STATE OF TENNESSEE.
STATE GEOLOGICAL SURVEY.
Wilbur A. Nelson, State Geologist.

BULLETIN 24
Being Part 2-B, Annual Report of 1919

Oil and Gas Resources of the Northeastern Part of Sumner County, Tennessee

By KIRTLEY F. MATHER

NASHVILLE, TENNESSEE
1920
(Reprinted 1962)

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By Kirtley F. Mather.

Work done in co-operation with the United States Geological Survey.

INTRODUCTION

LOCATION AND EXTENT OF AREA

Sumner County is in north-central Tennessee. It is bounded on the north by Allen and Simpson counties, in Kentucky, and on the east by Macon and Trousdale counties, on the south by Wilson and Davidson counties, and on the west by Robertson County, all in Tennessee. The rapid development of the oil industry in Allen County gives special interest now to the adjoining northeastern part of Sumner County, in the general vicinity of Westmoreland, the area mainly considered in this report.

THE SEARCH FOR OIL IN SUMNER COUNTY

During the last three years more than a quarter of a million barrels of oil has been obtained from wells in Allen County, and the search for increased production there, which has gone steadily forward from year to year, has been rewarded by success sufficient to direct the attention of oil producers to the neighboring counties. Among these neighboring counties is Sumner County, Tenn., which has been extensively explored by test wells, more than thirty having been sunk there in 1918 and 1919. Unfortunately none of these wells proved successful, and at this time (October, 1919) there is no producing oil well in the county.

The close proximity of the oil fields near Adolphus and Petroleum, just across the State line, in Allen County, Ky., sugests that oil may be found beneath the similar lands of Sumner County. The failure to find oil in Sumner County in economic quantities therefore presents a problem for both the "practical oil man" and the geologist. In this report the problem is considered from the point of view of the geologist.

THE GEOLOGIST'S PROBLEM

The geologist who begins to study the possible oil resources of a region thus situated would have in mind five questions, namely: (1) Are the geologic conditions that determine or influence the oil resources of the area identical with those in the neighboring oil fields? (2) If not, how do they differ? (3) If they are essentially the same and drilling has failed to

find oil in commercial quantities, what are the reasons for the failure? (4) If there are considerable differences in the geology of the two regions, what has been the effect of those differences on the accumulation of oil? (5) Have geologic features that may have influenced the accumulation of oil been overlooked in both areas?

So far as Sumner County is concerned the answers to certain of these questions were known before field work was begun in 1919. The oil fields of Allen County had been studied in detail by geologists of the United States Geological Survey in the spring of 1917, and a report based on those studies was published in 1919.[1] In the progress of the work in Allen County in 1917 it was found necessary to make a brief reconnaissance into Sumner County, which revealed a number of important features of the geology there.

The surface rocks in Tennessee, as far south as the Highland Rim, to which more detailed reference is made elsewhere in this report, are identical with those in the vicinity of the oil fields in Allen County, Ky. Along the lower slopes of the escarpment which separates the Highland Rim Plateau from the Nashville Basin are numerous outcrops of the black shale and underlying limestones that are known to serve as reservoirs for oil in the oil fields a few miles to the north. Within the Highland Rim area, therefore, the general geologic conditions are similar to those in Allen County. Here, as in Kentucky, there is a shale that is heavily charged with bituminous material and is well adapted to serve as a source for the oil of an oil pool. Beneath the shale there are likewise coarse-textured limestones that might serve as reservoir rocks.

Examination of the Allen County oil fields had revealed the fact that the accumulation of oil pools in those fields has been determined by two features—the attitude or structure of the rocks beneath the black shale, which include the oil-bearing "sands," and the porosity of the limestones that serve as reservoirs for the oil. Most of the oil fields in Allen County are situated on or near the crests of anticlinal folds, where the structure of the rocks has localized the accumulation of oil. In certain places, however, other factors, such as variations in the texture and porosity of the oil-bearing stratum, have induced the formation of pools where the structure is not anticlinal. Similar conditions might be reasonably expected to prevail in the adjoining northeastern part of Sumner County.

With these facts in mind, it was necessary to explain the large number of dry holes and the absence of producing wells in that part of Sumner County. It might be suggested that no one of these dry holes had been drilled in a locality where the attitude of the underlying rocks was favorable for the location of an oil pool. In that case drilling in closely adjacent localities where the structural conditions were favorable ought to pro-

[1]Shaw, E. W., and Mather, K. F., The oil fields of Allen County, Ky.: U. S. Geol. Survey Bull. 688, 1919.

duce good results. On the other hand, examination might reveal the fact that many of the holes already drilled were excellently located with reference to the structure. In that case the absence of oil in paying quantities might be attributed to the "tightness" of the rocks beneath the black shale, a condition which would render them unfit to serve as oil "sands." If this condition existed and if most of the structurally favorable areas had thus been tested and found to be without oil, further prospecting in this region would be useless.

To settle this question the geologist must examine the strata in the vicinity of each test well, and if possible he should see the cuttings from the drill holes. His first purpose in field work therefore would be to make a detailed study of the attitude of the strata and thus determine the exact localities where the structural conditions most favored the accumulation of oil. His second purpose should be to ascertain all the facts concerning the nature and especially the porosity of the rocks immediately beneath the black shale. With this information before him he would be ready to state whether further prospecting is warranted in the region.

FIELD WORK

Co-operative arrangements between the Tennessee Geological Survey and the United States Geological Survey made possible the field work upon which this report is based. The writer spent three weeks in August and September, 1919, in the general vicinity of Westmoreland. He was ably assisted in this work by C. Langdon White, who served as instrument man. Several days in October were also spent in the field, special attention being then given to the results of drilling operations and the collection of well records.

Acknowledgment is made to Mr. Wilbur A. Nelson, State geologist of Tennessee, for many valuable suggestions and for hearty co-operation during the progress of the work. The drillers and oil operators of the region without exception placed all the information which they had at the disposal of the investigators.

GEOGRAPHY OF THE REGION

PHYSIOGRAPHIC PROVINCES

Sumner County embraces within its boundaries portions of two physiographic provinces, which are sharply differentiated from each other both in topography and in geology. The southern third of the county lies in the Nashville Basin, and the remainder of the county forms a part of the Highland Rim Plateau. The escarpment that bounds the plateau and overlooks the Basin is locally referred to as "The Ridge."

NASHVILLE BASIN.

That portion of the Nashville Basin included within the boundaries of Sumner County ranges in altitude from 450 feet above sea level in the southwest corner of the county to 650 feet at the foot of the line of hills which bound this physiographic province on the north. The surface of this part of the county is gently rolling and lies at an average height of 100 to 200 feet above Cumberland River, from which it rises gradually. Near the Highland Rim there are many outlying hills that reach nearly the same altitude as the surface of the plateau, but have gently rounded summits. These are especially numerous in the area a few miles north of Gallatin.

The soil throughout most of the basin is rich and fertile; it is of residual origin, having been derived in place from the decomposition of fairly pure limestones which are chiefly of Ordovician age. It is peculiarly adapted to the production of grasses, especially blue grass, and is the soil that has made the whole central basin of Tennessee famous for its live stock.

HIGHLAND RIM PLATEAU.

The northern two-thirds of Sumner County consists of a much dissected plateau at an average altitude of about 1,000 feet above sea level, or nearly 400 feet above the central basin. The divides between the streams that have cut deeply into this plateau display a general accordance in summit level, suggesting that they were originally part of a plain that sloped gently downward toward the north. In the eastern part of the county these divides are generally sharp, narrow ridges; in the central and western parts of the Highland Rim portion of the county they are broad, rolling table-lands a mile or more in width. In general the stream valleys are youthful or in early maturity, with flood plains only a few rods in width and with steep stony slopes.

The roughest part of the county is found along the southern margin of the Highland Rim Plateau, where the topography is irregular, with numer- vicinity of Westmoreland the topography is everywhere due to stream erosion, but farther west, in the neighborhood of Portland, there are numerous sink

ous narrow ridges extending out into the Nashville Basin. In the general holes, most of which are broad and shallow.

The soil of the Highland Rim Plateau is much less fertile than that in the southern part of the county. Where the divides are sharp and narrow the stony hillsides afford only a meager return for the arduous labor of caring for small patches of tobacco and fields of corn. Where the divides are broad table-lands, however, as near Portland, the soil is deep and loamy, and small fruits such as strawberries are produced in great profusion.

DRAINAGE

The southern boundary of the county follows the sinuous course of Cumberland River, into which the run-off from all that portion of the county south of "The Ridge" is carried directly. Among the larger streams tributary to the Cumberland are Bledsoe Creek, in the eastern part of the county; Station Camp Creek, in the central part; and Drake Creek, in the southwest corner. Within the Highland Rim Plateau the streams flow in a general northerly direction and are eventually tributary to Green River. The head-waters of Trammel Fork are near the eastern border of the county. A short distance to the west is Little Trammel Creek, which joins Trammel Fork a few miles north of the Kentucky line. The next stream of importance toward the west is the Middle Fork of Drake Creek (a stream altogether separate from the Drake Creek of the southern part of the county), with its tributary Dutch Creek. The central part of the Highland Rim portion of the county is drained by the West Fork of Drake Creek and its many tributaries, of which Caney Fork is the largest. Still farther to the west are the head-waters of Red River.

The larger streams have gentle gradients of 10 to 20 feet to the mile, but upstream the gradient steepens, and near the head of each stream it is 30 or 40 feet to the mile. None of the creeks within the Highland Rim portion of Sumner County have developed more than incipient meander curves. Any of them may be safely forded almost anywhere along its course except in time of flood. There are no falls or rapids worthy of note in the county.

ROADS AND TOWNS

Gallatin, near the center of the Nashville Basin portion of the county, is the county seat. In 1910 it had a population of 2,399. It is the junction point between the Scottsville branch and the main line of the Louisville & Nashville Railroad.

Next in size is Portland, on the main line of the Louisville & Nashville Railroad, in the northwestern part of the county. Westmoreland is the center for the northeast quarter of the county and is on the branch line midway between Gallatin, Tenn., and Scottsville.

The roads within the Highland Rim Plateau are generally poor, but may be traversed without difficulty by automobiles except in wet weather.

The road from Gallatin through Westmoreland and down Little Trammel Creek is part of the Jackson Highway, which is much used as an automobile route between Nashville and Louisville, by way of Mammoth Cave. It is not difficult to build roads anywhere in the county, and natural supplies of excellent road materials are abundant.

GEOLOGY

GENERAL FEATURES

The rocks underlying the surface of Sumner County are without exception of sedimentary origin, consisting of nearly flat-lying beds of limestone, shale, and sandstone. In general these beds dip slightly toward the north and northeast, pitching gently away from the crest of the great Nashville dome. They are all Paleozoic and range in age from Ordovician to Mississippian.

Careful examination of these rocks in nearly any locality will reveal the conditions under which they were formed. They are composed of sediments which were at one time either chemically or mechanically deposited on the floor of a great shallow sea. The fact that they contain numerous remains of animals which could live only in salt water indicates that in the main these are marine formations, although at certain times and places the waters may have been brackish or even fresh. Deposited layer upon layer, the sediments gradually accumulated and thus have the form of great sheets of material covering hundreds of square miles of the earth's surface. It can not be expected, however, that exactly the same succession of beds will be found at every locality where rocks of similar age are examined. Variations in the strength of ocean currents, in the profusion of living organisms in the water, and in the quantity and character of the detritus brought into the basins of accumulation by wind and running water were so numerous that there are marked differences in most of these strata as traced from place to place. A certain bed may be at one locality a very pure limestone, and a short distance away a cherty limestone or very sandy. Consequently there may be much variation in materials encountered by the drill at the same horizon in two adjacent wells; moreover, the nature of a bed where it crops out at the surface may be quite different from that of the same bed a mile or two away, where it is covered by overlying rocks.

Differences in the composition of the rocks in different parts of the county may also have resulted from the fact that the building up of these successive layers of sediment was not a steady process. On the contrary, sedimentation and the building up of rocks seems to have been frequently interrupted by erosion and the destruction of rocks. At many different times in the Paleozoic era the sea floor of this region was transformed into dry land; streams cut deep channels into it; and huge quantities of debris were removed to distant basins, there to add to the accumulation of other sediments. Later the sea submerged this eroded land surface and new accumu-

lations of sediments were made. Thus it may happen that strata present in one exposure are entirely absent in another at no very great distance.

STRATIGRAPHY

In a geologic study of any region that may possibly produce oil, questions concerning the nature and sequence of the rocks far below the surface are of great importance. The oil producer is anxious to know what chance there exists of finding productive sands at the depths to which the drill may penetrate. It is a common thing for an oil field to produce for a time from one sand and then from other rich sands to be found at greater depths. Information concerning the deeper strata beneath the surface of Sumner County therefore is of great practical value. Beds that may form oil reservoirs are of special interest, but water-bearing beds, which may interfere with drilling, are also worthy of description. In Sumner County such beds are likely to include limestones, as well as sandstones, for many of the limestones beneath this region are porous and in places cavernous.

Knowledge concerning these deeper beds is not very complete. Information may be obtained from the outcrops of these beds in distant areas within the same general region, as well as from the records of the deeper holes drilled near by. The following reports cover the areas in which the earlier Paleozoic beds appear at the surface within the general region in which Sumner County lies:

Ulrich E. O., and Smith, W. S. T., The lead, zinc, and fluorspar deposits of western Kentucky: U. S. Geol. Survey Prof. Paper 36, 218 pp., 15 pls., 1905.

Butts, Charles, Geology and mineral resources of Jefferson County, Ky.: Kentucky Geol. Survey, 4th ser., vol. 3, pt. 2, 270 pp., 65 pls., map, 1915.

Matson, G. C., Water resources of the Blue Grass region, Ky.: U. S. Geol. Survey Water-Supply Paper 233, pp. 14-17, 1909.

Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Columbia folio (No. 95), pp. 1, 2, 3, 1903

The areas described in these reports are, however, so far distant that their rocks may be quite different from those in Sumner County. The need for more exact information is only in part supplied by the logs of the deep wells in and near this area. Reference to these logs will be made as the individual formations are discussed.

ORDOVICIAN SYSTEM.

The rocks that crop out in the portion of Sumner County included within the Nashville Basin, as well as those lying from about 400 feet to more than 2,000 feet below the surface of the Highland Rim Plateau, belong to the Ordovician system. They consist largely of limestone, most of which is probably too compact to serve as an oil reservoir. The rocks of this system underlie the greater portion of the Nashville Basin, dip beneath the surface of the Highland Rim Plateau, and rise again to the surface in northern Kentucky, where Ordovician rocks are exposed throughout an area about 100 miles in diameter, extending from a point near Louisville westward to Fer-

risburg and Irvine and from Cincinnati to Marion and Lincoln counties. Only the upper part of the Ordovician system crops out within the area shown on the map accompanying this report (Pl. 1). Excellent exposures of this part may be seen along the Jackson Highway between Gallatin and Westmoreland. As the observer travels northward along this road toward Bransford he passes progressively from older to younger formations, all of later Ordovician age. The earlier Ordovician rocks, underlying those which cropt out in this area, are exposed nearer to the center of the Nashville Basin.

Near the bottom of the Ordovician system is a persistent sandstone which is regarded as equivalent to the extensive and widely known St. Peter sandstone of the upper Mississippi basin, or the "Calciferous" of the southern Appalachian region. The St. Peter sandstone does not crop out within the Nashville Basin, but is not far below the surface in the vicinity of Murfreesboro. It has been penetrated by numerous wells within the Nashville Basin and has been reached in certain of the deepest wells in several of the oil fields of Kentucky. Near Irvine, Ky., it is believed to lie about 2,800 feet below the valley bottoms, and in Wayne County it is 1,500 to 1,600 feet below the base of the black Chattanooga shale. The J. W. Cook well, near Rhoda, Edmonson County, Ky., about 35 miles north of Sumner County, Tenn., penetrates to a depth of 1,659 feet below the black shale and was stopped near the top of the St. Peter sandstone. No well in Sumner County, so far as known, has been drilled to so low a horizon as this. Throughout most of its extent the St. Peter yields either an abundance of good fresh water or a smaller quantity of highly mineralized water, but generally not the ordinary salt water of oil fields.

The so-called "Trenton limestone," which is 600 or 800 feet higher in the stratigraphic section, contains large quantities of oil and gas in Indiana and Ohio and has long been considered an Eldorado by the drillers and operators in Kentucky and Tennessee. In Sumner and adjacent counties this formation has been penetrated in a score of wells, but has so far failed to yield more than a faint show of oil. It has generally been found to be a hard, gritty limestone, too "tight" to serve as a reservoir for oil or gas. The depth of its upper surface below the base of the black Chattanooga shale in certain wells in southern Kentucky is given in the following table:

Distance from Base of Chattanooga Shale to Top of "Trenton Limestone."

Well.	*Location.*	*Interval Feet.*
J. W. Cook	Rhoda, Edmonson County, Ky.	636
	Bowling Green, Ky.	655
Cox No. 1	Forest Springs, Allen County, Ky.	614
Long Creek Oil Co.	Near Holland, Allen County, Ky.	640

The uppermost beds of Ordovician age in Sumner County are exposed near Bransford and Bethpage, along the hillsides overlooking Bledsoe Creek. On the lower slopes ledges of fairly massive gray limestone are common. Certain of these ledges are richly fossiliferous, carrying a profusion of

bryozoans, and the limestone is doubtless to be referred to the Richmond group, and possibly in whole or in part to the Fernvale formation. A collection of fossils from these beds along the west slope of Bledsoe Creek valley immediately above the Jackson Highway, between Bledsoe and Bransford, contains, according to E. O. Ulrich, the following species, which show that the containing beds belong in the Richmond group:

Rhombotrypa quadrata.
Cyphotrypa sp.
Homotrypa sp.
Bythatrypa sp.
Homotrypella.
Undeterminable crinoids.
Streptelasma divaricans.

Above these limestone ledges the hillsides are covered by loose debris and soil that entirely conceal the underlying strata for an interval of 15 or 20 feet below the cliff-forming Silurian limestones. This interval is probably occupied by the clay shales that have been designated the Mannie clay by Foerste, which belong in the top of the Fernvale formation to the south, or it may be occupied by younger Richmond beds. The top of the Richmond group and the base of the Silurian system is about 125 feet below the black Chattanooga shale.

None of the beds of Ordovician age that have been observed to crop out within Sumner County seem suitable to serve as reservoirs for oil or gas. The Ordovician beds yield petroleum at but few points in the Kentucky-Tennessee region. The Sunnybrook pool, in Kentucky, and the oil in the Spurrier-Riverton field, in Tennessee, are in rocks of this age.

SILURIAN SYSTEM.

Rocks of Silurian age are exposed beneath the Chattanooga shale and above the Ordovician strata along the lower slopes of the Highland Rim throughout its extent from east to west across the area under consideration. They reappear at the surface just outside of Sumner County, in the northwest corner of Macon County, Tenn., near the town of Barefoot, 6 miles northeast of Westmoreland.

The Silurian system as exposed in Sumner County includes five formations, named in ascending order the Brassfield limestone, Osgood shale, Laurel limestone, Waldron shale, and Louisville limestone. (See columnar section, fig. 1.) The Brassfield and Osgood are not known to crop out in the northern part of the county, and therefore they are not shown in the columnar section of outcropping rocks.

Along the banks of Bledsoe Creek in the vicinity of Bransford the Silurian rocks have a total thickness of about 125 feet. Of the formations exposed there, the Laurel and Louisville limestones are of especial interest because of their capacity to serve as oil reservoirs. Th Laurl is a brownish-gray massive limestone that forms heavy ledges on the hillsides and in many places weathers to an almost black color. Certain of the beds are very sandy and might almost be called calcareous sandstone. Partings of blue

clay, from 1 inch to 3 inches thick, may be observed here and there at different horizons.

It seems quite probable that certain of the pay sands in the oil fields of Allen County are included within the Laurel limestone. The deeper pay sand in Crowe well No. 7 of the North Petroleum field, from 130 to 148 feet below the bottom of the Chattanooga shale, is almost certainly in this formation. Again, the best pay sand in Mantlo well No. 3, in the Wildwood field, 112 to 116 feet below the Chattanooga, must likewise have the same stratigraphic relation. Several wells in the fields of Allen County report heavy flows of water from similar depths below the Chattanooga, and these in all probability came from the sandy strata of the Laurel limestone.

The large amount of sand in certain beds of the Laurel limestone along the Highland Rim makes it certain that throughout most if not all of the northern part of Sumner County this formation must be suitable to serve as an oil reservoir.

Between the Laurel and Louisville limestones the Waldron formation appears to be represented by 3 to 5 feet of thin-bedded bluish-green clay shale. The best exposure of this formation noted occurs in a stream channel at the east side of the Jackson Highway a short distance north of Bledsoe. Thin partings of shale reported by the drillers at depths of 50 to 65 feet below the Chattanooga shale in several wells in Sumner County, Tenn., and Allen County, Ky., probably indicate the presence of this shale generally beneath the surface of the Highland Rim Plateau.

The Louisville limestone near Bransford is about 55 feet thick. The upper 35 feet is a sandy-textured magnesian limestone, the top bed of which is coarsely crystalline and pinkish gray. It is thickly crowded with fossils, among which the brachiopod *Pentamerus oblongus* is the most conspicuous. It is associated with another brachiopod, *Atrypa reticularis*, and a tabulate or "honeycomb" coral. Many of the beds in the upper 35 feet of the Louisville limestone contain so high a percentage of sand grains that they might almost be called calcareous sandstone.

A collection of fossils obtained from the sandy-textured magnesian limestone lying between 5 and 35 feet below the Chattanooga shale near Bransford was made in 1917 and submitted to E. O. Ulrich, who reports as follows:

> This collection consists of coarsely silicified and otherwise imperfect corals and a few specimens of brachiopods. The corals comprise an undetermined species of *Stromatopora*, three forms of cup corals (indicating species of *Zaphrentis*, *Cyathophyllum*, and probably *Omphyma*), *Favosites favosus*, and a *Coenites*. The brachiopods are of three species—one specimen of *Dalmanella elegantula*, three fragmentary valves of a *Conchidium* cf. *C. littoni*, and one valve of an apparently new species of *Parastrophia* allied to *P. greenii*, a Niagaran fossil in Wisconsin.
>
> All things considered, I see no reason to doubt that this lot of fossils came from beds of the age of the Louisville limestone, a late Niagaran formation.

At the same locality the rock 35 to 45 feet below the Chattanooga shale is less impure limestone and carries a somewhat different fauna. Concerning the collection made at this horizon Ulrich reports:

Though this lot comprises 20 or more specimens only four or possibly five species of fossils are suggested, and of these but two are definitely determinable. Fortunately, according to American standards, these two species—*Pentamerus oblongus* and *Atrypa reticularis*—when found associated, may be said to establish the age of the containing beds as Niagaran and most probably late Niagaran (Louisville limestone). Two of the other specimens suggest *Stricklandinia*, but are too imperfect to be more closely identified. There is, besides, an imperfect ventral valve of some species of *Camaratoechia* and a coral, showing only in transverse section, of some species of *Zaphrentis*.

Apparently there are two beds in the Louisville limestone which are especially characterized by a profusion of *Pentamerus* shells. A short distance upstream from the locality that yielded the two collections thus described by Mr. Ulrich the beds which occupy the first 5 feet below the base of the black Chattanooga shale are exposed in the stream channel. These beds were examined during the field season of 1919 and were found to contain a fauna practically identical with that in the second lot submitted by Mr. Ulrich. *Pentamerus oblongus* is the most abundant fossil; *Atrypa reticularis* is also very common. There is an occasional valve of a *Camarotoechia;* one specimen of a *Zaphrentis* was observed, and in addition a honeycomb coral, probably *Favosites favosus.*

A similar *Pentamerus*-bearing bed immediately underlies the Chattanooga shale near Barefoot, Macon County, Tenn., 9 miles northeast of Bransford. On the other hand, the limstones immediately beneath the black shale exposed in the region 4 miles to the west, drained by the headwaters of the stream tributary to Bledsoe Creek at Bethpage, are barren of fossils. At that locality the upper 4 inches of this formation, immediately underlying the sandstone member in the base of the Chattanooga shale, is a brown coarse-textured sandy limestone, which yields when broken a strong odor of bitumen. The brown color is apparently due to the downward migration of petroleum from the Chattanooga shale. The part of the Louisville limestone beneath this sandy bed is a bluish-gray dolomite containing scattered crystals of calcite as much as three-quarters of an inch in length. Greenish splotches and streaks give the limestone a mottled appearance. A few small open cavities, probably due to solution at the outcrop, occur in the dolomite, but in the main it is too compact to serve as a reservoir for volatile compounds. No fossils were observed in this upper portion of the formation, but about 25 feet below the top of the Silurian limestone is the same fossiliferous bed characterized by a profusion of *Pentamerus oblongus* that was observed at the other exposures.

It is evident from the appearance of certain beds of the Louisville limestone at the outcrops along the Highland Rim that if these same conditions of high porosity and comparatively large content of sand grains persist throughout the area to the north, the beds of this formation are admirably suited to serve as reservoirs for oil and gas. This conclusion is further borne out by the fact that in a large number of the wells in Allen County, Ky., the best pay sand is at a depth of 50 to 75 feet below the black Chattanooga shale, a position which in Allen County almost certainly places

those sands in the Louisville limestone. Cuttings from certain of the wells that were being drilled in Sumner County at the time of the field investigations upon which this report is based indicate that between 10 and 35 feet below the base of the Chattanooga shale the sandy limestone is well suited to serve as an oil reservoir. This "oil sand," as the driller calls it, is more than likely a part of the Louisville limestone. Its presence in the wells, combined with the sandy texture of the outcropping beds, suggests that this portion of the Louisville generally throughout Sumner County is probably suitable to hold and yield petroleum.

DEVONIAN SYSTEM.

"Corniferous" Limestone.

If we make the determination, which seems to the writer entirely justifiable, that the black Chattanooga shale is of early Mississippian rather than of late Devonian age, it becomes extremely doubtful whether any representative of the Devonian system is present in Sumner County. Wherever the outcrops of the Chattanooga shale have been observed within this area, that formation rests directly on the eroded top of the Silurian limestone. On the other hand, the formation upon which the Chattanooga shale rests in the valley of Trammel Fork, 1 1-2 miles northeast of the northeast corner of the county, is almost certainly a Devonian formation. Somewhere between that locality and the outcrops along the Highland Rim the Devonian limestone disappears; hence the possibility must be recognized that there is a limestone of Devonian age intervening between the Louisville and Chattanooga formations in the northern part of Sumner County, even though it is not exposed at the surface anywhere within this area.

This Devonian limestone is known as the "Corniferous" and may be best described from its outcrops along Barren River, Long Creek, and Trammel Fork, in the eastern part of Allen County, Ky. It has a porous somewhat sandy texture and is rather heavily bedded and much jointed so that it weathers out into large blocks which gradually disintegrate into sandy material. Elsewhere it is a cleaner and more dolomitic limestone with fairly large crystals or more commonly fine grained. The more porous and sandy zones are well adapted for holding oil but the greater part of the formation is ordinarily too "tight" to serve as an oil reservoir. The rock pores are small though numerous and the total pore space is relatively low.

The thickness of this formation is not known and without doubt is variable. The base of the formation was not observed at any of the exposures in Allen County and it is impossible to determine its lower limit in the well records. Trammel Fork, east of Adolphus, has cut 12 feet into the "Corniferous" without exposing its base. Long Creek has penetrated it to a depth of 40 feet, and Barren River near Holland has cut 56 feet below its top without exposing underlying strata. Presumably the formation wedges out somewhere near the Kentucky-Tennessee boundary line, but it

is entirely possible that wells in the northern part of Sumner County would penetrate it before they reached the Louisville limestone. Probably the highest pay sands in the oil fields near Scottsville are contained in this Devonian formation.

Fossils are extremely scarce in this limestone where it is exposed, and its exact age is indeterminate. According to Ulrich[2] the few fossils that were obtained in 1917 indicate the Middle Devonian age of the containing beds. Possibly the "Corniferous" of this region is the equivalent of the Middle Devonian Pegram limestone of central Tennessee.

DEVONIAN OR CARBONIFEROUS SYSTEM.

Chattanooga Shale.

The most easily recognized among all the formations that appear at the surface or have been penetrated by wells in Sumner County is a hard black fissile shale, known to the drillers as the "Black shale" and to the local inhabitants as "black slate." In Tennessee, southern Kentucky, and adjoining territory, where it is generally 5 to 125 feet thick, this black shale has been named the Chattanooga shale, from a typical exposure at Chattanooga, Tenn. In northern Ohio and western Pennsylvania, where in some places this shale is thousands of feet thick and has several distinct subdivisions, it is known as the Ohio shale group. The region of transition from the northern to the southern phase is in northern Kentucky. In southern Indiana and adjacent areas the shale is known as the New Albany shale.

Nearly everywhere the Chattanooga shale is dead black in color, but in some localities it is dark brown. Some variation in hardness is reported by the drillers, and here and there thin lenses of dark, coarsely crystalline, richly bituminous limestone are interbedded with the shale. In the Settle well, in the southern outskirts of Scottsville, Ky., for example, a limestone parting 6 feet thick was penetrated in the midst of the black shale. The formation is, however, remarkable for its uniformity in composition and appearance throughout the broad region of its occurrence, which covers thousands of square miles in the northeastern part of the Mississippi Valley.

Within Sumner County the Chattanooga shale crops out continuously along the lower or middle slopes of the sinuous escarpment which separates the Highland Rim Plateau from the Nashville Basin. At many localities along these hillsides it is concealed beneath soil or debris from the overlying rocks, but it may be observed in the bed of nearly every stream which flows southward from "The Ridge" and generally can be found without difficulty by searching for the upper limit of the loose "float" particles of black "slate." The formation has been removed by erosion from all the Tennessee portion of the Nashville Basin except the numerous outlying hills around its margin, but it extends continuously beneath the surface of

[2]Shaw, E. W., and Mather, K. F., The oil fields of Allen County, Ky.: U. S. Geol. Survey Bull. 688, pp. 47-48, 1919.

the Highland Rim portion of Sumner County. In the eastern part of the county it is at a much higher elevation than in the western part and has consequently been exposed by several of the larger streams. None of these, however, have cut through it into the underlying limestones.

The tributary of Trammel Fork that rises in the northeastern outskirts of Westmoreland has cut its channel to a maximum depth of 5 feet below the surface of the black shale, and excellent exposures of the formation may be observed 1 1-2 miles northeast of the town. Trammel Fork at and just below the mouth of this tributary is likewise eroding its bed in this formation. At the Sumner-Macon County line the creek is only a few feet below the upper surface of the shale, but for several miles to the northeast in Macon County the down gradient of the stream is steeper than the dip of the strata, so that the creek bed descends lower and lower in relation to the Chattanooga strata and finally, near Barefoot, it is several feet below the bottom of the shale.

Garretts Creek has exposed the uppermost beds of the black Chattanooga shale throughout a distance of less than a mile in the vicinity of Garretts Creek church. A bank of shale with a maximum height of 7 feet overlooks the westernmost of the three tributaries that unite above the church and extends for a quarter of a mile along the stream bed upstream from that junction point. Other good exposures are found along the west side of the valley immediately north of the church. The top of the black shale is about 5 feet below the excellent spring 100 yards north of the schoolhouse.

The same formation appears at the surface in two localities along the bottom of the valley of Dutch Creek. The more conspicuous of these outcrops is a mile downstream from the Westmoreland-Portland pike. There a tributary of Dutch Creek has cut 5 feet below the top of the black shale. About halfway from this locality to the mouth of Dutch Creek that stream flows for a considerable distance over the uppermost beds of the black shale, which may be seen through the water in the stream channel, but which nowhere form the bank of the creek.

The contact between the black shale and the underlying limestone is in general sharply defined, and the surface of the limestone, if the shale were removed, would be described as rough or unevenly undulating. Generally the shale rests immediately upon the limestone, but in at least one locality a thin bed of dark-brown shaly sandstone intervenes between them. This may possibly represent the Hardin sandstone member of the Chattanooga shale as developed in southern Tennessee. It may be best observed in the channel of the stream that joins Bledsoe Creek at Bethpage, at the point, 4 miles west of Bransford, where this stream leaves the Highland Rim to flow southward into the Nashville Basin. The sandstone bed is there about 1 inch thick and yields a strong odor of bitumen when broken.

On the other hand, the contact between the upper beds of the black Chattanooga shale and the lower strata of the overlying New Providence

shale is far from sharp and distinct. There is rather a transitional zone several inches thick, and in few exposures is it possible to indicate the exact upper surface of the Chattanooga shale. The outcrops along the east bank of Trammel Fork, 1 1-2 miles northeast of Westmoreland, illustrate clearly the transition from the black shales of the Chattanooga formation to the overlying blue-green shales of the New Providence formation.

The thickness of the black Chattanooga shale is variable. In general it decreases toward the north from the central part of Sumner County into the oil fields of Allen County. Toward the northwest and west it increases in thickness with a fair degree of uniformity. Toward the east it remains fairly constant, so far as the known data indicate, but toward the southeast it becomes notably thinner. The following table gives a number of the more significant facts concerning its thickness. Additional data from wells may be found in the table at the end of this report.

Thickness of Black Chattanooga Shale at Outcrops and in Wells in and Near Sumner County, Tenn.

	Feet.
Sumner County, Tenn.:	
Bledsoe Creek, 3 miles north of Bransford	53
Nimmo well No. 1, 2 miles north of Westmoreland	34
Turner well No. 2, 1 mile northeast of Sugar Grove	35
Baskerville well No. 1, near Portland	37
Saunders well No. 1, South Tunnel	27
Macon County, Tenn.:	
Trammel Fork, near Barefoot	27
Allen County, Ky.:	
North Petroleum oil pool	40-45
Rodemer oil pool	38-47
Wildwood oil pool	42-48
Warren County, Ky.:	
Deep well at Bowling Green	90
Higgenbotham well No. 1, 9 miles northwest of Bowling Green	107
Robert Hurd well, near Hadley	135
Wiley well, Gasper River, 10 miles west of Bowling Green	152

The age of the black Chattanooga shale is still in doubt. It has been customary in the past to refer it to the Devonian period, but the great mass of evidence obtained in the last few years appears to the writer to be conclusive that the black shale of northern Tennessee and southern Kentucky, at least, is of early Mississippian age. In Sumner County, Tenn., and Allen County, Ky., the data obtained during the two short periods of field work in 1917 and 1919 seem to indicate that there are in reality two black-shale formations, which in at least one locality are separated by an erosional unconformity. The lower of these formations may be of Devonian age, but the upper, in the writer's opinion, must be considered Mississippian.

The most significant exposures of the black shale are those along the banks of Bledsoe Creek, 2 or 3 miles north of Bransford. At this locality the Chattanooga is divisible into two members, the lower of which, 45 feet thick, is softer and more calcareous than the upper, which is about 8 feet thick. The lower beds are also less evenly laminated and generally are thicker than the upper ones. At the base of the upper, more resistant mem-

ber there is a thin stratum which presents unusual features. This thin bed, half an inch to 1 inch thick, is composed of dark-brown or black sand grains and pebbles with numerous fragments of fossilized plant and animal organisms. Many of the sand grains and pebbles are phosphatic, and the rock gives off a strong bituminous odor when broken. The larger pebbles approximate a quarter of an inch in diameter, and some of them consist of brown-stained vein quartz. Most of these quartz pebbles are well rounded and have evidently been transported a considerable distance. The bed presents all the characteristics of a residual deposit reworked and modified by waves and currents. The black shales above this conglomerate bed are horizontal; those below have a variable dip, which in one place attains a maximum of 8° S.

A collection of fossils and "pebbles" from this conglomerate bed was made by Wallace Lee and the writer and submitted by Mr. Lee to E. O. Ulrich for determination. Mr. Ulrich reports that in addition to the quartz pebbles there are also some phosphatized clay pebbles, but most of the lark-colored "pebbles" are of organic origin, being more or less beach-worn fossilized bones and teeth of large fishes. One of the teeth is of a species of *Cladodus*.

Besides these larger fish remains, minute conodonts in considerable variety are present in both the matrix and some of the clay pebbles. Many of the forms are definitely identifiable with species commonly found in the Cleveland shale of Ohio, in the lower and middle parts of the Chattanooga shale in the Appalachian region, and in the phosphatic basal deposit of the same formation in central Tennessee.

Finally the material includes more or less imperfect remains of two species of *Lingula*, one of them evidently the same as *L. melie*, the other a more broadly elliptical species. * * * I think that the conglomerate layer may represent a part of the Berea.

No collections were obtained from the lower part of the black Chattanooga shale at this locality, but a collection from the same stratigraphic horizon near the base of the formation where it is exposed on Trammel Fork in Allen County, Ky., was likewise submitted to Mr. Ulrich, who states that the containing beds are "possibly of late Devonian, but more probably very early Mississippian (Cleveland shale[3]) age." In this collection the principal fossil is a *Lingula* suggesting *L. subspatulata*, but associated with it are "a few very unsatisfactory remains of a nearly smooth calamitoid plant, probably referable to the genus *Pseudobornia*, also a few disks of '*Sporangites huronensis*' and a few conodonts too imperfect to determine accurately."

[3]The Cleveland shale is classified by the United States Geological Survey as part of the Ohio shale group, all of which is referred to the Devonian.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

The strata overlying the black Chattanooga shale and underlying the St. Louis limestone are of special interest to the petroleum geologist, because the discovery of structural conditions favorable for the retention of oil must depend largely upon the study of these strata. In considering the petroleum possibilities of the region the geologist is interested not in the exact formation units so far as their succession, separation, and age are concerned, but rather in the determination of strata which lie at definite horizons above the black shale and which can be recognized with accuracy from place to place. The description which follows will therefore deal chiefly with this latter phase of these rocks.

The early Mississippian rocks in Sumner County comprise three distinct lithologic units, which are not differentiated on the accompanying geologic map because of the lack of an accurate topographic base, as well as because of the brief time available for field work. They are generally distinguishable in the field, however, and are customarily separated from one another by rather abrupt changes in composition. The determination of the position of the beds at any locality with respect to these three formations will indicate before drilling the depth at which the black shale will be encountered at that point, and therefore the depth to which it is necessary to go to strike the possible oil-bearing beds.

The general nature and sequence of the formations are indicated on the accompanying columnar section (figure 1).

New Providence Shale.

The lower 30 to 60 feet of Mississippian rocks overlying the Chattanooga shale consist of shale and shaly limestone with a predominant bluish-green tinge. The formation is thin bedded in most localities, the more calcareous strata having a maximum thickness of 10 inches, but in places very massive limestone has been observed. Geodes are common, but chert is not abundant. Many of the beds are composed of fragments of crinoid stems rather loosely cemented by calcareous greenish-gray mud or sand. The lithologic character of these rocks is not constant, but nearly everywhere the formation may be recognized by its abundance of crinoid stems and its green color. The chert is scattered throughout a few bands and as a rule is not aggregated into slabs or concretions, as it is in the overlying formations. These rocks are roughly equivalent to the Burlington limestone, but may include some beds of Kinderhook and basal Keokuk age. In this part of Tennessee and the adjoining regions in Kentucky they are known as the New Providence shale.

The shaly beds are easily weathered, and the more resistant beds commonly slump down over the shaly beds or over the underlying black shale where it is exposed. Consequently good exposures are not abundant. The

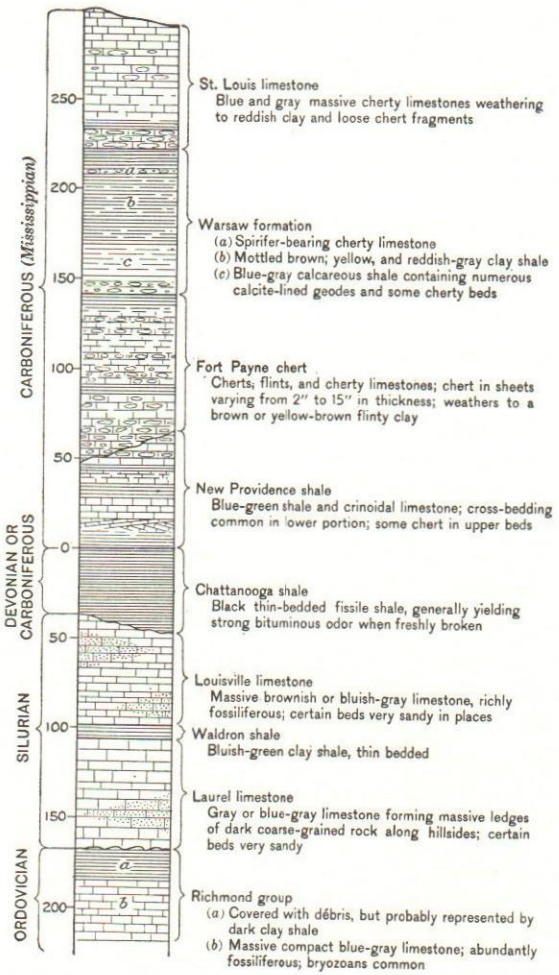

FIGURE 1.—Columnar section showing nature of rocks that crop out in Sumner County, Tenn.

best outcrops noted are those along Bledsoe Creek, north of Bransford, near Trammel Fork along the east margin of the county, and along Dutch Creek and the Middle Fork of Drake Creek.

The thickness of the New Providence shale is variable, probably owing to the presence of an erosional unconformity between it and the overlying Fort Payne chert. Near Epperson Springs, in Macon County, 2 miles northeast of Westmoreland, the New Providence shale appears to be little more than 25 feet thick, but along the margin of the Highland Rim Plateau north of Bransford and Bethpage it is between 45 and 55 feet thick. Because of this lack of uniformity the top of this formation, although generally easily recognizable, is not useful as a key horizon in determining the structure of the region.

A characteristic feature of the New Providence shale and one which is likely to be a source of error in studies of geologic structure unless it is clearly understood is the cross-bedding that is commonly present. False bedding or cross-bedding may be observed on a small scale at most outcrops, but in some localities, as along the railroad track between Adolphus and Petroleum, a few miles north of Sumner County in Kentucky, it is developed on a remarkable scale. Beds that apparently dip as high as 10° cut across the edges of horizontal beds and are in turn beveled and overlain by strata in an approximately horizontal attitude. So persistent is this feature in the basal portion of the Mississippian of the region that no directly observed "dip" in these rocks may be safely recorded as indicative of structural deformation affecting the oil-bearing strata.

Fossils are comparatively abundant in this formation. In addition to the ubiquitous crinoid stems, a species of horn coral, *Zaphrentis cannonensis*, and a large thick-shelled *Spirifer* seem to be the characteristic fossils.

The New Providence, in spite of its high content of lime, is a truly clastic formation—that is, it is composed of fragments accumulated under the influence of waves and currents. Its fossils were broken and dashed to pieces, the crinoid heads were disintegrated, the brachiopod valves were torn asunder, and the horn corals were scratched and worn before they found a resting place in the calcareous muds and silts of the ocean floor. The activity of waves and currents is also attested by the abrupt variations between superjacent beds, the thickening and thinning of individual strata, and the cross-bedding referred to above.

This formation occupies the same stratigraphic position in Sumner County as that of the beds which contain the Beaver Creek "sand" in Wayne County, Ky., 75 miles to the northeast. Certain of its more sandy or geodiferous beds are well adapted to serve as reservoirs for oil and gas. Throughout the eastern half of the Highland Rim portion of the county the formation is so much dissected by erosion that any oil which it might have contained in past ages has long since been dissipated. In the north-

western part of the county, on the other hand, this formation is below the present valley bottoms and may contain oil pools. The show of oil reported to have been observed in Blaha well No. 1, near Fountain Head, at a depth of 165 feet, "just above the black shale," must have come from a "sand" in the New Providence formation. Additional impetus for searching for an oil pool in this formation is afforded by the fact that the oil from this horizon in Sumner and the neighboring counties toward the north is "amber oil" having a greater value than that obtained from the older formations beneath the Chattanooga. On the other hand, it should be recalled that there are at present no wells that obtain commercial quantities of oil from these higher sands in the adjacent counties of Kentucky. Little hope should be held forth for obtaining any large amount of oil from this formation in Sumner County.

Fort Payne Chert.

About 50 feet above the black shale there is generally a well-marked change in the lithologic character of the strata, although in few localities is there a recognizable break in the stratigraphic section at this horizon. Massive beds of fairly pure and coarsely crystalline limestone overlie the thin shaly limestones of the New Providence formation. Some of these massive beds contain sheets of chert, which increase in amount in the higher beds until, 75 or 80 feet above the black shale, the beds are characterized by numerous sheets of light-brown or milky-white chert, 3 or 4 inches thick, which weather out in the form of flat slabs or blocks. In some localities these sheets of chert are a foot or more in thickness. The next 50 or 60 feet of strata consist of thin-bedded buff or brownish-gray limestones that carry numerous geodes and contain an abundance of chert in sheets or plates. This entire series of beds, from about 50 to about 140 feet above the black shale, is referred to the Fort Payne chert.

Outcrops of this formation are common along the slopes of nearly every valley in the northeastern and north-central parts of the county. Excellent exposures may be seen in the railroad cuts between half a mile and 2 miles south of Westmoreland.

Fossils are practically lacking in this formation, although they are comparatively common in the overlying and underlying beds. Certain of the more geodiferous or more sandy beds in the Fort Payne are fairly porous or open and might under favorable conditions serve as reservoirs of oil and gas. It is not likely, however, that volatile hydrocarbons could have been retained in these beds anywhere in Sumner County, because of the profound erosion to which they have been subjected.

Warsaw Formation.

The Warsaw formation overlies the Fort Payne chert in apparent conformity and comprises about 100 feet of limestone and shale. It is thin bedded, ranges from gray or bluish gray to lemon-yellow, and weathers to

a brick-red cherty soil. Two "key beds" within this formation were found to be easily recognizable, and both were used in the determination of the geologic structure in the area mapped. The outcrops of these two beds wherever they were observd within the county are indicated on the map.

The lower portion of the Warsaw formation includes a variable thickness of steel-blue or blue-gray calcareous shales or shaly limestones. These rocks are in beds which are commonly about an inch in thickness and contain an abundance of blue chert or flint as well as many geodes. The shales and limestones are fairly hard, break with a conchoidal fracture into angular blocks, and have been used with considerable success as road metal in many places. The distinctive blue color may be seen in all fresh exposures such as those along the roadside ditches, but is of course lost on weathering. The top of this blue member of the Warsaw is approximately 170 feet above the surface of the black Chattanooga shale. In searching for this key bed care must be taken to make certain that the higher beds of the members are found, as it is in many places as much as 30 feet thick. It is, however, overlain nearly everywhere by a thin-bedded soft clay shale, which also contains many geodes, but is of a brown or mottled yellow and brown color, so that the determination of the upper limit of the blue beds is generally not difficult.

About 40 feet above these blue calcareous shales and resting directly upon the brown clay shale is a single massive bed of siliceous limestone about 10 inches in thickness. It is thickly crowded with fragmentary remains of a large brachiopod, *Spirifer washingtonensis*, and hence may be referred to for convenience as the *Spirifer*-bearing bed. Silicia makes up nearly half the total volume of the rock and is not aggregated into sheets, nodules, or concretions, but is scattered throughout the thickness of the bed. On weathering the lime is leached away and the silica remains as a porous. spongelike mass with the silicified shells of the *Spirifer* etched in bas-relief on the weathered surfaces. The color of the weathered blocks that indicate the outcrop of this bed is generally a dark gray, but in some places is brick-red. This *Spirifer*-bearing bed is 210 feet above the surface of the black Chattanooga shale and is not far below the top of the Warsaw formation.

St. Louis Limestone.

The St. Louis limestone differs from the underlying formations in that the beds are more massive and contain only a little shale and fewer fossils. It seems to dissolve in rain water charged with organic acids from the soil more readily than any of the underlying limestones, and hence its outcrops are not abundant. Perhaps this solubility is due to a lower percentage of chert, perhaps to greater fracturing, and perhaps to its more porous character. The area underlain by the St. Louis beds may, however, be easily recognized by the bright-red soil containing many rounded nodules of

dense structureless chert which results from its weathering and by the many deep, steep-sided sink holes present wherever any great thickness of these beds has remained.

The main area of its outcrop is in the western half of the Highland Rim portion of the county, in the region around Portland and Mitchellville. The higher elevations between Sulphur Fork and West Fork of Drake Creek, in the vicinity of Perdue and Boiling Springs Church, are likewise composed of this limestone.

The upper limits of the St. Louis formation have not been observed in Sumner County, but in the vicinity of Bowling Green, in Warren County, Ky., it is about 300 feet deep. The only common fossil is a species of colonial coral, *Lithostrotion basaltiforme*, which is popularly called a "petrified hornets' nest."

QUATERNARY SYSTEM.

The rocks above described are covered almost everywhere by deposits of clay and sand, belonging to several formations of Quaternary age. These deposits are of comparatively little interest to the oil prospector, except in regard to their thickness and their content of boulders. They include the alluvium underlying the bottom lands, commonly 5 to 15 feet thick, and the products of weathering, slumping, or gradual creep of the older formations that mantle uplands and hillsides throughout the region. The thickness of these deposits and hence the amount of drive pipe needed in drilling through them is generally only 5 to 10 feet, but in places may reach 20 or 30 feet. All the surficial deposits are more or less stony and here and there certain boulders which locally make some trouble in drilling.

STRUCTURE

GENERAL RELATIONS.

The dominant feature of the geologic structure of Sumner County is the general northwesterly dip of the beds. The formations that crop out along Cumberland River at the south margin of the county are buried to a depth of more than 2,000 feet along Green River, 40 miles to the northwest in Kentucky. The average slope of the beds is consequently about 40 feet to the mile throughout the country intervening between these two rivers.

This general northwestward dip of the beds is, however, modified by many minor warpings and flexures, which have resulted in local dips in all directions. Wherever the northwestward dip is reversed so that the rocks plunge downward toward the east a structural trap suitable for the retention of oil migrating up the dip of the beds is probably present. As indicated in the introductory paragraphs of this report, the primary purpose of the geologist in ascertaining the oil possibilities of Sumner County must be to determine the presence or absence of anticlinal folds or domes which might have localized the oil content of underlying rocks.

To determine the exact attitude of the strata appearing at the surface in the northeast corner of the county, level lines were run by means of telescopic alidade and plane table from bench marks along the Louisville & Nashville Railroad, the elevations of which were supplied by the railroad officials. Elevations of the surface of the black Chattanooga shale at frequent intervals along its outcrop were determined directly. Wells already drilled or in process of drilling at the time of the field work were located, and the elevations of the well mouths were determined in like manner. Wherever possible logs of these wells were procured; the depth to the surface of the black shale subtracted from the elevation of the well mouth indicates the height above sea level of the black shale at that point. The elevations of certain key beds whose distance above the black shale was known were used in a similar manner wherever the key beds could be recognized. From the elevation of such a bed at an outcrop could be determined the elevation of the black shale beneath that point, on the assumption that the interval between the two beds is the same as had been determined where both were exposed.

To portray the structure of the region in easily legible form, contour lines were drawn on the base map, to represent the surface of the black Chattanooga shale. The structure-contour map thus made is reproduced herewith as Plate I. Each contour line passes through all points on the upper surface of this formation having the elevation indicated.

The black shale was chosen as the datum plane for the contour map because of the ease with which it is recognized in drill holes or outcrops and because of its proximity to the oil sands. The oil sands themselves were not contoured, because of the variations in the position occupied by the oil-bearing beds in the formations beneath the shale. It is certain that a contour map based on the elevations of the top of the pay sands would not be at all similar to a map that showed the structure of the formations in which those sands occur.

DETAILED DESCRIPTION OF STRUCTURE.

The prevailing northwesterly dip of the strata in Sumner County is modified by the presence of several small anticlines or domes, none of which are very extensive or abrupt. They display a tendency toward elongation in an east-northeast or northeast direction, roughly parallel to one another and to the general trend of the major axis of the Cincinnati anticline. As a rule a single dome is a mile or so in length and half to three-quarters of a mile in width, with an area of about 1 or 1 1-2 square miles. Four of these anticline folds were discovered in that portion of the county in which detailed mapping with plane table and alidade was done. Undoubtedly there are many other similar features elsewhere in the northern portion of the county.

Westmoreland Dome.

The Westmoreland dome is the largest of the four anticlinal folds mapped and has a roughly oval outline. Its summit is about a mile west of Westmoreland and a quarter of a mile north of the New Hope Church. A little more than 1 square mile is embraced within the lowest closed contour line, but the favorable structure covers a much larger area than that. The closure is about 15 to 20 feet.

In spite of its large dimensions and the considerable height of its summit above the saddle-like syncline which bounds it on the southeast, this fold is not the most favorable one for localizing a commercial accumulation of oil. It is bounded on the north, east, and west by synclines at no great distance from its crest, and these would limit the gathering ground from which it might have drawn its supply of oil to an area of only about 3 square miles. On the southwest the supply of oil is not thus cut off, but the Highland Rim is so close that little oil could have escaped loss at the outcrops of the beds.

It is therefore not altogether surprising to find that there are three dry holes on or near the summit of the Westmoreland dome. Two of these, drilled on the property of the New Hope Church, are not far from the crest of the dome and serve admirably to test its oil possibilities. It is reported that the first of these two wells displayed a small showing of oil and that it was drilled at least 250 feet below the bottom of the black shale.

The second test on the same property, 160 feet distant from well No. 1, gave no showing of oil and was abandoned at a much shallower depth. Three-quarters of a mile to the northwest there is a third dry hole on the Escue farm, concerning which no records are available. It is a short distance down the northwestern flank of the dome.

Dutch Creek Anticline.

A smaller but more favorably situated anticlinal fold may be called the Dutch Creek anticline, from its proximity to the stream of that name. It is elongated in a northeast-southwest direction, extending from the valley of Dutch Creek an unknown distance toward Turner's Station. As indicated on the map, the southwestern part of the fold is crossed by Dutch Creek 1 1-4 miles downstream from the Westmoreland-Portland pike. At that locality the stream has cut a few feet into the black shale exposed in the stream channel and along the banks of the small tributary from the northeast. This anticline has a closure of about 15 feet, and apparently there is nothing to hinder the migration of oil toward it for considerable distances from the west and north. It should be tested by at least two holes. A good location for one of these is at or near a point 1 1-4 miles south and 1 1-4 miles west from Turner's Station. Other tests should be made along the crest of the fold, which extends to the southwest from that point for about 3,000 feet.

Trammel Dome.

A dome of small dimensions but unusual prominence is situated in the drainage basin of Trammel Fork 1 1-2 miles northeast of Westmoreland. The black shale is there exposed in the stream bed of a tributary to Trammel Fork, but it has not been incised deeply enough to jeopardize its ability to retain oil in the subjacent formation. The lowest closed contour embraces an area of less than a quarter of a square miles, but nearly three times that area is considered as favorable territory so far as oil production is concerned. The closure is nearly 20 feet. There is a dry hole at the bottom of the syncline which bounds this dome on the southeast, but no tests have been made on the summit or flanks of the dome. Test wells should be sunk in the general vicinity of the summit and on its northwest flank. Good locations will be found between 1 1-4 and 1 1-2 miles south-southwest of Pleasant Grove Church.

Garretts Creek Anticline.

The Garretts Creek anticline is closely similar to the Dutch Creek anticline, with which it is almost in line. Its longer axis extends from a point three-quarters of a mile due east of Turner's Station northwestward for more than 2 miles, almost to the Kentucky line. The summit of the fold is very near Garretts Creek Church. It has a closure toward the southeast of nearly 20 feet and a large gathering ground toward the northwest. The wells recently abandoned or now being drilled on the Carter and Turner leases, northeast of Sugar Grove, are far down the northwestern flank of this fold, and the reported showing of oil in Carter well No. 1 is suggestive of the presence of oil nearer the summit of the fold. There are two dry holes in the syncline southeast and south of this anticline, but no tests have been made in favorable localities upon its summit. Good locations for test wells are in close proximity to Garretts Creek Church or within a quarter of a mile of it to the northeast and southwest. The Marsh property, on the northwestern slope near the summit of this fold, should likewise be tested for oil.

Sugar Grove Anticline.

A long, low flexure of the beds in the region immediately northwest of Sugar Grove may be referred to as the Sugar Grove anticline. It extends from the Meador farm in a direction a few degrees north of east toward the Carter property, on the Kentucky-Tennessee line, half a mile east of Little Trammel Creek. Although this is a true anticline, it plunges in only one direction, toward the southwest, and is not a dome. It should not be regarded as suitable for the localization of an oil pool. This conclusion is borne out by the absence of oil in the four test wells that have been drilled along or near its crest. Apparently a doubly plunging anticline or dome around which at least one contour line will close is essential for the retention of oil in this general region.

Fairfield Terrace.

For the same reason the slight departure from the normal northwesterly dip that was observed near Fairfield Church should not be considered as of great importance so far as oil production is concerned. This structure is apparently a mere flattening of the beds for a very short distance, and unless the more pronounced anticlinal folds already described prove productive it would scarcely be worth while to make tests here.

Other Anticlines.

Because of the short time available for field work in Sumner County it was impracticable to extend the detailed plane-table studies very far west of the Middle Fork of Drake Creek. A brief examination of the surface in that region, however, indicates the presence of key beds well adapted for the working out of the geologic structure in detail, and certain suggestions as to the probable location of other anticlinal folds may be advanced. It would appear that throughout the drainage basin of Caney Fork and in the region between Portland and the Kentucky line the normal northwestward dip of the rocks is constant. It is very likely, however, that north of Boiling Springs Church favorable anticlinal structure would be found by detailed studies. Similarly the unusually high position of the New Providence formation between Buck Lodge and Fountain Head suggests the presence in that region of an anticline favorable for the localization of oil. The crest of this anticline, which was not mapped in detail and can not now be accurately described, is probably about 1 1-4 miles north of Buck Lodge. Blaha well No. 1, half a mile southeast from Fountain Head is a dry hole from which a showing of oil was reported. It is situated too far down the western flank of this anticline to be influenced by the structure.

CHARACTER AND POSITION OF THE OIL SANDS

The discussion of the oil resources of Sumner County would be far from complete if it did not include a consideration of the probable nature and position of the sands that may have served as reservoirs for oil or gas beneath this region. The oil of the producing fields in Allen County is derived from porous beds that lie beneath the Chattanooga shale—either just below it or at a maximum depth of 140 feet below it. It should be expected, therefore, that the most favorable position for an oil reservoir in Sumner County would be at a similar stratigraphic horizon. It is worthy of note that in the western part of Allen County oil has also been found at an altogether different horizon, above rather than below the black shale. Reservoirs of oil at this horizon have been tapped in Barren County and elsewhere in Kentucky. This sand is probably the equivalent of the Beaver Creek "sand" of Wayne County, Ky. A similarly situated sand has also been found to be oil-bearing in the Glenmary oil field of East Tennessee.

"SANDS" IN THE "CORNIFEROUS" LIMESTONE.

A large proportion of the oil production of Allen County, Ky., is obtained from "sands" in the so-called "Corniferous" limestone. Probably nine out of ten of the "pay sands" tapped within 50 feet of the base of the black shale in every field in that county are within this limestone formation. Thus the greater part of the oil produced in the Rodemer, Gainesville, and other fields is derived from rocks of Devonian age.

In those fields it is customary for the drill to pass through a cap rock of hard limestone, 3 to 12 feet thick, immediately below the black shale and then to enter an oil "sand" which averages close to 15 feet in thickness. This oil "sand" is in reality limestone in which no true sand grains—that is, grains of quartz—are known to be present. In color it is some shade of brownish gray, in sharp contrast to the blue-gray tint of the dolomitic limestone encountered at this same stratigraphic horizon in many dry holes, which is too "tight" to serve as an oil reservoir. The petroliferous portion of the limestone is invariably soft and crumbly and is evidently full of minute intercommunicating cavities that form an excellent reservoir for the oil.

Because of the demonstrated importance of this limestone as an oil-bearing formation in Allen County, the question whether it is present or absent beneath the surface of Sumner County is highly pertinent to this discussion. There are no outcrops of the "Corniferous" limestone within the county, nor has it been recognized in any of the wells already drilled. Its position, immediately beneath the black Chattanooga shale, is occupied in Sumner County wherever the base of that shale is exposed by older rocks of Silurian age. It is apparent, therefore, that in the eastern part of the county the "Corniferous" limestone can not extend far south of the Kentucky line, if indeed it is present at all along the southern margin of Allen County. No hope may be entertained, therefore, of finding oil pay "sands" of "Corniferous" age in the east half of the Highland Rim portion of Sumner County. Oil in that district must be sought in other formations.

No data are available concerning the distribution of the "Corniferous" limestone in the southwest quarter of Allen County nor in the northwestern part of Sumner County. It is possible that this formation may be present there; and if present, it may contain suitable porous beds that may yield oil under favorable structural conditions.

"SANDS" IN THE SILURIAN LIMESTONES.

The oil sand in most of the wells in the North Petroleum and Wildwood fields of Allen County, Ky., is found at depths of 50 to 130 feet below the base of the Chattanooga shale. In certain wells in the Rodemer and other fields the "Corniferous" pay zone has been passed through and oil or water bearing sands have been penetrated at deeper levels. The conclusion seems altogether justified that these "sands" are in the limestone of Silurian

age. Probably those about 65 feet below the black shale are in the Louisville limestone, and those between 110 and 125 feet below the shale are in the Laurel limestone.

As stated above, these two limestones are not separated from the black shale in the Sumner County outcrops by the intervening "Corniferous" formation. The beds which in Allen County are 50 to 100 feet below the Chattanooga shale will be encountered in Sumner County 0 to 50 feet below the shale. Likewise, the Laurel limestone, which in Allen County is found between 100 and 150 feet below the black shale, will be penetrated in Sumner County at depths of 50 to 100 feet below the shale.

In general, it may be said that in Allen County there are three groups of pay "sands" at depths approximating 25, 70, and 110 feet below the black Chattanooga shale and contained respectively in the "Corniferous," the Louisville, and the Laurel limestones. Of these three "sands" the uppermost, or "Corniferous sand" is lacking beneath the greater part, if not all, of Sumner County. In the Tennessee region the possibilities for oil are therefore limited to the two groups of "sands" of Silurian age. The ability of these Silurian limestones to serve as reservoirs in this region thus becomes the significant factor in a forecast of its oil possibilities.

At the outcrops both the Silurian limestones have a sandy texture and contain a variable amount of sand grains—that is, grains of quartz. Certain beds in these limestones might be described as calcareous sandstones, although it is probable that the proportion of sand in them is increased at the outcrops by the surface leaching of the lime, so that under cover they are merely sandy limestones. Neither formation displays the numerous fissures and large cavities which characterize the "Corniferous," but this lack is balanced by the abundance of small openings and pores, which are probably intercommunicating. Lithologically the Silurian limestones in Sumner County are better suited than the "Corniferous" limestone in Allen County to serve as reservoirs for oil and gas, so far as the data obtainable at the outcrops indicate.

Information gleaned from examination of the well cuttings obtained from wells in Sumner County at the stratigraphic horizon occupied by these limestones is somewhat conflicting. In Graves well No. 1, a quarter of a mile northwest of Sugar Grove, for example, both the Louisville and Laurel formations are absolutely unfit to carry volatile hydrocarbons. Throughout the 110 feet below the base of the black shale the rocks penetrated consisted of hard, compact bluish-gray limestone, containing no visible sand grains and apparently with very low porosity. On the other hand, strata admirably suited to carry and yield oil were penetrated at similar stratigraphic horizons in the Nimmo and Kentslo wells, near Pleasant Grove. The cuttings from the Nimmo well at a depth of 4 to 16 feet below the black shale indicate the presence of sandy limestone, brown in color and

sugary in texture, comparatively soft, and apparently containing a rather high percentage of quartz grains. So far as could be judged from the pulverized cuttings, the porosity of the Louisville beds at that place must be fairly high and the beds would form suitable reservoirs of oil if the structure were favorable for concentration of the migrant fluids there. Similar porous sandy beds were encountered in the Kentslo well between 4 and 30 feet below the black shale. Here, in addition, the cuttings displayed abundant particles of gypsom. Apparently the lithology and porosity were all that might be desired of a petroliferous reservoir, but here again the structural conditions were distinctly unfavorable.

It may therefore be safely concluded that in Sumner County, as in Allen County, the Louisville and Laurel limestones are in many localities admirably suited to hold and yield oil, but that elsewhere they are too "tight" and compact to serve as oil reservoirs. In the present state of our knowledge concerning these formations and the causes of their varying porosity, it is impossible to offer any suggestions that might guide the prospector in advance of drilling operations in his search for the localities beneath which the lithologic conditions make possible the presence of oil in these limestones.

SUGGESTIONS FOR PROSPECTING

FAVORABLE STRUCTURAL CONDITIONS

Experience indicates that in those Kentucky-Tennessee oil fields which derive their product from limestones beneath the black shale the location of oil pools has been determined by two factors—the structure and the nature of the pore space of the oil-bearing formations. As indicated above, the limestones beneath the black shale are not everywhere in Sumner County sufficiently open and porous to serve as reservoirs for oil and gas. A small patch of porous rock in the Louisville limestone, for example, entirely surrounded by dense, firm, impervious portions of the same formation, might contain an oil pool, even though it were at the bottom of a syncline or structural basin. On the other hand, the tendency of oil to migrate to higher levels and rise toward the summit of an anticline or dome when water is available to fill the pores vacated by it will result in the accumulation of oil in structurally favorable localities wherever possible. The conclusion is entirely justifiable, both from theoretical grounds and from the study of known conditions in the neighboring oil fields, that in Sumner County, as in most other areas where prospecting for oil is warranted, there is much more likelihood of discovering new pools in localities where the structure is anticlinal than elsewhere. The search for new fields will therefore be expedited by a knowledge of the areas where anticlines or domes are known to be present and by suggestions that may help in deciphering the structure of regions which have not been examined in detail.

KNOWN AREAS OF FAVORABLE STRUCTURE

Four important anticlinal areas, the only ones revealed by the field work in Sumner County upon which this report is based, are described in detail on preceding pages. Only one of these has been tested with the drill. The other three all merit careful tests, and the locations where these tests may best be made have already been given. It happens that on or near the crest of each of the three domes, here called the Dutch Creek anticline, the Trammel dome, and the Garretts Creek anticline, the upper beds of the black Chattanooga shale have been exposed along stream beds by erosion. In none of them, however, has the stream cut more than a few feet into the black shale, so that the fitness of the shale to retain oil or gas in the underlying beds can not have been jeopardized. Presumably it is only where erosion has cut through the black shale and laid bare the underlying limestones that the oil content of those limestones may have been dissipated by escape at the surface. Good production is now being obtained from the small anticline close to Adolphus, Ky., in spite of the fact that the black shale crops out along Little Trammel Creek on its crest.

Similarly, the fact that these and other anticlinal folds which may be present in the Highland Rim portion of Sumner County are within a few miles of the outcrop of the reservoir rocks along the Highland Rim should not be considered a disadvantage in estimating their petroleum possibilities. Drilling within a short distance of the outcrop of the Louisville or Laurel limestone is warranted, provided a synclinal fold intervenes between the site of the drill hole and the outcrop. Under those conditions the upward migration of oil along the dip from the northwest toward the southeast is stopped and the oil is trapped. On the other hand, if the structure is such that the reservoir strata rise constantly from the site of the well to their own oucrop, drilling is entirely unjustified, even though the location may be only 3 or 4 miles from the outcrop. In Allen County, for example, the Adolphus field is only 3 miles and the North Petroleum field 3 1-4 miles from the outcrop of the oil-bearing limestone along Trammel Fork a short distance below Barefoot, Tenn. But each of these fields is situated on an anticlinal fold and is separated from that outcrop by synclinal troughs.

SEARCH FOR OTHER AREAS OF FAVORABLE STRUCTURE

Because of the strong influence exerted upon the location of oil reservoirs by the composition and porosity of the oil-bearing formations, prospecting in synclinal areas or in regions where the beds display the prevailing gentle northwesterly dip should not be discouraged. Nevertheless, detailed geologic examination to determine structural relations should precede drilling operations if the possible oil resources of Sumner County are to be economically and promptly developed. The presence of several anticlines in the small portion of the county which was examined in detail

is in itself good evidence of the presence of similar structural features in other parts of the county. Wells drilled near the summits of these folds will have very much better chances of tapping productive reservoirs of oil than those drilled promiscuously without reference to structure.

The location of anticlinal structure favorable for the accumulation of an oil pool can not in Sumner County be determined by observations upon the contour of the earth's surface, the shape of the hills, or the trend of the valleys. These surface features have apparently no relation whatever to the attitude of the beds of rock beneath the surface, which determines the situation of most oil fields. Structural conditions which may have served to trap oil in commercial amounts can be discovered only by determining the exact attitude of the strata at and beneath the surface. Fortunately, the rocks of Mississippian age which appear at the surface throughout nearly all of the Highland Rim portion of the county are of such a nature as to facilitate the determination of structure in that area. The blue member of the Warsaw and the *Spirifer*-bearing beds, previously described, will serve admirably as "key beds" in all except the western part of the area which may be classed as possible oil territory.

The beds of the New Providence formation, however, are especially untrustworthy as clues to the structure. Cross-bedding and original deposition on inclined surfaces are so common within that formation that little reliance may be placed on observed dips of its strata.

In many localities removal of the more soluble limestones by the action of underground water has permitted the overlying beds to settle, or more massive strata above shaly zones have slumped a few feet downhill. The exposure that results from either process may closely stimulate the ordinary hillside exposure of gently tilted beds and may be misinterpreted as indicating the dip of the formation.

DEPTH OF TEST WELLS

The foregoing discussion of the character and position of the possible "pay sands" beneath the black shale has made it clear that the sands now producing oil in Allen County will all be penetrated in Sumner County within about 100 feet or certainly within 150 feet of the base of the Chattanooga formation. Drilling to depths greater than is necessary to reach these sands is not justified unless the hole can be carried down to the so-called "Trenton" limestone, whose surface is between 600 and 700 feet below the black shale.

Whether or not drilling to the "Trenton" is at all warranted in Sumner County is a question to which no definite answer may be given. Certainly such drilling is taking an extremely long chance. At least a dozen holes in and near Sumner County have penetrated that formation, and so far none have proved successful. It is probably true, however, that none of

these tests have been made where structural conditions favored the accumulation of oil or gas in that formation. At the same time, there are no data available which suggest that the "Trenton" limestones contain oil or gas in commercial amounts anywhere within many miles of the Sumner County region. None of the tests that have reached that horizon south of Ohio River have given more than a small showing of oil.

If it is desired to test this deeper limestone, the test should certainly be made at some locality where the structure of these beds is known to be favorable for the accumulation of oil. It may be questioned whether the small anticlinal flexures detected in the Devonian and Mississippian strata of the Highland Rim Plateau are accurately reproduced in the older Ordovician rocks at considerable depths below the surface. Such folds may "play out" downward, and it is possible that they disappear within 500 or 1,000 feet. More reliable information concerning the attitude of the "Trenton" limestone may be obtained by geologic examinations in the Nashville Basin portion of the county, south of the Highland Rim, where these beds are nearer the surface and are not separated from the surface strata by major unconformities. Tests of the "Trenton" should be made in that part of the county, because of the smaller expense involved in drilling shallower holes.

At the time of writing preparations are under way for drilling to the "Trenton sands" at two localities in the eastern part of the county south of the Highland Rim. One of these is near Bethpage, and the exact location selected was not visited by the writer. The other locality is indicated on the map as Albright well No. 1 and is about 4 miles west of Bethpage. Only a hasty examination of that locality was possible because of the short time available, but nothing was seen which would indicate that the structure is at that point favorable for the accumulation of oil in the underlying strata.

WELL RECORDS

Most of the tests already made in Sumner County were made by individuals or by small groups of men who associated themselves together for that purpose rather than by the established oil companies. In most of them the men in charge were not sufficiently experienced in the oil business to know the value of keeping accurate records of the wells drilled. In others the failure of the project produced a strong desire to forget the entire matter as promptly as possible, and hence the records were immediately discarded. Consequently much valuable information that would greatly assist in the development of the possible oil resources of the region is not now available. The following records, many of which are only partial or approximate, have been obtained. The numbers in black face indicate corresponding numbers on the map (Pl. I).

1. Carter well No. 1, 1 mile northeast of Sugar Grove. Altitude, 788 feet. Small show of oil; well abandoned Sept. 29, 1919. Driller's log:

	Thickness, Feet.	Depth, Feet.
Unrecorded	120	120
Green shale	14	134
Black shale	45	179
Cap rock	8	187
Unrecorded	18	205
Sand, show of oil	3	208
Lime	4	212

Water at 42 and 92 feet; sulphur water immediately below the black shale and in the lower part of the "oil sand."

3. Turner well No. 3, 1 mile north of Sugar Grove. Altitude, 807 feet. Being drilled at 140 feet Oct. 4, 1919.

4. Turner well No. 2, 1 mile north of Sugar Grove. Altitude, 795 feet. Dry hole; abandoned Sept., 1919. Driller's log:

	Thickness, Feet.	Depth, Feet.
Soil	12	12
Fresh water		15
White lime	50	125
Green shale	15	140
Black shale	35	175
Brown sandy lime	5	180
White water sand	25	205
Gray lime	10	215
Blue lime	10	225
Fine brown sand	5	230
Brown sandy lime	5	235
Blue lime	5	240
Brown sandy lime	18	258
Rotten blue lime	17	275

Turner well No. 1, 1 mile north of Sugar Grove. Altitude, 675 feet. Dry hole; casing plugged. Driller's log:

	Thickness, Feet.	Depth, Feet.
Unrecorded	20	20
Black shale	36	56
Lime	18	74
Sand	9	83
Lime	103	186

6. Graves well No. 1, half a mile northwest of Sugar Grove. Altitude, 708 feet. Well dry; abandoned Sept., 1919. Driller's log:

	Thickness, Feet.	Depth, Feet.
Unrecorded	70	70
Black shale	37	107
Blue lime, hard and tight	114	221

7. Groves well No. 2, three-quarters of a mile west of Sugar Grove. Altitude, 779 feet. Being drilled at 75 feet Oct. 4, 1919.

8. Meador well No. 1, 1 1-2 miles northwest of Sugar Grove. Altitude, 796 feet. Dry hole; casing plugged.

9. Marsh well No. 1, 1 mile northwest of Pleasant Grove. Altitude, 745 feet. Dry hole; casing plugged.

10. Kentslo well No. 1, 1 mile north-northeast of Pleasant Grove. Altitude, 884 feet. Being drilled at 205 feet Oct. 6, 1919. Driller's log:

	Thickness, Feet.	Depth, Feet.
Unrecorded	145	145
Black shale	30	175
Cap rock	4	179
Sandy lime	26	205

11. Williams well No. 1, 2 miles southeast of Sugar Grove. Altitude, 806 feet. Dry hole.

12. Nimmo well No. 1, three-quarters of a mile west of Pleasant Grove. Altitude, 904 feet. Being drilled at 248 feet Oct. 4, 1919. Driller's log:

	Thickness, Feet.	Depth, Feet.
Surface material	15	15
Lime	183	198
Black shale	34	232
Cap rock	4	236
Sandy lime	12	248

14. New Hope well No. 1, 1 mile west of Westmoreland. Altitude, 852 feet. Small show of oil; casing plugged. "About 60 feet to black shale; bottom of hole about 250 feet below the black shale."

15. New Hope well No. 2, 160 feet from New Hope well No. 1. Altitude, 846 feet. Dry hole; casing pulled.

16. Escue well No. 1, 1 1-2 miles northwest of Westmoreland. Altitude, 935 feet. Dry hole.

17. Coates well No. 1, 1 1-2 miles northeast of Trout. Altitude, 858 feet. Dry hole. Total depth, 313 feet.

18. Johnson well No. 1, 1 mile north of Trout. Altitude, 878 feet. Dry hole.

19. Trout well No. 1, Trout. Altitude, 774 feet. Well reported to be about 100 feet deep; strong flow of very bitter sulphur water and considerable H_2S gas issuing from well Sept. 11, 1919.

27. Baskerville well No. 1, 1 3-4 miles north-northeast of Portland. Dry hole. Driller's log:

	Thickness, Feet.	Depth, Feet.
Unrecorded	347	347
Black shale	47	394
Unrecorded	141	535

29. Blaha well No. 1, half a mile east of Fountain Head. Small show of oil; hole abandoned. Only record available is that there was a "showing of oil at 165 feet, just above the black shale."

31. Taylor well No. 1, South Tunnel. Show of oil; hole abandoned. Driller's log:

	Thickness, Feet.	Depth, Feet.
Dirt	3	3
Lime	108	111
Shale, gray	27	138
Shale, black (Chattanooga)	36	174
Lime cap	6	180
Slate	3	183
Sand, brown, show of oil	14	197
Lime, light bluish gray	10	207
Lime and slate	43	250

32. Saunders well No. 1, South Tunnel. Dry Hole; casing plugged. Drillers' log:

	Thickness, Feet.	Depth, Feet.
Dirt	20	20
Lime	85	105
Shale, gray	30	135
Shale and lime shells	27	162
Shale, black (Chattanooga)	27	189
Lime	6	195
Shale, gray	3	198
Stray sands	10	208
Lime cap	3	211
Sand, gas	24	235
Break	12	247
Lime and sand	371	618