OIL RESOURCES OF BLACK SHALES OF THE EASTERN UNITED STATES.

By George H. Ashley.

PURPOSE AND SCOPE OF INVESTIGATION.

It has long been known that black shales owe their color to bituminous or carbonaceous matter and that most such shales, if heated, will yield gas, oil, and other by-products. For many years such shales have been distilled for oil in Scotland and other European countries. The Scotch distilleries are reported to have been of the greatest aid to England during the present war in supplying the oil-burning ships of her navy, thus saving the excessive cargo rates on oil from America. It has long been recognized in this country that the time would come when the decline of yield in the oil fields would lead to tests of the black shales as a possible source of oil. The recent great increase in the use of light oils in internal-combustion engines has renewed interest in the black shales and has led to definite exploratory work on certain oil shales of the West and preliminary studies on the black shales of the East. Preliminary reports on the results of the studies of the western oil shales by the United States Geological Survey have already appeared.[1]

In 1914 the writer visited and sampled black shales at a number of places east of the Mississippi River. Later other samples were obtained in Pennsylvania by R. V. A. Mills and William R. Cameron, in Ohio by Wilbur Stout, in Illinois by Wallace Lee, in Kentucky and Indiana by Charles Butts, and in Tennessee by F. R. Clark. The samples are described and the results of their distillation given in this report. The writer's samples were all cut on the outcrop with an army adz. First a trench was dug through the weathered surface of the shale until the hard surface of the apparently unweathered shale had been reached. Then a shallow trench the width of the adz was cut in the unweathered rock, and

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[1] Woodruff, E. G., and Day, D. T., Oil shale of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 581, pp. 1–21, 1915. Winchester, D. E., Oil shale in northwestern Colorado and adjacent areas: U. S. Geol. Survey Bull. 641, pp. 139–198, 1916 (Bull. 641–F).

the material thus obtained was broken down and quartered after the manner of taking coal or other samples, until a 5-pound sample was obtained, and this was sent to Washington in a canvas bag. In most places where samples were taken the soft, weathered portion of the shale proved to be very thin and the underlying rock very firm and tough. In a few places the shale was exposed as a vertical face, with little or no weathered material on the face.

OCCURRENCE OF THE SHALES.

The black shales of the Eastern States are mainly at one general horizon, in the Upper Devonian or possibly in part lower Carboniferous, which extends from New York to Alabama and westward to Mississippi River. Other extensive deposits of black shale occur at one or more horizons in the lower part of the Devonian and at one horizon in the Ordovician. In addition, black shales overlie some of the coal beds, especially certain beds in the eastern interior coal field.

The principal body of black shale is known as the Chattanooga, New Albany, or Ohio shale. This bed underlies the eastern coal fields and crops out in a long line from central Alabama northeastward through Tennessee and Virginia and all around the Nashville Basin, in central Tennessee. West of the Appalachian coal field its outcrop extends from north to south across central Ohio, passing close to Columbus and reaching Ohio River near Vanceburg. Thence the outcrop makes a loop through central Kentucky, past Lebanon, and northward to Louisville, from which it stretches in a broad belt northwestward across Indiana, past Indianapolis nearly to Chicago. From this western belt of outcrop the shale extends eastward under eastern Ohio and underlies nearly all of Kentucky except the area within the loop described and all of Indiana west of the outcrop. Samples of this shale were cut at Cumberland Gap, Rockwood, and Chattanooga, Tenn., on the eastern front of the coal field; at Bakers station and near Newsom station, Tenn., in the Nashville dome area; and near Columbus, Ohio, and at New Albany, Ind., on the western outcrop.

The Middle and Lower Devonian of New York, Pennsylvania, Maryland, and West Virginia contain thick beds of dark shale that is locally black and fissile. Samples were cut near Hancock station, W. Va., in the black layers of the Onondaga shale member of the Romney shale.

Black shales overlying coal beds were sampled near Boonville, Ind., where the No. 5 bed was being stripped by a steam shovel, and at Springfield, Ill. Few of the black shales over the coals have a thickness of more than 5 feet.

SAMPLES OF THE SHALES.

INDIANA.

Samples were cut at two places in Indiana, at New Albany in the New Albany black shale, which is there about 100 feet thick, and northeast of Boonville, where black shale makes the roof of the No. 5 coal.

Sample 1 was cut in the upper part of the New Albany black shale in the bank of Ohio River at the mouth of Falling Run, just below New Albany. The sample represents a 10-foot section, of which the upper 5 feet was taken in the face of a vertical cliff on the east side of the run and the lower 5 feet from the shelving exposure just below. About 20 feet of black shale, carrying many thin streaks of hard, apparently limy shale, is exposed here, of which the sample represents the lower 10 feet. The shale in the vertical face was very tough. The shale in the shelving river bank breaks out into quadrangular plates 2 to 4 inches thick, which may be as much as 3 or 4 feet in length or width. The edges follow jointing planes that run S. 65° W. and S. 30° W.

Sample 2 was cut in 1915 by Charles Butts at the same place as sample 1.

Sample 3. Many large bowlders or concretions of the black shale occur on the river bank at New Albany. The outside portions of these bowlders for a variable distance in are weathered to a gray color. The central portions are still a dark bluish black and give off a marked oily odor when broken. Sample 3 was made up of fragments from the black centers of a number of these bowlders. The bowlders appear to be concretionary.

Sample 4. At low water the immediate bank of the Ohio under the Kentucky & Indiana Railroad bridge at New Albany is a gentle slope, exposing about 25 feet of New Albany black shale. A trench 15 feet long and 6 to 10 inches deep was cut in this rock near the upper edge of the exposure. Sample 4 was cut in the bottom of this trench and represents a vertical thickness of about 5 feet.

Sample 5 was cut just above the Kentucky & Indiana Railroad bridge at New Albany in 1915 by Charles Butts.

Sample 6. A short distance northeast of Boonville the No. V coal bed is being stripped on a large scale by the Ohio Valley Coal Co. The coal is from 6 to 9 feet thick, and over it is 4 feet of black shale. Sample 6 was cut from the full thickness of the shale where freshly dug by the steam shovel. The black shale is overlain by 9 feet of drab to dark shale, 10 inches of limestone, 6 feet of light-gray shale, and 10 feet of light-brownish clay and soil. This sample should be as unweathered as any to be obtained by such stripping.

Sample 7 was obtained from a 5-foot cut in the lower part of the 9 feet of dark shale immediately overlying the shale cut for sample 6.

The sample was cut to determine if the dark shales carried even a small amount of oil.

Sample 8 was obtained from a second cut in the black shale immediately over the coal at a point near the power house at the upper end of the stripping. At this place the black shale is 6 feet thick and is overlain by 3 to 4 feet of gray shale and 10 feet or less of clay and soil. The black shale at this point had been exposed for many months, if not a year. It is of interest, however, to note that notwithstanding this fact and the small thickness of covering, the sample gave a larger yield of oil than sample 6. It may be noted that this shale is dead black on the fresh surface instead of having the chocolate-brown color of many of the shales sampled.

ILLINOIS.

Sample 9 was obtained from the black shale roof of No. 5 coal at the East Capitol mine, in Springfield, Ill., by breaking up a number of large blocks of black shale that had been removed from the mine about a week before in cleaning up a roof fall. Only the "hearts" of the blocks were taken to avoid including any shale that might have been weathered along the joints after the removal of the coal. The breaking down of the shale would naturally follow the joints, and the joint faces would form the outside surfaces of the blocks. The shale appeared to be massive, nonfissile, and blackish drab.

Sample 10 was cut by Wallace Lee in the roof shales of the No. 5 coal at the Saline mine, Gallatin County.

KENTUCKY.

Sample 11 was obtained by Mr. Butts in 1915 from an 8-foot cut in the New Albany black shale at the west end of the canal at Louisville.

Sample 12, taken by Wallace Lee, consists of the so-called coal rash or mother of coal associated with the coal bed at the Barnaby mine, Crittenden County.

Sample 13, also taken by Wallace Lee, represents carbonaceous shale that lies 50 feet above the Bell coal at Caseyville, Ky.

OHIO.

On the recommendation of Prof. J. A. Bownocker, State geologist of Ohio, samples were cut in the Ohio shale in a ravine at Glen Mary, 8 miles north of Columbus. The cuts were made in the nearly vertical face of a wash, about 200 yards below the pike.

Sample 14 represents a cut 5 feet long. The shale, after the removal of 6 inches of weathered rock, broke out in small chips, which had a drab color outside or where cut but black cross sections where broken.

Sample 15 represents a 3-foot cut at the same place but lower in the section. Instead of taking all the material, it was prepared by using only the "heart" of the largest chips, in the hope of obtaining a sample more nearly representative of the rock away from the outcrop. About 15 feet of shale shows at this point.

Sample 16. The Sunbury shale in Ohio is in the lower part of the Carboniferous system, overlying the Berea sandstone, one of the principal "oil sands" of the State. Sample 16 was cut by channeling from the middle of the Sunbury by Wilbur Stout, at Columbus, on the Broad Street pike near Black Lick Creek.

Sample 17 was cut from the base of the Sunbury shale by Mr. Stout on Rock Fork, above the covered bridge northeast of Gahanna. The shale is 6 to 8 feet thick and was sampled by channeling.

PENNSYLVANIA.

Sample 18. The Upper Kittanning coal is a cannel coal at many places in Pennsylvania. Near Cannelton, Beaver County, a deposit of cannel coal at this horizon occupies a narrow, oblong oxbow channel, 5 miles in length and 600 feet wide. The coal is 15 feet thick in the center of the basin, but thins to 2 feet or less at the edges. It is underlain by 1 foot of bituminous coal. Over the coal is a black shale that in places in the mine has broken down for several feet. Sample 18 was cut from the edge of one of these breaks, where the shale had been exposed to the air for 60 years or more. The black shale roof may have a much greater horizontal extent than the minable coal beneath. I. F. Mansfield, who has mined the coal here for many years, estimates that there is a thousand acres of shale from 3 to 5 feet thick.

Samples 19 to 24 were taken by R. V. A. Mills in Butler County but in connection with the geological survey of the Butler quadrangle. Probably none of these samples represents sufficient thickness to indicate a workable deposit, but they are of interest as showing what may be obtained from such shales.

Sample 19 represents a cannel-like shale, 1 foot thick, underlying 16 inches of thin-bedded black shale and overlying 15 inches of mottled clay that in turn overlies the Lower Freeport coal 2 feet thick, in the southwest corner of Clay Township. The yield from this sample suggests a true cannel coal.

Sample 20 was taken from the dump of an old mine 1 mile north of Muddy Creek, three-quarters of a mile west of the Bessemer Railroad, 1 mile northwest of Queen Junction. The material is probably a low-grade cannel coal, apparently about 2 feet thick.

Sample 21 represents 1 foot of cannel-like shale or cannel coal in a weathered outcrop beside the road in the southwest corner of Clay Township, 1,000 feet west of the Butler and Mercer Pike.

Sample 22 represents 1 foot of cannel shale and 3 inches of cannel coal from the unmined roof over the Upper Freeport coal in the Muntz mine, just south of Butler.

Sample 23 was gathered from the dump of an abandoned mine on the north bank of Swamp Run, on the eastern edge of the Zelienople quadrangle. The bed is reported to have been lenticular, to have had a maximum thickness of 6 feet, and to have consisted entirely of black shale at the Lower Freeport horizon.

Sample 24 represents the lowest 10 feet of a black shale over the Upper Freeport coal exposed on the old State road on the hill just south of Butler. The upper part of the shale grades into sandy shale.

TENNESSEE.

The Chattanooga black shale underlies nearly all the upland region of middle Tennessee. It crops out along the foot of the escarpment east of the coal field and near the foot of the escarpment facing the Nashville Basin. West of the Nashville Basin and along Tennessee River are many areas where the black shale underlies gentle slopes. It was sampled at Cumberland Gap; at Rockwood, where the writer was taken to the best exposures by Mr. George E. Sylvester, formerly State mine inspector; at the south end of the ridge south of Alton Park, near Chattanooga, in some old workings for "phosphate"; at Bakers station, on the Louisville & Nashville Railroad, north of Nashville; and at the top of a quarry about halfway between Newsom and Pegram stations, on the Nashville, Chattanooga & St. Louis Railway, west of Nashville.

Samples 25 and 26 were taken at Cumberland Gap in the railroad cut at the mouth of the tunnel. At this point a fault crosses the mountain and the shales are much crushed and contorted. Where sample 26 was cut nearly a quarter of the rock is sandy and calcareous material. All the rock has been crushed until it mines out in slickensided flakes. These samples do not afford a fair test of what this shale should yield away from the fault.

Sample 27. The samples obtained at Rockwood give a better test of the oil contents of the Chattanooga shale along the front of the Cumberland escarpment. Sample 27 was taken from a 2-foot cut at a corner one block north of the main street, near the railroad, where the shale has a high dip and is much crumpled.

Sample 28 represents a 5-foot cut at a point north of Rockwood and west of the iron mines. The shale here also has a high dip and is much crumpled.

Sample 29. A connecting spur built northeast of Rockwood station about 1900 cut through the black shale, which at this point has a dip of about 15°, but is contorted so as to resemble material having cone in cone structure. Sample 29 represents a 3-foot trench at the west end of this cut.

Samples 30 and 31. Some years ago a mine was opened in the Chattanooga black shale a few miles south of Chattanooga, close to the road at the south end of a ridge extending south from Alton Park. The shale at this place is only 6 feet thick. It is underlain by 10 feet or more of light-drab clay and overlain in order by 18 inches to 2 feet of cream-colored clay, 6 inches to a feather edge of dark-drab to black shale, 18 inches of drab shale, 2 feet 6 inches of cream-colored cherty clay, and 20 feet or more of gray chert. The rocks at the mine have a dip of about 12°. Sample 30 was cut 30 or 40 feet from the entrance to the mine and sample 31 about 15 feet from the entrance. The black shale here is not typical. Sample 30, for example, resembles a hard grayish-black massive to fissile clay.

Samples 32 to 34 were taken at Bakers station, where the Louisville & Nashville Railroad crosses the Chattanooga black shale in descending from the highland rim to the Nashville Basin. The top of the black shale at this point rises above the railroad track a short distance above the station, and the whole of it is exposed a short distance below the station. The shale has a thickness of 27 feet, of which the upper 11 feet is jointed and "sheety"—that is, it breaks out in large thin sheets—and the lower 16 feet is fissile. Over the black shale is 1 foot of green shale with concretions (Maury glauconitic member of Ridgetop shale), then 30 feet or more of characteristic Ridgetop shale. The railroad cut is only a few years old, having been made in a realignment and regrading of the road. The dip is less than 1°.

Sample 32 includes 5 feet of the top of the bed where it reaches that height above the drain. Part of the rocks come out in plates one-fourth to one-half inch thick, but most of it breaks out as irregular massive chunks several inches thick. In places partly weathered pieces indicate that this massive phase weathers into the characteristic thin flakes. The rocks were shattered by blasting in making the cut, and the action of weathering has penetrated along the fracture planes to a slight extent. The top 18 inches has a chocolate-brown streak where cut across, but the next 30 inches gives a blackish-gray to grayish-black streak.

Sample 33, taken at the west end of the bluff below the station, includes 5 feet of a section starting 6 feet below the top of the formation. The shale is hard and massive and of a dark chocolate color. It is strongly jointed, and the long or face joints run N. 63° W. and the short or butt joints N. 48° E.

Sample 34 represents 5 feet in the middle of the lower 16 feet of thinly laminated shale. The color is a grayish black. On the joint faces the shale has the appearance of a dull-black clay.

Sample 35. Around Newsom and between Newsom and Pegram are a number of large limestone quarries. At one of these, about halfway between the two stations, the limestone is overlain by 10 feet or more of black shale, which is exposed only at the top of the vertical face of the quarry. Sample 35 was taken at one side where the black shale reaches the slope of the hill and is obviously weathered, as after a preliminary trench several feet deep had been cut the material taken out below it was soft.

Sample 36 was taken at the same place as sample 35, but from the vertical face of the shale at the top of the quarry by cutting steps down to a slight quarry shelf. The shale, though dull brown and weathered, had the usual firmness.

Sample 37 was cut by F. R. Clark and represents 6 inches of bituminous shale overlying the cannel coal at Newcomb, Tenn.

WEST VIRGINIA.

Samples 38 to 42 were cut in the black shale of the Onondaga member of the Romney shale, of Middle Devonian age, at a locality well east of the coal fields, in what has been called the Appalachian Valley. In this region the rocks have been closely folded, and it was therefore thought that the oil in the black shale must have been driven out and that the black color was due entirely to the residue of carbon. The distillation tests confirm this opinion. The samples were cut on the West Virginia side of the Potomac, near Hancock station. In the large cut half a mile above the station the rocks dip 40° S. 45° E. The section shows 25 to 30 feet of black fissile shale, 25 feet of olive-drab shale, and 40 feet of grayish-black shale with rusty joint faces, underlain by the Oriskany sandstone.

Sample 38 represents a 40-foot cut in the black fissile shale about 100 feet above the railroad track. This shale was cut out in pieces ranging from plates 1 inch thick down to thin scales. The plates are rusty on the bedding faces but black on cross faces when broken.

Sample 39 was taken from a 5-foot cut at a bold outcrop of the olive-drab shale.

Samples 40 and 41 represent two cuts in the grayish-black shale.

Sample 42 was cut in grayish-black shale beside the road to Berkeley Springs, about a quarter of a mile from the station.

DISTILLATION TESTS.

Two sets of tests of the writer's samples were made under the direction of David T. Day by means of an electric furnace or a gas heater, in which the temperature was raised slowly until all the oil appeared to have been driven off, when the temperature was raised further to drive off the remainder of the gas. The first series of tests were of a preliminary nature and were made at the Geological Survey by J. A. Dorsey; the second series were made at the Bureau of Mines by C. R. Bopps. The samples collected in 1915 were tested at the survey by D. E. Winchester. In order to show how the yields of these samples compare with the yields of cannel coal, results obtained from a number of cannel coals that were distilled at the same time and in the same manner are included in the subjoined table. These coals are described in a bulletin on cannel coal to be published by the Survey. With the possible exception of the Cannelton cannel they are not as rich as many of the Kentucky cannels.

Tests of black shale and of some cannel coals from the eastern United States.

[By David T. Day, except those marked *, which were made by D. E. Winchester.]

Sample No.	Locality.	Preliminary test.			Final test.				
						Yield per short ton.			
		Amount used (grams).	Oil obtained (cubic centimeters).	Yield per short ton (gallons).	Amount used (ounces).	Oil (gallons).	Water (gallons).	Gas (cubic feet).	Ammonia (pounds).
	SHALE.								
1	New Albany, Ind	100	3	7	6	3.5	5.6	719	0.08
2	....do				6	9.1	4.2	958	0
3	....do	100	7	16	6	11.2	7	2,043	.15
4	....do	100	3	7	6	4.9	8.4	1,097	0
5	....do				6	11.9	6.3	1,197	0
6	Boonville, Ind	100	3	7	6	14	11.2	2,522	.97
7	....do	100	0	0	6	None.	9.8	479	0
8	....do	100	9	21	6	15.4	12.6	2,922	.61
9	Springfield, Ill	100	5	12	6	11.9	9.8	2,186	.65
*10	Gallatin County, Ill				8½	16	7.5	Not det.	3.44
11	Louisville, Ky				6	11.2	4.2	1,016	0
*12	Crittenden County, Ky				8½	14	12	Not det.	2.58
*13	Caseyville, Ky				8½	Trace.	Trace.	Not det.	2.28
14	Glen Mary, Ohio	100	3	7	6	7.7	5.6	1,199	.11
15	....do	100	4	9	6	5.6	5.6	958	0
*16	Columbus, Ohio				8½	4	18	Not det.	1.02
*17	Gahanna, Ohio				8½	11	18	Not det.	1.61
18	Cannelton, Pa	100	12	28	6	27.3	9.1	2,905	.92
*19	Clay Township, Pa				8½	45	15	Not det.	3.72
*20	Queen Junction, Pa				8½	43	13	Not det.	4.99
*21	Clay Township, Pa				4¼	34	18	Not det.	5.21
*22	Butler, Pa				8½	24	11	Not det.	9.43
*23	Zelienople quadrangle, Pa.				4¼	18	10	Not det.	2.53
*24	Butler, Pa				8½	1	11	Not det.	1.66
25	Cumberland Gap, Tenn	100	1	2	6	1.4	8.4	598	.28
26	....do	100	1	2	6	Trace.	3.5	230	0
27	Rockwood, Tenn	100	4	9	6	7.7	9.8	1,488	.15
28	....do	100	3	7	6	5.5	7	1,128	.17
29	....do	100	1	2	6	2.8	14	1,077	0
30	Alton Park, Tenn	100	0	0	6	Trace.	14	835	0
31	....do	100	Trace.	0	6	.7	9.1	1,437	0
32	Bakers station, Tenn	100	4	9	6	9.1	4.2	1,916	.33
33	....do	100	3	7	6	9.1	4.9	1,485	.10
34	....do	100	3	7	6	6.3	8.4	1,557	.10
35	Newsom, Tenn	100	0	0	6	None.	12.9	835	.15
36	....do	100	3	7	6	4.2	8.4	835	.21
*37	Newcomb, Tenn				8½	21	2	Not det.	5.07
38	Hancock station, W. Va	100	0	0	6	Trace.	7	538	0
39	....do	100	0	0	6	7	9.8	636	1.00
40	....do	100	0	0	6	Trace.	11.2	393	0
41	....do	100	0	0	6	7	8.4	230	0
42	....do	100	0	0	6	None.	7	319	0
	CANNEL COAL.								
	Altoona mine, Indiana County, Pa	100	10	24	6	20.3	7.7	4,790	5.57
	Bostonia mine, Armstrong County, Pa	100	17	40.8	6	33.6	7	5,029	5.37
	Pine Run No. 1, Armstrong County, Pa	100	14	33.6	6	25.2	9.8	5,029	5.06
	Pine Run No. 3, Armstrong County, Pa	100	8	19	6	31.5	8.4	4,311	3.68
	Cannelton, Beaver County, Pa	100	21	50.4	6	37.3	10.5	5,268	2.24

According to these figures the Devonian black shale can be expected to yield not over 10 or 12 gallons of oil, 2,000 cubic feet of gas (as a by-product), and one-third of a pound of ammonia to the ton. Shales that are highly folded yield less oil or none at all, though the first sample cut at Rockwood, Tenn., gave an unexpectedly high result, notwithstanding the folded condition of the rocks at that place. Later experiments show that by distillation under steam the yield of ammonia may be increased above the figures given in the table.

It seems possible, if not probable, that many of the apparently unweathered samples have lost some or much of their oil. The black shale was found to be unexpectedly tough, so that the attempt to cut samples in the same manner as coals or clays are sampled proved extremely slow, and, moreover, doubt remained as to whether the shale face had been trenched deeply enough to be beyond the reach of surface weathering. This toughness will have a marked influence on the cost of mining. At the stripping near Boonville it has been found that the steam-shovel teeth ordinarily used wear out at once in digging the black shale, so that it is necessary to use special teeth of manganese steel, and even these last only two weeks.

OIL CONTENT.

To give some idea of the amount of oil in this shale a few figures are given for the body of black shale in southwestern Indiana. The weight of this shale is not known. Common shale weighs about 160 pounds to the cubic foot, or practically twice as much as coal, but this weight is reduced by the presence of hydrocarbons, and high-grade oil shales weigh as little as 100 pounds to the cubic foot. If a weight of 130 pounds to the cubic foot is assumed, it will require about 15.4 cubic feet of shale to weigh a short ton. If 1 ton of shale is assumed to yield 10 gallons of oil, 100 cubic feet of shale may be assumed to yield 64.9 gallons, or say roughly 1½ barrels (of 42 gallons).

The following table gives some measurements of the thickness and depth to the top of the black shale at places in Indiana, as obtained in drilling oil wells:

Reported thickness and depth of New Albany black shale in Indiana.

Locality.	Thickness.	Depth to top
	Feet.	*Feet.*
Albion, Noble County	65+	[a] 375
Bloomington, Monroe County	120	790
Bridgeport, Marion County	124	140
Brownstown, Jackson County	147	318
Columbus, Bartholomew County	87+	26
Crawfordsville, Montgomery County	80	550
Fowler, Benton County	92	[a] 280
Kentland, Newton County	100+	[a] 100
La Fayette, Tippecanoe County	120	100
Martinsville, Morgan County	120	408
New Albany, Floyd County	104	80
Oxford, Benton County	100+	[a] 385
Remington, Jasper County	85	5
Rockville, Parke County	102	1,044
Salem, Washington County	103	627
Seymour, Jackson County	130+	[a] 75
Thornton, Lawrence County	87	303

[a] Roof of black shale is glacial clay.

These figures give an average thickness of not far from 100 feet. As exposed from Jeffersonville to and beyond New Albany, the shale shows little variation from top to bottom. It is not certain that the black shale as reported in the well logs is all of the same character. In fact, some of the exposures of the "black shale" in the northern part of the State indicate that the shale in that region is not uniformly black, as is shown by the following section:[1]

Section of "black shale" at Delphi, Ind.

	Ft.	In.
Drift	7	0
Bluish-black shale, sheety and tough	45	0
Drab-grayish, slightly sandy shale	4	6
Band of gray concretions	6	14
Drab sandy shale	10	6
Bluish-gray sandstone	4	10
Drab sandy shale	5	6
Covered	8(?)	
Devonian limestone.		

The log of a deep well at Terre Haute, believed to have gone through this black shale, shows the following beds:

Partial record of deep well at Terre Haute, Ind.

	Thickness	Depth.
	Feet.	*Feet.*
Blue shale	40	1,622
Black shale	15	1,637
Red shale	5	1,642
Black shale	15	1,657
Limestone	5	1,662
Black shale	5	1,667
Limestone.		

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[1] Kindle, E. M., Indiana Dept. Geology and Nat. Res. Twenty-fifth Ann. Rept., p. 533, 1900.

It is a very moderate assumption to place the average thickness of the oil-yielding rock at say 30 feet, of which it might be possible to mine out one-half, or 15 feet. The New Albany black shale underlies about 16,000 square miles. If 15 cubic feet of rock weighs 1 ton and yields 10 gallons of oil, 10 gallons of oil should be obtainable for every square foot of this area in southwestern Indiana. As a square mile contains roundly 28,000,000 square feet, the yield would be 280,000,000 gallons or nearly 7,000,000 barrels of oil to the square mile, or say 100,000,000,000 barrels for the total area underlain by the shale in southwest Indiana.

FUTURE DEVELOPMENT.

If it costs as much to mine a ton of shale and distill the oil from it as it does to mine a ton of coal, say $1 (as a matter of fact the cost is likely to be higher), a barrel of crude oil obtained in this way will cost about $4.20. This estimate assumes that the gas yielded is used in the distillation of the oil and takes no account of the value of by-products nor of the possibility that the oil may yield products of higher value than the crude oils now obtained by drilling.

At present interest in the mining of the eastern black shales as a source of oil must confine itself to localities where one of three conditions is met. The shale can be utilized, first, where it outcrops in a position to permit mining on a large scale by steam shovel at a minimum cost; second, where coal that is overlain by bituminous shale is being stripped; and third, where a coal bed that is being mined has a black shale roof that comes down and must be removed from the mine in large amounts. Of these the second condition seems to offer the best opportunity for a trial plant, as the overlying black shale must be removed in mining the coal. At such pits it would require only that another shovel be installed to lift the shale, or the small shovel now used to lift the coal could be used to lift the black shale first. This black shale over the coal appears to have the advantage of a higher oil yield. Where the roof shale is as rich as at Cannelton, Pa., it may pay to mine the shale with the coal.

ANALYSES.

In the Twenty-first Annual Report of the Department of Geology and Natural History of Indiana Hans Duden gives two analyses of black shale obtained at New Albany, and as that report is now out of print, they are quoted here:

Analyses of black shale from New Albany, Ind.

[By Hans Duden.]

	1	2	
Water expelled at 100° C.	0.50		
Water expelled at 100° C. during 4 hours			0.56
Volatile organic matters	14.16	14.30	23.60
Fixed carbon	9.30		
Fixed organic matters		9.30	
Silica	50.53		
Silicates insoluble in HCl			65.43
Pyritic iron and alumina [a]	25.30		
Ferric oxide			8.32
Calcium oxide	.09		.09
Magnesium oxide	.12		.12
Sulphur			2.08
	100.00		100.00

[a] The amount of pyrite and alumina changes considerably in different layers. This piece had 10.367 per cent iron pyrite and 14.933 per cent alumina.

In the same report Duden gives the results of experiments in making illuminating gas from the shale, using as a retort a 4-inch pipe 6 inches long, capped at both ends and connected by a ¾-inch pipe with washing and refining apparatus.

Gas produced from black shale and Pittsburgh coal.

	Gallons.
5 pounds of Pittsburgh coal	105
8.5 pounds of black slate	45
8.5 pounds of black slate, Ohio banks	50
8.5 pounds of black slate, Falling Run banks	65
15 pounds of freshly broken slate	105
15 pounds of the same after exposure to air for 14 days	100

He also quotes from a letter describing an experiment in the production of gas at the New Albany Gas Light & Coke Co.'s plant:

> I carbonized 3 tons of the New Albany black slate and obtained a yield of 2.20 cubic feet per pound of 22-candlepower gas. Ordinary unenriched coal gas is about 18 candlepower. The quality of gas, therefore, is better and the yield 45 per cent of that obtained from Pittsburgh coal. Of the amount of oil or tar obtained I know nothing, as I did not make any measurements. The slate does not materially change its color or form by being carbonized. The residue contains much sulphur and, so far as I know, is useless for fuel. I made no scientific test. With the arrangement we have for making gas, it would not pay us to use the slate, even though we could obtain it for nothing. The slate was obtained from near the exposed surface of a creek bottom, and I am sure that if a sample was gotten at a greater depth, a much better yield of gas would be obtained.

Duden then describes the oil obtained in his experiments:

> Crude oil obtained by atmospheric pressure from the slate exhibits a black coloration, has a very bad smell, and is very difficult to refine. In oil obtained with stills provided with a vacuum pump the vapors are removed from the hot still walls as quickly as formed. At the same time the temperature necessary

to form the vapors is materially lowered (about 100° C.). A vacuum of 15 inches gave very good results. The oil is nearly colorless and without much smell. By leading into the still a small amount of steam and the vacuum apparatus left as in the last case, then in the watery part of the distillate ammonia was increased materially and can be used for manufacturing sulphate of ammonia.

GOVERNMENT INVESTIGATIONS.

In 1916 Mr. Winchester continued his studies of the oil shale in the Uinta Basin of Utah, and it was planned that C. F. Bowen should examine the black shale in southwestern Montana, near Dillon. In addition to these studies, samples of black shales are being collected by other members of the Survey as opportunity offers and tested by Mr. Winchester.

In addition to this work by the Geological Survey, the Bureau of Mines proposes to erect a shale retort of the Del Monte type in the navy yard at Washington, D. C., for the purpose of carrying on preliminary investigations of the commercial possibilities of oil shales. This work will be under the direction of David T. Day. If the results justify further investigation on a large scale, the bureau will probably erect a large retort, with a capacity of possibly 500 pounds, at either the petroleum experiment station at San Francisco or the Pittsburgh station, for the purpose of obtaining complete information upon the value and possible by-products to be derived from the distillation of shale. This work will be predicated upon the results of the distillation of shale in other countries. The bureau contemplates sending an expert to Scotland to study the Scottish practice at first hand.

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