisulphide continuously for a period of three weeks oil shale was still capable of yielding on distillation oil that was not extracted by the solvent indicates that probably earth processes have not completely converted the vegetal matter to petroleum.

In examining the papers of Dr. C. A. Davis since his death the writer discovered the following notes, which indicate his ideas as to the origin of the oil in oil shale after returning from the field in 1914:

RELATION OF BITUMINOUS COMPOUNDS TO MINERAL MATTER IN THE OIL SHALE OF THE GREEN RIVER FORMATION.

[Notes by C. A. Davis, dated Oct. 30, 1914.]

The shale is composed of organic matter, bituminous matter, and mineral matter. The amount of bituminous matter increases as the mineral matter decreases—that is, it increases with the increase of organic matter in the shales. However, it needs only a casual inspection of the shales in place to see that the beds run very irregular in mineral matter; the rich shales are very compact and almost as impervious as rubber, being made up of what seem to have been partly decomposed remains of minute plants, algae, fungi, spores, pollens, bacteria, etc., embedded as a jelly-like mass; between these there are few, if any, interspaces, and such grains of mineral matter as are present seem to be firmly embedded in this jelly-like mass. Some thin sections show the silt to be exceedingly fine and in thin laminae which are much thinner than the laminae of combustible material of the section. In fact, the mineral part of the rich bed is physically so minute that if it were the sole orignal material into which the bituminous matter was injected, the intrusion must have greatly distorted the beds overlying the invaded beds, but even where the layers are very thin no such distortion is observable. If the invasion by the bituminous matter occurred while the beds were still forming and the grains were free to move, it would be necessary to assume that the silts were dry, a possibility that seems barred by the great number of algae and other water plants present in the deposit. If the silt and sandy layers were dry it is also difficult to see how the finer, more compact layers absorbed and retained so much more bituminous matter than those containing larger grains and having a large number of capillary interspaces, for although a given volume of clay will hold more water than the same volume of sand, it is evident that the rich beds in these oil shales, volume for volume, contain a vastly smaller amount of mineral matter than the leaner sandy beds. If, on the other hand, the bituminous matter originated in the highly organic beds and has begun to migrate under pressure or other factors, the most obvious place for it to be stored first would be in the adjacent more sandy beds, and from this theory it would be expected that the more sandy beds would yield larger percentages of more volatile petroleum than the others. If, however, the bituminous matter is held in the partly bituminized organic matter seen in an incompletely decomposed state in the shale, heat might decompose the parent fossil material, and petroleum in quantities proportionate to the percentages of the plant remains might be produced, and from both kinds of shale the product would be essentially the same. These facts seem to be developed in reported tests.

NITROGEN.

Analyses of 18 samples [1] of oil shale of the Green River formation, each of which gave 15 gallons or more of oil to the ton, show an average nitrogen content of 0.64 per cent, which is equivalent to 59.4 pounds of ammonium sulphate to the ton of shale. In the destructive distillation of oil shale it is not possible to reclaim all the nitrogen in the form of ammonium sulphate, either in the commercial works or in the laboratory. Part of the nitrogen will be driven off as ammonia, part will be removed as organic nitrogen compounds (pyridine compounds, etc.) and be retained in the shale oil, and some will be retained in the ash.

According to Steuart,[2]

A good fragment of the Boxburn seam (Scotland) gave in a small glass tube 42 gallons (Imperial) of crude oil per ton (long), or 16.5 per cent; sulphate of ammonia 26.88 pounds per ton (long), or 1.2 per cent. The nitrogen was accounted for as follows:

	Per cent of sulphate of ammonia.	Pounds.
Total nitrogen in the shale	3.03	67.87
In crude oil	.76	17.11
In ammonia water	1.20	26.88
In spent shale	.86	19.27
Unaccounted for	.21	4.61

No steam was used in the distillation.

It will be seen by these figures that by dry distillation of the oil shale of Scotland approximately 40 per cent of the total nitrogen in the shale may be reclaimed as ammonia and converted into ammonium sulphate. By distillation with steam, according to Charles

[1] Winchester, D. E., Oil shale in northwestern Colorado and adjacent areas: U. S. Geol. Survey Bull. 641, p. 159, 1916.

[2] Steuart, D. R., The chemistry of the oil shales: The oil shales of the Lothians, 2d ed., p. 158, Scotland Geol. Survey Mem., 1912.

Baskerville,[1] 60 to 70 per cent of the total nitrogen in oil shale should be reclaimed as ammonia. It seems probable, therefore, that the oil shales of the Green River formation, containing nitrogen equivalent to as much as 60 pounds of ammonium sulphate to the ton of shale, should yield as much as 35 pounds of ammonium sulphate to the ton when distilled with steam, as in the commercial practice of Scotland. With this figure as a basis it is estimated that the oil shale of the Uinta Basin in northeastern Utah is capable of producing 500,000,000 tons of ammonium sulphate as a by-product in the production of shale oil.

Woodruff and Day[2] reported the presence in shale oil of "pyridine compounds easily extracted from the shale oil by dilute acids," and it has been suggested that these compounds may occur in sufficient quantity to be of value as such. Fifteen samples of oil from shale distilled in the field apparatus previous to the 1916 field season and discussed in a previous report[3] were therefore submitted to the Bureau of Mines for study. The samples were chosen to represent wide geographic distribution, as well as great range in character of shale. The following table gives data relative to the samples and the results of the chemical determinations, made by D. T. Day, of the Bureau of Mines:

"Pyridine compounds" in dry-distilled shale oil.

Sample No.	Locality.				Nitrogen in original shale (per cent).	Yield of oil (gallons per ton).	Specific gravity of oil.[a]	Pyridine compounds in oil (per cent by weight).[a]	Ammonium sulphate from gas obtained in distillation of shale (pounds per ton).[a]
	Sec.	T.	R.	State.					
63	20	11 S.	25 E.	Utah	0.53	32	0.8998	3.88	7.0
64	20	11 S.	25 E.	do	.35	15	.8870	4.28	4.1
65	20	11 S.	25 E.	do	.73	32	.9090	2.83	5.4
66	20	11 S.	25 E.	do	.80	55	.9052	3.82	(b)
67	20	11 S.	25 E.	do	1.30	90	.8745	5.99	6.9
69	20	11 S.	25 E.	do	.32	19	.9021	2.38	5.0
77	26	10 S.	25 E.	do	.68	37	.8727	6.13	7.8
87	15	10 S.	25 E.	do		54	.8866	3.47	5.5
88	15	10 S.	25 E.	do		25	.8914	4.64	4.1
92	9	13 N.	99 W.	Wyoming	.60	30	.8709	2.35	3.9
101	13	13 N.	108 W.	do	.68	34	.8994	2.26	5.7
120	19	17 N.	106 W.	do		14	.8702	4.35	7.9
129	5	21 N.	107 W.	do	.10	8	.8705	8.91	.7
131	5	21 N.	107 W.	do	.50	50	.8889	2.36	2.0
132[c]			(b)		.85	50	.8449	1.25	4.5

[a] Determinations by Bureau of Mines, D. T. Day, chemist.
[b] Not determined.
[c] Collected by David White from a point near Elko, Nev

[1] Personal communication.

[2] Woodruff, E. G., and Day, D. T., Oil shale of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 581, p. 7, 1915.

[3] Winchester, D. E., Oil shale in northwestern Colorado and adjacent areas: U. S. Geol. Survey Bull. 641, pp. 138-198, 1916.

The percentage of "pyridine compounds" is large for the samples tested. It is suspected that the distillation of shale with the injection of steam into the heated retort will convert a considerable part of the nitrogen (here present in the oil as "pyridine compounds") into ammonia in the gas, which will be reclaimed as ammonium sulphate. Here again is needed research to determine the effect of steam on the nitrogen of the shale and the relative cost and value, as end products, of ammonia sulphate and the "pyridine compounds" produced by the dry distillation of oil shale.

VEIN HYDROCARBONS.

Hydrocarbon materials filling fissure veins are common in the Uinta Basin. Of the different varieties gilsonite, elaterite, tabbyite, albertite, wurtzilite, and nigrite are asphaltic materials, and ozokerite is of the paraffin type. In this region the ozokerite is known only in veins that cut rocks of the Wasatch formation, which is older than the oil shale, but the asphaltites are found chiefly in veins that cut beds younger than the oil shale and all in Green River or younger formations. One thick vein of gilsonite west of Watson is known to cut rocks both above and below the oil-shale beds, although the oil shale shows no actual vein and no trace of gilsonite in the bedding planes in line with the vein above and below. (See Pl. VI, *B*, p. 31.) This vein has been mined extensively at the Rainbow and Temple mines, where the fissure was formed in the heavy sandstone beds above the thin-bedded oil shale, and also at the Old Black Dragon mine, where the vein cuts beds of oolite and sandstone below the oil shale. The depth to which the veins extend has never been tested even in the Old Black Dragon mine, where the workings had not gone much below the level of the canyon bottom before a fire in the mine prevented further work. In the lowest workings the wall rocks belong to the Green River formation.

The source of the hydrocarbon material filling the fissures of the Uinta Basin is not known, although Eldridge [1] has suggested that it came from below under pressure, where it was originally formed in black shales of perhaps Cretaceous age. The writer is inclined to believe, however, that the oil shales of the Green River formation may have been the source of all the vein hydrocarbons of the Uinta Basin, as well as of the asphaltic material that saturates certain sandstones of the region.

[1] Eldridge, G. H., The asphalt and bituminous rock deposits of the United States: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 1, p. 351, 1901.

BIBLIOGRAPHY.

Since the publication of the bibliography contained in Bulletin 641 the following papers have appeared dealing with the subject of oil shale:

CADELL, H. M., The story of the Forth, 283 pp., Glasgow, 1913. Gives discussion of oil shale, its origin, etc., and a chapter on the Scottish mineral-oil industry.

CONACHEV, H. R. J., Origin of oil shale. Summary published in Petroleum Rev., December, 1916.

CUNNINGHAM-CRAIG, E. H., Kerogen and kerogen shale: Inst. Petroleum Technologists Jour., vol. 2, pp. 238–273, 1916.

——— The origin of oil shale: Roy. Soc. Edinburgh Proc., vol. 36, pp. 44–86, 1916. Exhaustive discussion of origin, giving geologic and chemical data.

DE BEQUE, G. R., The bituminous-shale industry in northwestern Colorado: Eng. and Min. Jour., vol. 102, pp. 1011–1012, 1916. Brief discussion of occurrence, character, and development of oil shale near De Beque, Colo.

DU TOIT, A. L., Report on the oil shales of Impendhle County, Natal: South African Min. Jour., vol. 26, pp. 193–194, 1916. Brief description of occurrence and character of oil shale in Natal.

FORBES-LESLIE, WILLIAM, The Norfolk oil shales: Petroleum Rev., vol. 35, pp. 327–328, 347–348, 1916 (extract); Petroleum World, vol. 13, pp. 525–529, 1916 (extract); Inst. Petroleum Technologists Jour., vol. 3, pp. 2–26, 1916. Describes geology and tests of oil shale of Jurassic age in Norfolk County, England. Gives analysis of oil and shale.

KEELE, JOSEPH, Oil shales at Albert Mines and Baltimore: Canada Dept. Mines, Mines Branch, Summary Rept. for 1915, p. 137, 1916. Short discussion of value of spent shale in clay-working industry.

PHILLIPS, W. B., Texas oil shale is known to be rich in gasoline, kerosene, and by-products: Oil, Paint, and Drug Reporter, vol. 91, No. 17, p. 19, 1917. Note on oil shale and lignite of Texas as a source of oil, ammonium sulphate, and gas.

SCHEITHAUER, W., Shale oils and tars and their products; translated from the German by Charles Salter, London, 1913.

SIMPSON, LOUIS, Oil-bearing shales: Canadian Min. Inst. Bull. 54, pp. 868–873, 1916. Gives data regarding costs of mining and manufacture of oil-shale products with estimate of value of Canadian shales.

RESULTS OF DRY DISTILLATION OF MISCELLANEOUS SHALE SAMPLES.

By Dean E. Winchester.

During the last two years numerous samples of black shale, coal, and lignite have been subjected to dry distillation by the writer in order to furnish data regarding their availability as a source of crude oil. Many of the samples were collected by geologists as rock specimens, and some were taken expressly for the purpose of distillation, but regardless of whether the samples represent minable thicknesses or the richest material at the locality the results are given here as a record worth preserving.

ARKANSAS.

Sample **194.** Black shale collected along road 3 miles east of Fayetteville, Washington County, by David White, October 9, 1916, from basal bed of Fayetteville shale (Carboniferous). Sample included 3 feet of an 8-foot bed on weathered outcrop. Results of distillation: Oil, 1½ gallons to the ton; ammonium sulphate, 7.50 pounds to the ton.

Sample **195.** Black shale, collected on east side of road 2 miles north of Gravette, Benton County, by David White, October 11, 1916, from outcrop of Chattanooga shale (Devonian), bed 3 feet thick. Results of distillation: Oil, 1 gallon to the ton; ammonium sulphate, 2.59 pounds to the ton.

COLORADO.

The Green River formation was examined at two places by the writer at the end of the field season of 1916. Seven samples of the shale were taken, and the stratigraphic sections given below were measured. Three samples (187–189) were taken on the north side of Dry Fork Creek about sec. 7, T. 7 S., R. 100 W., and four (190–193) on Parachute Creek, about 10 miles north of Grand Valley.

Results of dry distillation of samples of oil shale from northwestern Colorado.

Sample No.	Locality.			Thickness of shale sampled.		Gravity of oil.		Yield of oil per ton of shale.	Yield of ammonium sulphate per ton of shale.
	Sec.	T.	R.	*Ft.*	*in.*	Specific.	Baumé. *Degrees.*	*Gallons.*	*Pounds.*
187	27	7 S.	100 W.	3	8	0.898	....	21	3.92
188	27	7 S.	100 W.	5	0	.891	....	38	7.38
189	27	7 S.	100 W.	3	6	.899	....	22	4.54
190	36	5 S.	96 W.	6	4	.892	....	18	8.70
191	36	5 S.	96 W.	5	4	.901	....	19	5.23
192	36	5 S.	96 W.	2	6	.890	....	36	5.71
193	36	5 S.	96 W.	5	0	.892	....	42	6.20

Sections of Green River formation in northwestern Colorado.

North side of Dry Fork Creek, above Armstrong sawmill, west of De Beque, about sec. 27, T. 7 S., R. 100 W.

	Ft.	in.
Shale to top of ridge (barometer 8,100). This series is about 40 per cent **shale** that will test probably more than 20 gallons. Upper 75 feet contains several beds 3 feet or more thick of hard black **shale** that may yield 30 gallons to the ton	480	0
Shale (estimated 20 to 30 gallons)	3	0
Shale (estimated 15 to 20 gallons)	12	0
Shale, thin bedded, rich (sample 188; 38 gallons)	5	0
Shale, moderate (sample 189; 22 gallons)	1	2
Shale, rich (sample 189; 22 gallons)		5
Shale, lean (sample 189; 22 gallons)		10
Shale, rich, papery (sample 189; 22 gallons)	1	1
Shale, lean (estimated 10 gallons)		9
Shale, rich (estimated 40 gallons)		5
Shale, lean (estimated 10 to 15 gallons)	1	8
Shale (estimated 40 gallons)		10
Shale, lean		11
Shale, (sample 187; 21 gallons)	3	8
Shale (estimated 10 to 15 gallons)	3	0
Shale, thin bedded (estimated 40 gallons)		5
Shale (estimated 10 gallons)	3	7
Sandstone, brown		4
Shale, papery (estimated 30 gallons)	1	7
Shale, lean to barren	1	2
Shale, papery (estimated 30 gallons)	1	1
Shale (estimated 10 gallons)	1	9
Sandstone, slightly asphaltic	1	0
Shale hard (estimated 20 gallons)	3	0
	528	8

Forks of Parachute Creek, about 10 miles north of Grand Valley, about sec. 36, T. 5 S., R. 96 W.

	Ft.	in.
Interval to top (estimated)	150±	
Shale (estimated average 15 gallons).	125	0
Shale (estimated average 30 gallons).	75	0
Shale, rich, hard (sample 193, 5 feet near middle of bed; 42 gallons)	25	0
Shale (average nearly as good as sample 192; probably 30 gallons)	30	0
Covered and lean shale	86	0
Shale (estimated 30 gallons)	45	0
Shale (as good or better than sample 192)	4	6
Shale, sandy, lean	6	0
Shale (estimated 25 gallons)	4	0
Shale (nearly as good as sample 192)	5	0
Shale, medium	15	0
Shale, hard, blue (like sample 192)	3	0
Shale, medium	9	0
Shale, hard, blue (like sample 192).	2	0
Shale, medium	9	0
Shale, hard, blue (sample 192; 36 gallons)	2	6
Interval, probably 40 per cent shale in beds 3 feet or more thick which will test 25 gallons or more to the ton	175	0
Shale (like sample 191)	2	0
Shale, medium rich	5	6
Shale (like sample 191)	3	0
Shale, medium rich	11	0
Shale (like sample 191)	2	0
Shale, lean	6	6
Shale, hard, blue (sample 191; 19 gallons)	5	4
Shale, sandy, yellow	5	0
Shale (estimated 25 gallons)	18	0
Shale, slightly less rich than 190	12	0
Shale, hard (sample 190; 18 gallons).	6	4
Sandstone		3
Shale, lean.		
	847	11

IDAHO.

Sample **196.** Black shale, collected at Mount Jefferson, in sec. 16, T. 14 N., R. 42 E., Fremont County, by D. D. Condit, September, 1916, from bed of carbonaceous shale 4 feet thick overlying phosphate bed in Phosphoria formation (Permian). Results of distillation: Oil, 6 gallons to the ton; specific gravity, 0.938; ammonium sulphate, 2.09 pounds to the ton.

ILLINOIS.

Sample **197.** Black shale, collected on Hicks Branch, southwest of Hicks, Hardin County, by Charles Butts, from top of Chattanooga shale (Devonian). Results of distillation: Oil, trace; ammonium sulphate, 4.98 pounds to the ton.

KENTUCKY.

Sample **198.** Black shale, collected in small quarry one block southeast of courthouse at Irvine, Estill County, by E. W. Shaw, November 3, 1916, from Ohio (Chattanooga) shale (Devonian). Hand specimen taken about 25 feet above base of the formation, which is here 120 feet thick. Shale being used for road metal. Results of distillation: Oil, 7 gallons to the ton.

MARYLAND.

Sample **199.** Lignitic clay, collected at about level of high tide at Point Sable, on Magothy River about 20 miles southeast of Baltimore, in Anne Arundel County, by R. H. Wood, October 21, 1916, from Magothy formation (Upper Cretaceous), bed about 4 feet thick. Results of distillation: Oil, 2 gallons to the ton; ammonium sulphate, 2.87 pounds to the ton.

Sample **200.** Lignitic clay, collected at about level of high tide at Point Sable, on Magothy River about 20 miles southeast of Baltimore, in Anne Arundel County, by R. H. Wood, October 21, 1916, from Magothy formation (Upper Cretaceous), bed about 4 feet thick. Results of distillation: Oil, 3 gallons to the ton; ammonium sulphate, 2.91 pounds to the ton.

Sample **201.** Chocolate-colored clay, collected at about level of high tide at Point Sable, on Magothy River about 20 miles southeast of Baltimore, in Anne Arundel County, by R. H. Wood, October 21, 1916, from Magothy formation (Upper Cretaceous), bed about 4 feet thick. Results of distillation: Oil, none; ammonium sulphate, 0.94 pound to the ton.

MISSOURI.

Sample **202.** Black shale, collected 1½ miles north of Noel, on east side of valley, by David White, October 11, 1916, from Chattanooga shale (Devonian). Results of distillation: Oil, 2 gallons to the ton; ammonium sulphate, 2.31 pounds to the ton.

Sample **203.** Black shale, collected from river bank west of Noel, by David White, October 11, 1916, from upper part of Chattanooga shale (Devonian). Results of distillation: Oil, 2½ gallons to the ton; ammonium sulphate, 2.53 pounds to the ton.

MONTANA.

Sample **204.** Black shale, collected from an old prospect in Smallhorn Canyon, about 12 miles south of Dillon, Beaverhead County, by C. F. Bowen, October 2, 1916, from beds regarded as probably representing the Phosphoria formation (Permian). The following section was measured:

Section of shale bed in Smallhorn Canyon.

	Ft.	in.
Shale, black	3	9
Shale, clayey [1]		1
Shale, black [1]	1	0
Shale, dull brown, earthy [1]		6
Shale, black [1]		6
Shale, brown [1]		7
Shale, black	1	9
	8	2
Part sampled	5	6

Results of distillation: Oil, 24 gallons to the ton, specific gravity, 0.975; ammonium sulphate, 12.02 pounds to the ton.

Sample **205.** Brown shale, collected a quarter of a mile west of MacKay's oil well on Muddy Creek, 14 miles west of Dell, Beaverhead County, by C. F. Bowen, October 8, 1916; represents a thickness of about 3 feet in the upper half of a Tertiary bed about 85 feet thick, which appeared uniform in character throughout. Results of distillation: Oil, 8 gallons to the ton.

Sample **206.** Black shale, collected 5 miles east of MacKay's oil well, in the "Hidden Pasture," about 10 miles west of Dell, Beaverhead County, by C. F. Bowen, October

[1] Not sampled.

9, 1916, near the base of an 80-foot bed of shale in the Phosphoria (?) formation (Permian). Results of distillation: Oil, 9 gallons to the ton.

Sample **207.** Black shale, collected in Warm Spring Canyon, sec. 22, T. 9 S., R. 3 W., Madison County, by D. D. Condit, September 10, 1916, from bed 1 foot 8 inches thick below phosphate bed, in Phosphoria formation (Permian). Results of distillation: Oil, 3 gallons to the ton; ammonium sulphate, 7.85 pounds to the ton.

Sample **208.** Shale, collected in sec. 29, T. 22 N., R. 8 W., Teton County, by M. I. Goldman, August 31, 1916, from weathered outcrop of bed 15 to 20 feet thick, 600 feet above base of Colorado shale (Upper Cretaceous).

Sample composed of pieces of shale picked at random along outcrop. Results of distillation: Oil, 1 gallon to the ton; ammonium sulphate, 2.08 pounds to the ton.

Sample **209.** Shale, collected in sec. 9, T. 24 N., R. 8 W., Teton County, by Eugene Stebinger, August 23, 1916, from bed 6 feet thick, 700 feet above base of Colorado shale (Upper Cretaceous). Sample consists of fragments picked up at random. Results of distillation: Oil, 1½ gallons to the ton; ammonium sulphate, 3.72 pounds to the ton.

Sample **210.** Shale, collected in sec. 9, T. 24 N., R. 8 W., Teton County, by Eugene Stebinger, August 23, 1916, from upper 10 feet of 25 feet at outcrop, 600 feet above base of Colorado shale (Upper Cretaceous). Sample composed of fragments of shale picked at random. Results of distillation: Oil, 2 gallons to the ton; ammonium sulphate, 5.09 pounds to the ton.

Sample **211.** Shale, collected in sec. 9, T. 24 N., R. 8 W., Teton County, by Eugene Stebinger, August 23, 1916; represents lower 10 feet of a bed 25 feet thick, 600 feet above base of Colorado shale (Upper Cretaceous). Sample selected at random from material along outcrop. Results of distillation: Oil, 2 gallons to the ton; ammonium sulphate, 3.51 pounds to the ton.

Sample **212.** Calcareous shale, collected in sec. 29, T. 22 N., R. 8 W., Teton County, by M. I. Goldman, August 31, 1916, from bed 3 feet thick, 600 feet above base of Colorado shale (Upper Cretaceous). Sample selected at random from outcrop. Results of distillation: Oil, trace; ammonium sulphate, 2.17 pounds to the ton.

OKLAHOMA.

Sample **213.** Shale, collected in the NE. ¼ sec. 22, T. 19 N., R. 12 E., Tulsa County, by R. H. Wood, February, 1917, from Pennsylvanian black shale about 2 feet thick above the Checkerboard lime. Results of distillation: Oil, 2.75 (?) gallons to the ton; ammonium sulphate, 3.11 pounds to the ton.

Sample **215.** Black shale, collected along road 1 mile east of Atoka, by David White, October 16, 1917, from bed 10 inches thick in Talihina chert (Ordovician). Results of distillation: Oil, 3 gallons to the ton; ammonium sulphate, 5.60 pounds to the ton.

UTAH.

Sample **218.** Cannel coal, collected in Cannel King mine, Kane County, in sec. 26, T. 39 S., R. 9 W., by G. B. Richardson,[1] in 1907; represents a bed 5 feet 6 inches thick. The sample used for distillation had been in a closed glass jar since 1907 and was therefore only slightly weathered. Results of distillation: Oil, 70 gallons to the ton; ammonium sulphate, 14.4 pounds to the ton.

Sample **185.** Oil shale, collected in sec. 2, T. 18 S., R. 4 E., at top of Wasatch Plateau, San Pete County, by D. E. Winchester, September, 1916, from Green River formation (Eocene). Results of distillation: Oil, 21 gallons to the ton, specific gravity 0.877; ammonium sulphate, 2.66 pounds to the ton.

---

[1] Richardson, G. B., The Harmony, Colob, and Kanab coal fields, southern Utah: U. S. Geol. Survey Bull. 341, p. 394, 1909.

Section of oil shale near head of Manti Canyon, in sec. 2, T. 18 S., R. 4 E.

	Ft.	in.
Shale.		
Shale, thin bedded		7
Sandstone [1]		2
Shale, thin bedded		6
Sandstone [1]		4
Shale, thin bedded		6
Sandstone [1]		2
Shale, thin bedded		3
Sandy limestone.		
	2	6

Sample **186**. Oil shale, collected in Chris Canyon, Juab County, by D. E. Winchester, September, 1916, from Green River formation (Eocene). Results of distillation: Oil, 22 gallons to the ton, specific gravity 0.893; ammonium sulphate, 2.57 pounds to the ton.

Section at mouth of old tunnel in Chris Canyon, southeast of Juab, Utah.

	Ft.	in.
Shale, green, barren	1	0
Sandstone	1	6
Shale, green, barren		10
Sandstone	1	8
Shale, thin bedded, yellow	1	2
Sandstone		10
Shale (as good as sample 186)	3	6
Shale, lean	3	4
Shale, rich (sample 186; 22 gallons)	2	3
Shale, lean.		
	16	1

WYOMING.

Sample **219.** Shale, collected along road from Raymond to Snells, on Crooked Creek, in sec. 33, T. 58 N., R. 95 W., Big Horn County, by C. J. Hares, near base of Thermopolis shale (Upper Cretaceous). Results of distillation: Oil, none; ammonium sulphate, 4.16 pounds to the ton.

Sample **220.** Shale, collected north of Beer Mug Ridge, near Hanna, by C. F. Bowen, October 1, 1915, from Mowry shale (Upper Cretaceous). Results of distillation: Oil, 1 gallon to the ton; ammonium sulphate, 1.4 pounds to the ton.

[1] Not sampled.