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THE MINERAL AND FOREST RESOURCES OF KENTUCKY

Published Quarterly by

THE

DEPARTMENT OF GEOLOGY AND FORESTRY

Of the

Commonwealth of Kentucky

Frankfort, Kentucky

J. E. Barton, Commissioner
W. R. Jillson, State Geologist

July 1, 1919.

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Prospectus of Economic Papers Which Will Appear In Vol. 1, No. 3, the October Issue of

The Mineral and Forest Resources of Kentucky.

Tentative Contents, Papers Now in Press.

No. 1. The Big Sinking Oil Pool (with map).....By W. R. Jillson
No. 2. The Stand of Timber in Kentucky Forests.....By J. E. Barton
No. 3. The Gainesville Oil Pool (with map).....By W. R. Jillson
No. 4. The Paint Creek Uplift in Johnson County.....By E. O. Rhodes
No. 5. The Oil and Gas Structure of Breathitt and Knott Counties (with map).....By W. R. Jillson
No. 6. A Key Correlation to the Coals of Eastern Kentucky.....By W. R. Jillson and I. B. Browning

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Additional Short Papers May be Included.

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Structural Deformation and Its Relation to Proven Oil and Gas Accumulation in Eastern Kentucky.

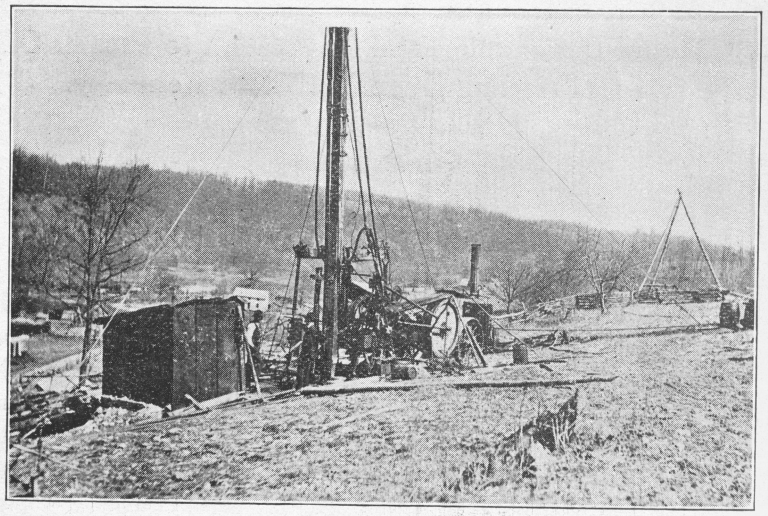
BY WILLARD R. JILLSON,
Kentucky State Geologist.

Introductory.

The sedimentary rocks of Eastern Kentucky, like those of the adjoining state of West Virginia, have long been known to contain many anticlinal and synclinal folds. A number of these are in fact nothing more than continuations of folds which are well known, named and mapped in West Virginia. All of these folds even westward as far as the Central Blue Grass section are probably the result of the same forces—strong crustal pressures exerted from the southeast in Post-Pennsylvanian times—that produced the major folding and faulting of the sister state of West Virginia. To date, little or no attempt has been made to map these interstate and associated structures in Eastern Kentucky. It is the purpose of this paper to show by sketch map the interlocking nature of some of the more important of these folds, and present briefly their established relationship to the proven oil and gas pools of this part of the state. The information presented in this paper is based upon data and notes taken by the author in the field during the summer and fall of 1917, and the full field season of 1918. The area referred to is that shown by the map (Fig 1), and is roughly the quadrangular section enclosed by Montgomery, Knox and Pike counties, Kentucky, and Mingo, West Virginia.

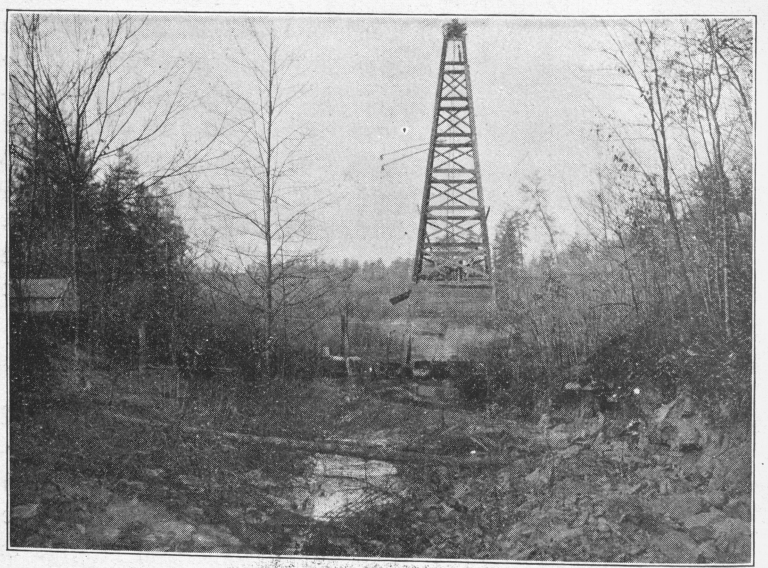
Structural and Stratigraphic Geology.

A birdseye view of the geologic structure of this part of Eastern Kentucky throws into immediate relief two major interstate features, (1) the Pine Mountain Fault and Fold, and (2) the Irvine-Paint Creek-Warfield Fault and Fold. Each of these features occupies an outstandingly high structural position in the Kentucky sediments from which strata dip away into geosynclines in either direction. A closer examination of these



Drilling in Buck Creek Pool.

Though the size of this oil pool is relatively small drilling is going rapidly ahead within the proven areas, the Onondaga Limestone (Irvine "sand") being found at between 225,300 feet below the surface. Photo by W. R. Jillson, Mar. 20, 1919.



Down in Big Sinking.

View of drilling on the George Booth farm by the Quaker Oil Company in he creek bottom. Photo by W. R. Jillson, April, 1919.

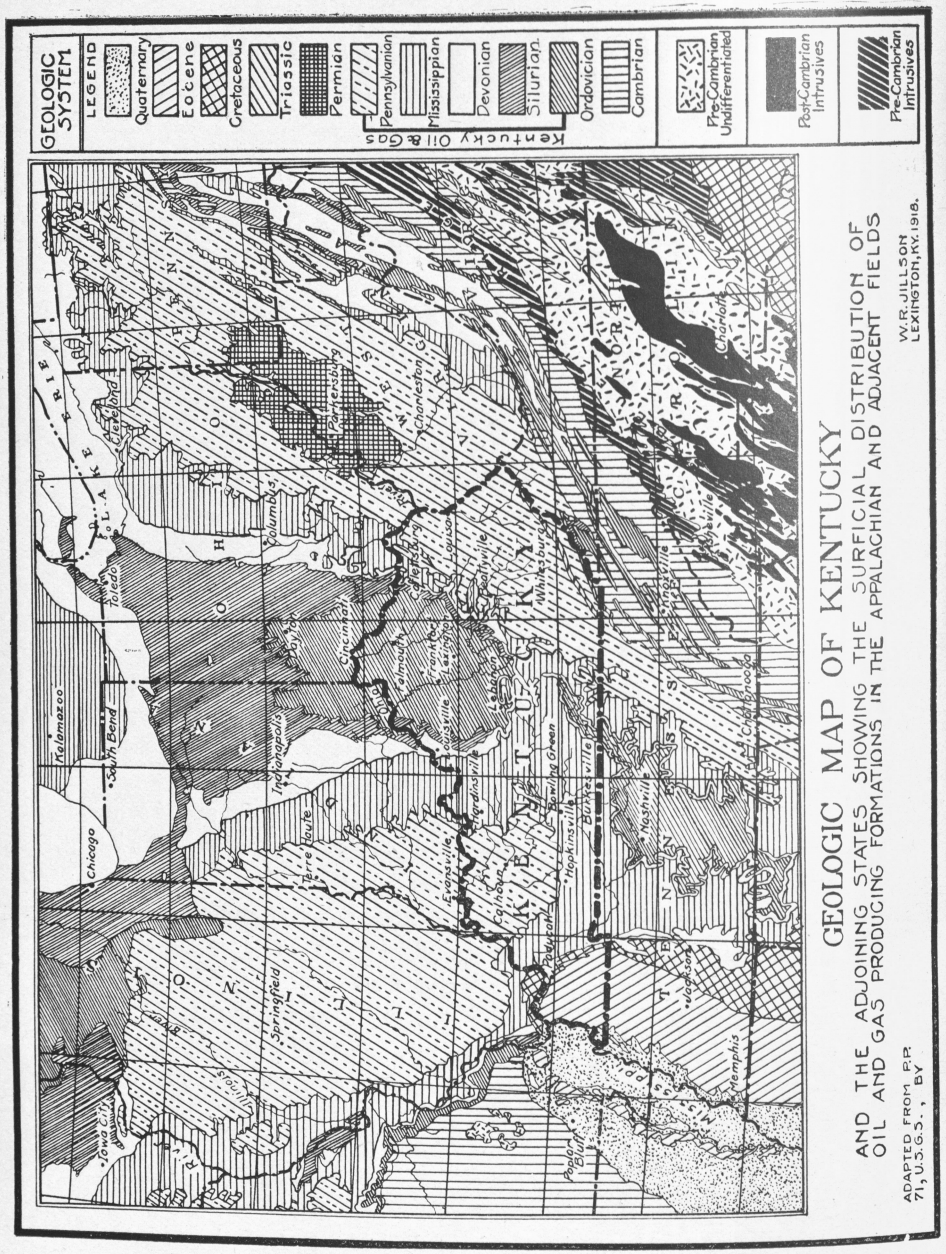
flanking areas show them to be deformed into a great number of smaller folds of only local importance. Occasionally small faults are found in this area whose importance is directly comparable only to those pigmy structures which adjoin them. Altogether these associated larger and smaller structures because of their location in the southern portion of the Appalachian Oil and Gas field have afforded many difficult problems to both oil operators and geologists. The fact that the surficial rocks are almost entirely Pottsvillian—famous for their extreme irregularity—has added to, rather than lessened the stratagraphic and structural confusion. The northwestern part of the area shows the Conglomerates of the Lee Formation. These are adjoined on the southeast by the sandstones, shales and coals of the Norton lying as a relatively narrow belt along a northeast-southwest line. Considerably over half the area—the southern and eastern part—is composed of that great succession of sandstones, shales, impure limestones, and commercial coals which make up the Wise or Upper Pottsville. A number of the very highest points in this latter area are capped by a relatively thin blanket of similar sandstones, shales and coals which have been referred to the Alleghany Formation. The Pennsylvanian sediments of Eastern Kentucky have never been differentiated and mapped, except in very small restricted areas, so it is impossible to outline more definitely the aerial geology of this section.

Underlying these exposed Pennsylvanian rocks are the unexposed representatives of the Mississippian, Devonian, Silurian and Ordovician systems. This much has been confirmed by a large number of test drillings. Whether the Cambrian underlies all of this area is not definitely known as these rocks, especially in the southern and eastern regions, are very deep—probably in some sections over a mile below the surface. And what lies below the Cambrian in this or any other part of Kentucky no one knows in spite of the ten thousand oil wells that have been drilled in the state.

Structural Features in Detail.

The Pine Mountain Structure.

The Pine Mountain Fault and Fold—one of the two real mountains of elevation in Kentucky—lies partly along the south



eastern boundary of Kentucky and marks the limit of the discussion of this paper in that direction. It is essentially a great overthrust fault in Bell and Letcher counties which in going northeastward into Pike county passes in to a faulted fold of large proportions as it leaves the state in its extension into Virginia. In Bell and Letcher counties it passed steadily through simple and overturned anticlinal features into those of fracture and overthrusting. Through this sequence of structural changes the extreme pressure exerted from the southeast was gradually decreased. The great significance of this release of pressures will be appreciated when it is understood that it undoubtedly marked the end of the development of all the other smaller structures of the area.

During the time of the overturning of the Pine Mountain Fold and just prior to the break and overthrusting, many small anticlines and minor faults were developed, with major axes angulating from or nearly parallel to the large structure. This condition of somewhat widespread fracturing and sharp folding has apparently resulted in great damage to this area as an oil and gas reservoir, since to date no commercially successful wells have been drilled in this area. In Knox county the Artemus-White Mountain Anticline, and in Pike county the D'Invillier Anticline have as yet—though with only a slight amount of drilling—proven dry.

The Irvine-Paint Creek-Warfield Structure.

Second to the Pine Mountain structure in point of size, the Irvine-Paint Creek-Warfield structure (fault and fold) has, as is generally known, proven itself to be of the very first importance from the standpoint of oil and gas accumulation and recovery. This structure in its varying expression is largely a normal fault in the west with throw up to 150 feet. The fault proper extends from near Irvine east to the Big Sandy river, in Johnson county. It crosses in part or in whole the counties of Estill, Powell, Wolfe, Morgan, Magoffin and Johnson. In Martin county this structure is a well defined anticlinal fold which extends eastward into Mingo county of West Virginia, and soon assumes a faulted condition along or near its crest. Like the Pine Mountain fold this large structural feature has smaller radiating

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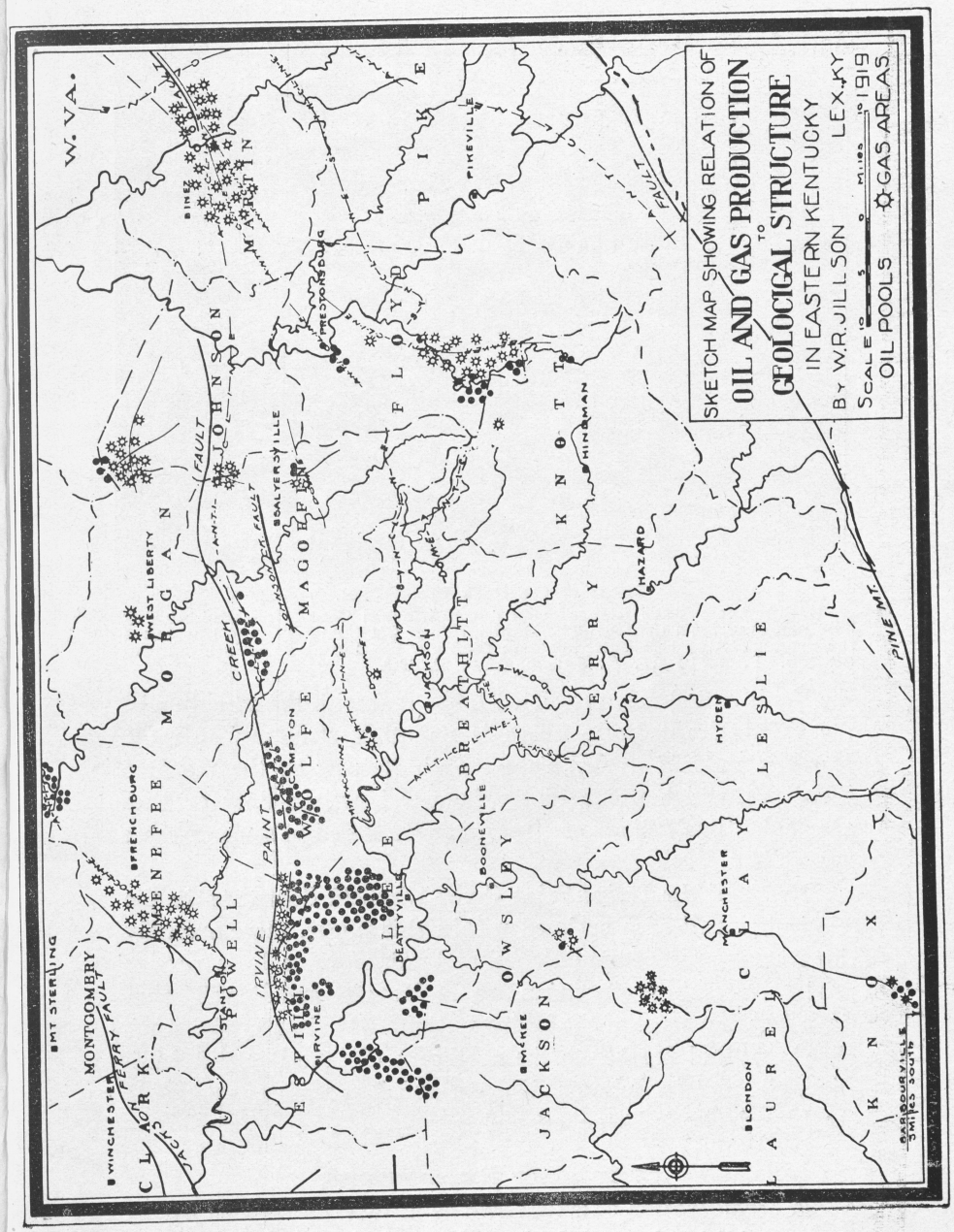
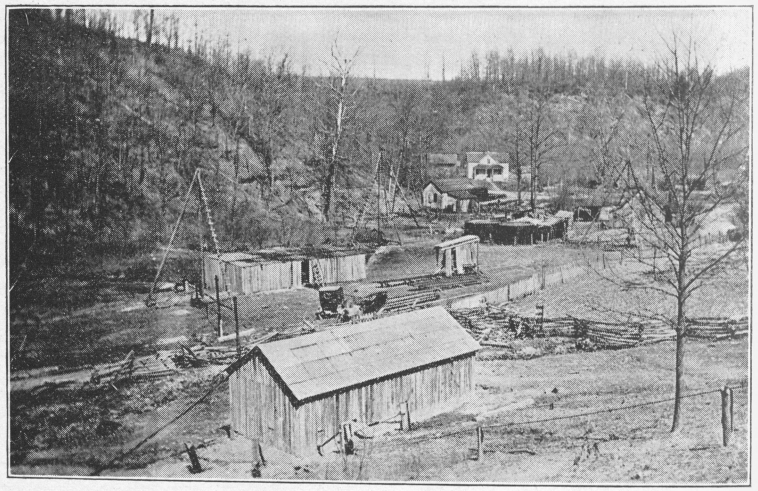
and parallel structures adjoining it. It is these smaller, and sometimes almost impreceptible structures which have proven the seats of Kentucky's most imporant oil and gas pools. These are: (1) Station Camp, oil; (2) Irvine, oil; (3) Ross Creek, oil; (4) Big Sinking, oil; (5) Ashley, oil; (6) Campton, oil; (7) Cannel City, oil and gas; (8) Paint Creek, gas, and (9) Laurel Creek oil and gas, and (10) Inez, gas.

Minor Structures.

Between these two structures there are a large number of folds, much smaller in size, which have been prospected for oil and gas with varying results. In Clay and Owsley counties there is an anticline with two dome-like humps on it which has proven gassy in Clay. In Owsley, just to the north, this structure shows both oil and gas. In Breathitt county there are five pronounced structures—two anticlines and three domes. Two of these, the Wilhurst or Frozen Creek Anticline, oil and gas, and the Cope's Fork Dome, gas, have been proven. The other three structures have not been tested either at all or adequately. In the southern edge of Wolfe county there is an anticline of rather small proportions—the Holly Creek Structure—that has been proven dry. In Magoffin county, just east of the Licking river and south of the Fault, between the Cannel City structure and the Paint Creek Dome (gas), there is a structure known as the Rockhouse or Raccoon Anticline that is as yet virgin. Southeast of Salyersville lies the Ivyton Dome, a small somewhat symmetrically contoured structure which has been proven (in the Pottsville) to contain small gas and low gravity black oil. In Knott county there is at least one structure of outstanding importance—the Yellow Mountain Anticline—which on its eastern flank has proven gassy. In Floyd county there are two structures (1) the Prestonsburg Anticline, and (2) the Beaver Creek Anticline, which are becoming well known. The first of these has proven oil of small quantity in the Weir or Berea "sand," and the second has proven both oil and gas with a stratigraphic range from the Pottsville down to the Black Shale of the Devonian. Berea oil and gas on this structure has been erroneously reported due to faulty correlations. Pike county, as before stated, has to date —in spite of the D'Invillier Anticline, which in its northeast-



ward extension, passes into West Virginia as the Williamson Anticline—proven unproductive. In Johnson county, south of



Heart of the Buck Creek Pool.

Within the proven area of this small Lincoln County oil pool no dry hole has ever been drilled. The Daniel Boone Oil Company pipe line takes the production of this entire pool to tank car station at Kenor's Mountain Station. Photo by W. R. Jillson, Mar. 20, 1919.

the Fault and closely associated folds, and with the exception of the Paint Creek Dome, there is no other structure of rank. Martin county is crossed along its middle part by the Warfield Structure, which produced the famous Martin county or Inez gas field. Small shows of oil were encountered in some of these gas wells.

North of the Irvine-Paint Creek-Warfield Structure, in the relatively small area enclosed within this paper, there are only three structures of importance and all of these have proven productive. These structures are, in Menefee and Powell counties—just northeast of the Irvine section—(1) the Menefee Anticline, gas; and further to the northeast (2) the Ragland Anticline, oil; and in Johnson, Morgan and Lawrence counties (3) the Laurel Creek Dome, oil and gas.

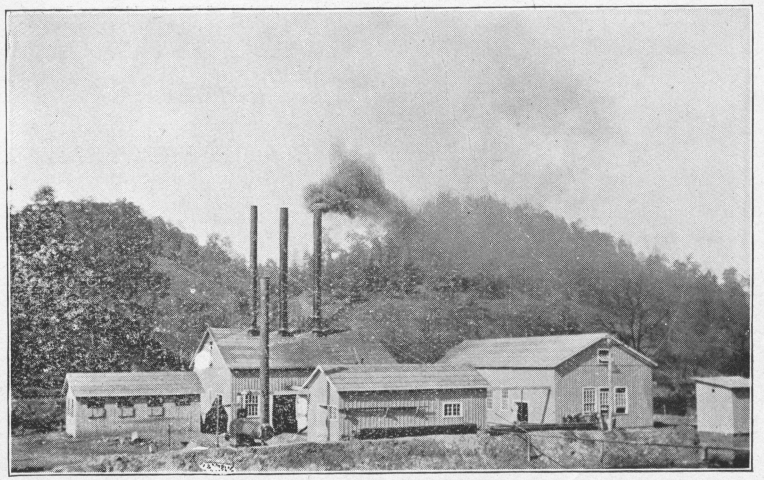
Summary of Relationships.

A consideration of actual field conditions as outlined briefly above establishes beyond doubt a close relationship between geo-



Tank Oil Going to Louisville.

Louisville and Nashville Railroad train of fifty tank cars filled with Kentucky crude oil enroute from the Lee-Estill field to refineries in Louisville. Partial view of train only, taken in Frankfort in front of Old Capitol. Photo by W. R. Jillson, April 16, 1919.



Lewis Pump Station.

This station is located in Morgan County, Kentucky, and is part of the new pipe line equipment of the Cumberland Pipe Line Company. Photo by W. R. Jillson, 1918.

logic structure and proven oil and gas areas in Eastern Kentucky. This relationship may be expresed as follows: (1) oil and gas occur in commercial quantities chiefly along anticlines which in this section may be divided into two classes on a basis of their size and structural importance. (2) Gas is usually found at the highest points of the structures—especially when the structures are closed or domed—though occasionally these highest points may be dry. (3) Oil is found to occur on the flanks of the larger anticlines just below the gas belts, and on the smaller anticlines frequently up to and over crestal points. However, occasionally due to geologic conditions—(A) unconformable strata and (B) tightening "sands"—not apparent at the surface, the "pay" belt may be so low structurally as to be confused with the observed synclinal areas. (4) Dry holes are rare in Eastern Kentucky, and are usually found to be located in the known synclinal areas though they may occasionally occur high on—(A) faulted or (B) sharply folded anticlines. (5) The best oil and gas production is found without exception along the largest and most pronounced anticlines. (6) The opposite is true, that is, the smallest structures show no wells producing either oil or gas in important commercial quantities. (7) The best oil and gas production has been developed along structures separated by wide synclinal areas, which apparently afforded the source for the accumulation of the hydrocarbons.

A broad conception of the structure of this part of Eastern Kentucky coupled with the known distribution of the oil and gas fields either wholly developed or in progress, suggests a definite sequence of events. These are: (1) The primal and simultaneous development of the Irvine-Paint Creek-Warfield Structure and the Pine Mountain Structure, with an attending further uplift along the Cincinnati Arch to the west. (2) The general concurrent migration of the various petroleums away from the Pine Mountain structure and the southeastern geo-syncline toward the Irvine-Paint Creek-Warfield Structure at the northwest. (3) The secondary development of many intermediate small structures in the geo-synclinal strata of only light petroleum productive capacity. (4) The overturning, faulting, and thrusting of the Devonian to Pennsylvania sediments in the Pine Mountain Area which produced a condition of equilibrium in the crustal

forces, and essentially terminated the period of structural growth. (5) Continued to final adjustment of all free hydrocarbons according to hydrostatic or hydraulic pressures.

Conclusions.

The large amount of wildcat drilling done in Eastern Kentucky during the last two years has permitted the determination of the presently considered productive and unproductive areas. An investigation of the location of these productive and unproductive areas operates as a substantiation of the anticlinal theory of oil and gas accumulation. Much unproductive drilling could have been avoided by an advance knowledge of structural conditions. A more widespread and careful use of sound structural interpretations will also avoid many unnecessary expenditures of this kind in the future. A great many apparently excellent structural locations still remain to be drilled and redrilled from shallow "sands" to greater depths in Eastern Kentucky.

The Irvine Oil District, Kentucky.*

BY STUART ST. CLAIR.

Consulting Petroleum and Mining Geologist.

In view of the great interest which has been shown in the eastern part of the United States concerning the oil possibilities of Kentucky, one is impressed with the paucity of reliable literature on the oil fields of the state. A few brief reports by the Federal and State Geological Surveys are about the only reliable guides for the stranger who may decide to investigate the oil fields of the state. When the estimated production figures for Kentucky are published by the U. S. Geological Survey for the year 1918** and a comparison is made between these figures and those of preceding years, for example, let us say for 1913, many will be surprised at the revival of the oil industry in the Bluegrass State during this half decade. There will also be increasing oil production figures for 1919 and 1920, at least.

Although Kentucky as an oil producing state is small when compared with some of our other oil states, the production at the present time and the area of undrilled proven territory is large enough to classify her as one of the important oil states of the Union. In view of this fact let us very briefly consider some of the important points regarding one of the oil producing areas, and allow me to express some of my personal deductions formed during two years of more or less intimate connection with the various fields of the state, and which I trust may be of some value in future prospecting.

This article will be confined to the Irvine District and immediate adjoining areas, which have been prospected with varying success. The Corniferous limestone or Irvine sand is the oil producing formation in the area discussed.

Location.

The Irvine District, in my divisional nomenclature, includes the Irvine field, which extends from the town of Irvine east-

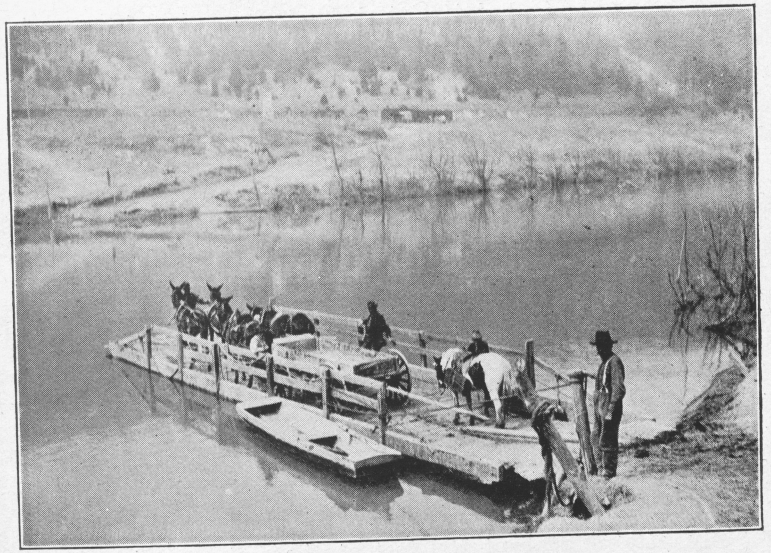
*Republished contemporaneously July, 1919, Bul. 151, A. I. of M. M. E.

**These figures have been published. W. R. Jillson, sketch of the development of the oil and gas industry in Kentucky during the past century. Dept. Geol. and Forestry, Series V, Vol. I, No. 1.

ward toward Campton; the Big Sinking area, which joins and lies to the south of the eastern part of the Irvine field; the Beattyville area, which lies to the north and northeast of the town of that name and joins the Big Sinking area; and the Ross Creek pool, which lies to the southwest of the big production and across Kentucky river. Except for the Ross Creek pool, the main producing area is bounded on the east by the L. & E. R. R. and on the west and south by the Irvine Branch of the L. & N. R. R. Winchester and Lexington are the cities at the gateway to the oil fields, and Torrent, on the east side, Irvine, on the west, and Beattyville, on the south are the principal entrances to the main fields. Evelyn, on the L. & N. south of Irvine, is the point of entrance to the Ross Creek area.

Geology.

The geology of the Irvine District is very simple. The rock formations with which the oil man should acquaint himself lie



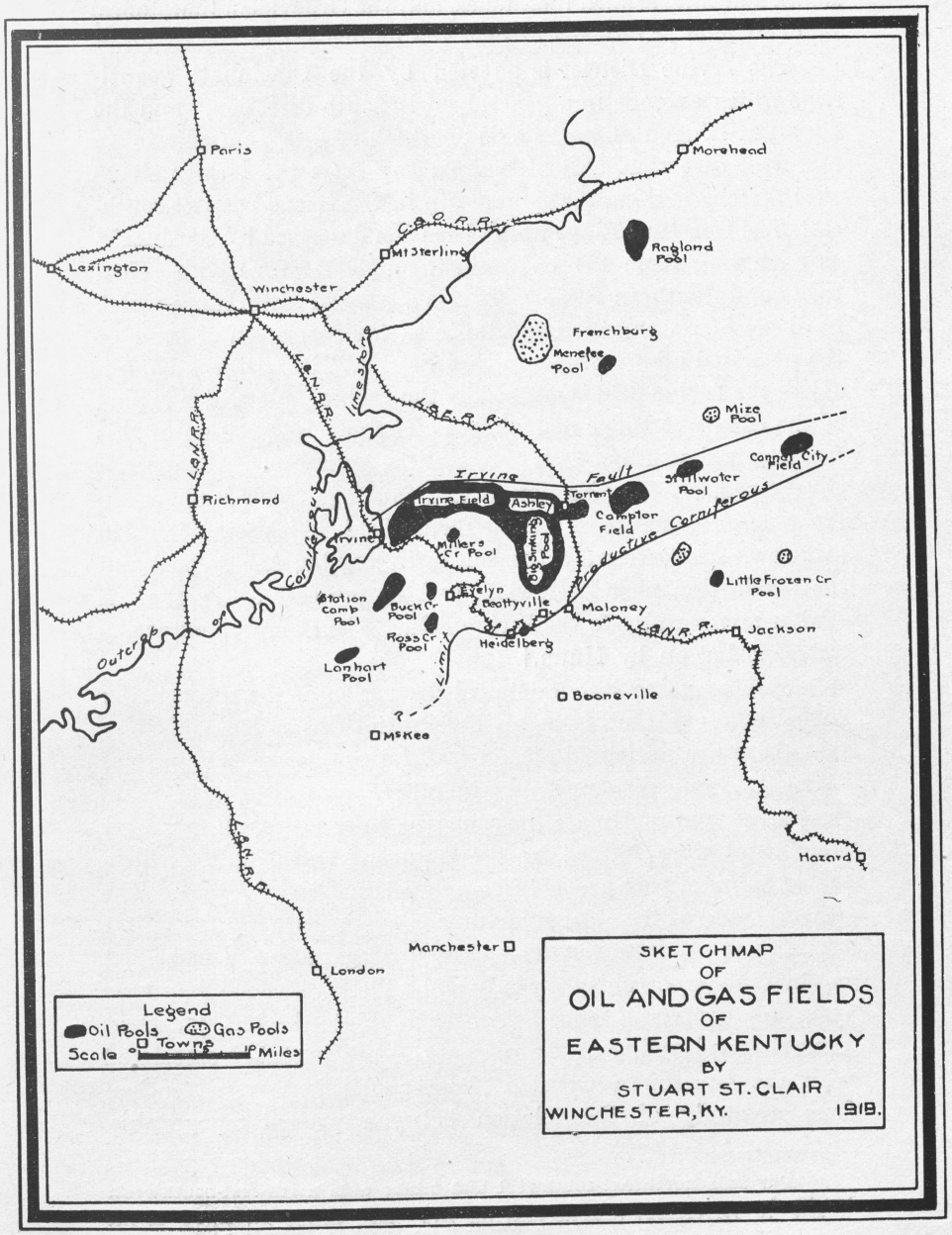
Gateway to Ross Creek.
View of the Ferry across the Kentucky River at Evelyn—the only way for men, mules and supplies to this important field. Photo by R. L. McClure, March, 1919.

between the lower measures of the Pennsylvania sandstones and shales and the Devonian or Corniferous limestone or Irvine

formation. Only a very brief description of these formations will be given as they have been described fully by E. W. Shaw in Bulletin 661-d of the U. S. Geological Survey, to which the reader is referred.

Capping the hills and forming a rim-rock over the eastern part of the Irvine field, the Big Sinking and Ross Creek areas is a cliff-forming sandstone above which are yellowish-gray and dark colored shales with irregular sandstone and conglomerate members, and also some persistent and valuable coal beds. Below and resting on the "Big Lime" are dark colored shales, with irregular thin sandstones, with a thickness up to about 50 feet. Underlying these is the "Big Lime" of the driller or Newman or St. Louis Limestone.* It is typically exposed along the L. & N. R. R. from a point south of Irvine nearly to Heidelberg, and in this district varies in thickness between 100 and 125 feet. The underlying Waverly is composed chiefly of a bluish-green shale and has an average thickness of about 450 feet. The Waverly and the underlying Black Shale formations increase in thickness eastward and southeastward from the Irvine field. The Berea sand is found in the lower part of the Waverly in the eastern part of Kentucky and in adjoining oil sections of West Virginia and Ohio. The Devonian or Chattanooga black shale varies in thickness between 120 and 170 feet in the Irvine District. The base of the formation in most places is a white shale, or fire clay as it is locally called, which varies up to 20 feet in thickness. In some localities brown shale from a few feet to 25 feet in thickness underlies this and directly overlies the Corniferous limestone, which is the Irvine sand of Kentucky. This formation is a dolomitic limestone, sandy at a few irregular strata, and contains chert in varying amounts. Porous beds, irregular in their continuity, are the oil sands of the formation. The outcrop at Irvine is brown in color and about eight feet thick, but in passing eastward the formation thickens rapidly, attaining about 100 feet at the eastern and southern edges of the main producing field. In Wolfe county, near the Breathitt county line, the formation has a thickness of approximately 175 feet. Underlying the Devonian are the Silurian

*Also a representative of the St. Genevieve Limestone. W. R. J.



shales and interbedded limestones, and the Ordovician limestones, one of which is perhaps in part the equivalent of the Trenton.

The Irvine District is affected by the Cincinnati geanticline which extends in a general north-south direction,* and the Chestnut Ridge uplift, the axis of which crosses Kentucky in an east-west direction. All beds dip away from the former structure thereby making the general dip in the Irvine District southeast. The Chestnut Ridge uplift has been described by Gardner** as extending from Pennsylvania through West Virginia, Kentucky and Southern Illinois. This is a general disturbance which has been of paramount importance in the formation of some of the principal oil structures in this district. The northern boundary of the Irvine field is marked by the Irvine fault, which is part of the Chestnut Ridge disturbance. The general position of this faulting is shown by Shaw. Most of the anticlines of the district closely parallel the direction of this faulting. This is shown in the general structure of the old Irvine field, which was described by Shaw. An eastward extension, including the Ashley pool and the production near Zachariah, and to the east of Torrent, is similar structurally to the Irvine field. The Campton extension was reported on by Munn.†

Without going into a detailed discussion of the subject, the writer may say that from his observations he is led to believe that there are anticlinal structures of two ages in this part of Kentucky, and very probably in other parts also. The main structures apparently are the younger, have a general east-west trend, and were formed by the Chestnut Ridge uplift which, in his opinion, was probably completed in Tertiary time. The general trend of the older structures is north-south but the writer hesitates to venture a statement regarding their age as he has not had the opportunity to study all of the facts which may bear upon this problem. Some evidently antedate the last period of general base-leveling of the region and are probably associated with the Cincinnati uplift. These conclusions were reached from a study of the relation between present topographic

*Major axis northeast-southwest and minor axis northwest-southwest. W. R. J.

**U. S. Geological Survey Bulletin 661d. The Irvine Oil Field, Estill County, Kentucky.

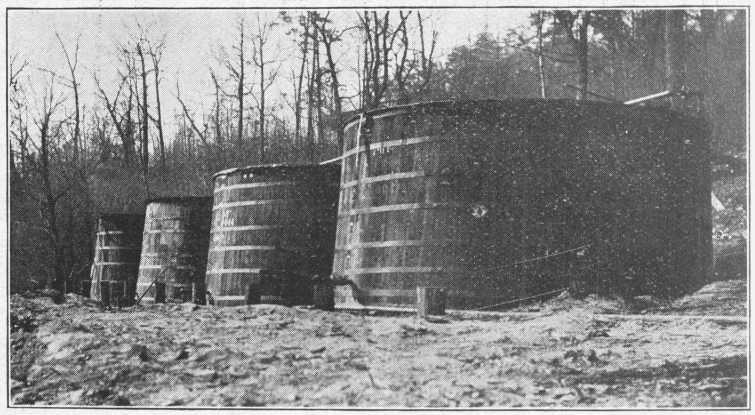
†M. J. Munn. U. S. Geological Survey Bulletin 471a.

features and the structure. A detailed discussion of the physiographic principles involved would be out of place in this paper. The localization of some of the large producing areas may be due in part to the intersection of the younger with the older structures.

Occurrence of the Oil.

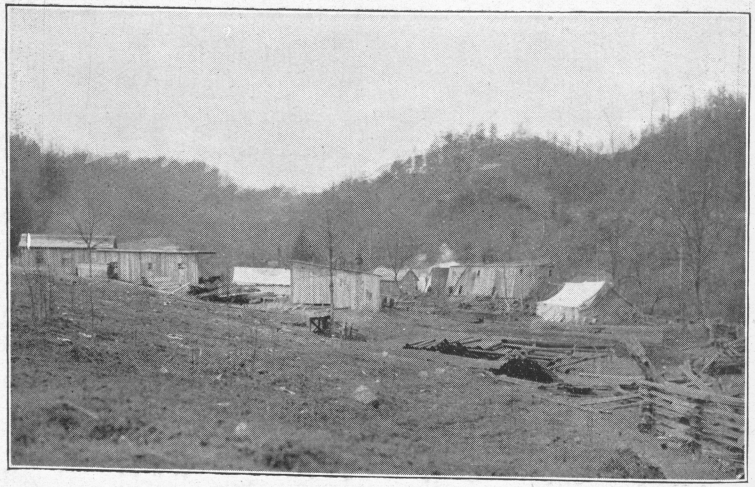
Oil men who have had experience in a field where the oil is found in a limestone will appreciate the eccentricities of sand condition which are encountered in development work in Kentucky. In localities where the limestone is hard and tightly cemented the whole formation may be barren. Tight sand conditions may be encountered in the center of an area with producing wells on all sides and but a few hundred feet distant. Such a condition is most unfortunate when encountered in a prospect well in undeveloped territory as the operator may be led to abandon the area prematurely. Drilling has shown parts of the Corniferous limestone to be generally porous over the area discussed in this paper. Usually a porous bed of variable thickness, a few feet to ten feet or more, occurs directly under a hard limestone cap-rock. Under favorable structural conditions this porous bed may be entirely filled with oil, and under less favorable structure part or all of this porous bed may contain salt water. Over part of the Irvine District only one pay streak is found, but in some localities two or more pays with a little, or in many wells without any, intervening salt water. In some areas abundant salt water may be encountered under the cap-rock, where the first pay should be found, and must be cased off before lower pays can be drilled into. In fact each locality presents varying conditions and an intimate knowledge of the field in general should be acquired so that the operator may know how to handle the problems confronting him in the development of his property.

In general, the oil accumulation has taken place under anticlinal conditions. In the producing areas all folds and well defined terrace structures have been productive and salt water wells have been the result of drilling in the less favorable places. Exception may be taken to the above statement by some or even many geologists when applied to the Big Sinking area, but when



Battery of Oil Storage Tanks.

Property of the Lincoln Oil Company on the Millie Freeman farm, Ross Creek, Estill County, Ky. Photo by R. L. McClure, March-April, 1919.



Field Construction on Big Sinking.

View on the Harve Williams farm showing buildings of the Rex Oil Company, et al., and the Cumberland Pipe Line Company. Photo by R. L. McClure.

other factors governing oil accumulation in this pool, which factors will be mentioned later, are considered in association with the anticlinal theory, the above general statement will be found to cover the case. Only a generalized description of the Big Sinking area will be given in this paper as a complete report on the oil pools of Lee county is being contemplated. From certain deductions which will be given regarding this field the reader may appreciate the writer's reasons for having strongly recommended the Big Sinking Creek area as early as the late spring of 1917, when the nearest drilling was some miles distant. At that time the writer outlined on the map of a prominent Kentucky oil producer the probable west boundary of the Sinking Creek area as being the divide between Little Sinking Creek and Billys Fork of Millers Creek, and the probable eastern limit as the divide between Hell Creek and Walkers Creek. So far nothing of importance has been developed beyond these bounds close enough to be classified as part of the Sinking Creek area.

From what has been said regarding the anticlinal occurrence of oil in the Irvine District, the reader has probably formed the opinion that drilling on such structure outside of the present proven area should also result in favorable strikes. However, experience has shown the opposite results. Wells located near Beattyville, farther south in Owsley county, in southern Lee county, in eastern Lee county, north of Tallega, in Breathitt, Wolfe, and Elliott counties, all located on well defined anticlinal structures, have struck at best only shows of oil in one or two pays. On those wells closest to the producing fields salt water was encountered; in those farther away the Corniferous limestone was hard and in most cases practically dry. When such conditions as these obtain, the geologist is face to face with a problem he must solve. Under a succeeding heading the writer gives his explanation for such conditions.

The Big Sinking Pool.

The structure of the Big Sinking area is not complicated. The regional monoclinal dip which is southeast is crossed by several very low folds, the axes of which are in a general east-west direction. The resultant would be plunging anticlines with a general southeast by east trend. Minor irregularities have pro-



An Eastern Kentucky Ridge Well.
View on Bobby's Ridge in Lee County. Well No. 1 of the Russell Oil Company, on the Burke Hall tract. Photo by R. L. McClure, April, 1919.



A Side Hill Drilling in Big Sinking.
Scene on the George Booth farm—development of the High Gravity Oil Company. Note the improvised road built by the drillers to get on to the location. Photo by R. L. McClure, April, 1919.

duced terraces. In conjunction with this type of structure, there is a broad low fold which extends in a general north-south direction and which definitely outlines, in the writer's opinion, the west and east limits of the Big Sinking pool. The axis of this fold roughly follows main Sinking Creek from Bald Rock Fork northward and the more productive part of the pool is along the crest and on the southeast flank of the fold, with the most productive points determined by the east-west folds described above.

The number of pay sands and their total thickness is variable in the Big Sinking pool. As many as three sands and as much as 40 feet of pay has been reported, but in some places five feet will cover all the actual pay encountered. Probably 15 to 20 feet is an average for the more productive parts of the pool. In general, the pay sand is very porous, although in short distances it may tighten up materially. The best sand condition for quick recovery apparently lies along the crest and the southeast flank of the north-south fold. Westward from this fold the sand changes rapidly; eastward the change is more gradual, but with the increasing depth due to the regional dip the sand becomes tighter and the pay is not so thick nor uniform. However, wells in the tighter sand, although the production is smaller per day, will be longer lived than the wells in the porous sand. The writer has estimated that from the very porous sand as much as 1,000 barrels, and in a few selected spots 1,200 barrels to the acre-foot of *actual* pay will be produced. This amount will decrease to 500 barrels and probably as low as 200 barrels to the acre-foot as the tighter sand areas are approached.

The thickness of pay reported by various owners and lease men is often misleading or in error. In most cases the thickness of the true pay is much less than it is thought to be when the well is being drilled in. Therefore, in making computations the thickness of *actual* pay should be carefully determined else the error in the calculated production per acre will be large. This rough method should be used only when there are no production data on the property or adjoining properties available from which decline and future production curves can be constructed.

The writer has been frequently asked why the oil is found throughout the Big Sinking area, on the higher and in the lower structural positions. It is quite evident that this condition is due to water pressure, chiefly from the south and southeast, which is behind a sufficient body of oil to cause the sand to be filled with oil over the entire area, thereby forming one large pool in which nearly every location is proven. Salt water will encroach upon the field from the south and the wells in that part of the field and in the lower structural positions will be affected first. Reasons for this general conclusion are given under the next heading.

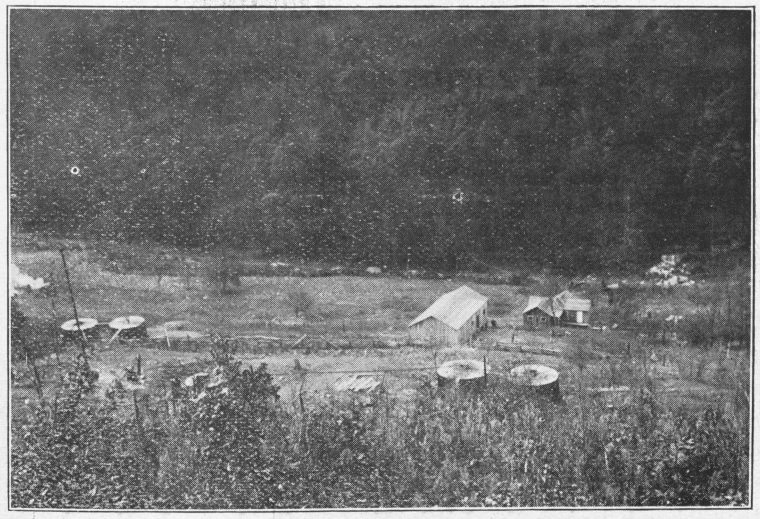
Extension of the Eastern Fields.

The writer's personal experience in the Kentucky oil fields has led to some deductions which may throw some light on the conditions described above and which may be of interest and possibly of some value in future prospecting of the Corniferous limestone or Irvine sand in the eastern part of the state. The area under which the Irvine sand will be productive of oil in commercial quantities is dependent upon three primary conditions listed in order of their importance. *First.* Distance from the outcrop of the Irvine sand and from the major faults. *Second.* Porous or non-porous character of the Corniferous limestone. *Third.* Geologic structure. The writer will probably be criticized for making the second condition less important than the first, but in this field, in his opinion, the porous on non-porous character of the oil formation is dependent *almost* entirely upon the distance from the outcrop and especially from the major faults along which meteoric water is able to reach the Corniferous limestone. It will be remembered that such a system of faulting extends along the northern boundary of the Irvine field and on eastward occupying a similar relation to the Campton and Cannel City fields. Water circulating through certain beds of the Corniferous limestone has dissolved out some of the mineral matter and left the rock porous. The irregularity in the thickness of these porous beds indicates that solution has taken place under non-uniform conditions of underground circulation. The distance to which this circulation of meteoric water has taken place from the outcrop or fault will mark the area of



Ross Creek Field Activity.

View on the J. F. Harris farm, development by the Comet Oil Company, Estill County, Ky. Photo by W. R. Jillson, March, 1919.



Oil well and storage tanks on the head of Cow Creek, Estill County, Ky. Photo by McClure Lexington.

continuous porous formation which may contain either oil or salt water, according to structural conditions, and will mark the limit of the area which has been unaffected by water circulation and in which the Corniferous limestone will be generally tight and hard. The water in the Irvine sand being heavier than the oil will occupy a position farthest down the regional dip and will be dammed back by increasingly less porous beds. This would form what we may term a monoclinal trough produced by differential cementation of the limestone. Obviously then, a well drilled on the crest of an anticline near the lower limit of this water area would encounter water and not oil in the Irvine sand. The position of the oil on the regional monocline would depend upon the amount of water in the trough. As stated before, it is the writer's belief that this pressure of salt water to the south of the Big Sinking area together with very porous rock conditions underlying the Big Sinking area is the explanation for the unusually large concentration of oil in this field and may explain the presence of oil-saturated sand strata in both high and lower structural positions in the Big Sinking pool. The pressure which causes flowing wells is water pressure and gas pressure combined. Some water has already been encountered at the southern edge of this pool, although none has yet been found in the main part of the pool.

Outside of the large area which has been affected by circulating waters, there may be small areas where the Corniferous limestone has sufficient porosity, either primary or through recrystallization or through dolomitization, or where minor faults have allowed some meteoric water to reach the Corniferous and dissolve some of the limestone, thus producing porosity in the rock, to allow small accumulations of oil. Chance drilling may strike small pools of this classification which may be found on anticlines or in lower structural positions. Tests, however, should be made on the most favorable structures that can be found. No wells in this category of any importance have yet been struck unless the Little Frozen Creek production is extended beyond its present limits.

Roughly, the probable line of separation of the possible productive area and the non-productive area for the Corniferous limestone may be drawn. Inside this line proper structural conditions are necessary for commercial accumulations of oil. This line should run along the east side of Ross Creek near the Lee county line to Kentucky River, thence eastward, crossing the river and running through Heidelberg, Beattyville, and Maloney. From here the line should run northeastward, probably passing close to Holly Creek, Wolfe county, thence paralleling and closely following the Campton-Cannel City anticline. This line is shown on Figure 1 as the limit of the area of productive Corniferous. The appropriate position of the Irvine fault and the outcrop of the corniferous or Irvine sand are also shown, together with the oil and gas pools producing from the Irvine sand.

If the theory which has been advanced, that the distance from the outcrop is of primary importance in determining whether the Corniferous limestone will be porous enough for oil to accumulate in, is correct, then in areas where this formation is present and of similar character to what it is in the Irvine District and if the overlying petroliferous black shale is present, then under favorable structural conditions there should be some accumulation of oil or gas, provided, the structure is far enough away from a fault of any magnitude which is on the down-dip side of the structure to allow a sufficient area from which accumulation may come. Reference to Figure 1 will show that the Menefee gas field, the Ragland oil field, and the Station Camp, Ross Creek, Buck Creek and Lanhart oil pools are not far from the outcrop of the Irvine sand. These fields are located on structures and, therefore, other small fields may be opened, under favorable structural conditions, within a restricted distance from the outcrop of the Irvine sand.*

Economic Conditions.

For the past two years Kentucky has enjoyed a great oil boom and prices for acreage have gone skyrocketing in certain parts of the state following each strike of importance. Probably no area has had such a quick advance in speculative prices in such a short time as the Big Sinking area, in Lee county. Two years ago the Irvine field extending northeastward from the

*Since this article was written several oil wells have been drilled in southeastern Menifee County on a well defined structure.

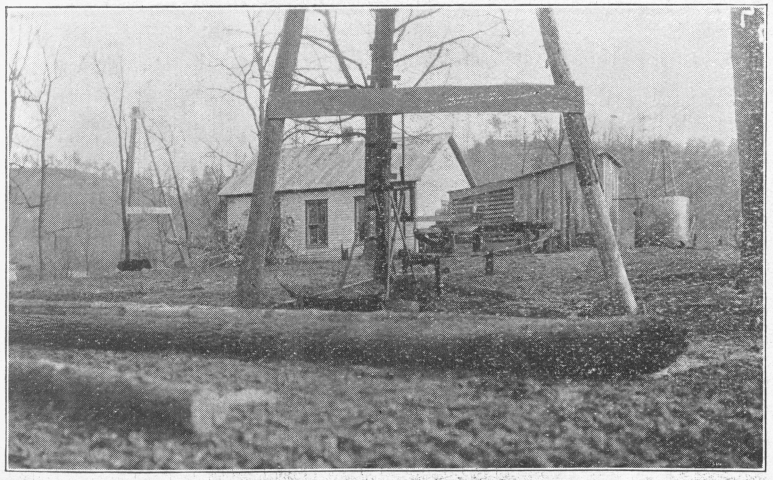
town of Irvine to Pilot was receiving nearly all the attention of the oil men. Acreage along Big Sinking Creek was selling for a very small bonus. About this time, with the opening up of the Ashley pool, Pilot district, the price of acreage began to advance as possibilities of extension of the proven territory became apparent. By the fall of 1917 acreage in the Big Sinking area was selling from $50.00 to $100.00 per acre, and during the year 1918 prices advanced to $2,000.00 and $3,000.00 per acre with extra royalties attached, in some cases. On such high priced acreage flowing wells are sometimes drilled, but the average initial production will probably be between 100 and 300 barrels per day. The writer knows of a few wells that produced close to 1,000 barrels the first day and another that flowed 24,000 barrels in a little over four months. Although the above illustrations are the exception, there are many wells which have produced and are producing way above the average.

A most unfortunate precedent set in the Kentucky field was the granting of additional royalty. It was started at a time when there was no valid reason for such action. The policy once begun soon became a "habit" and kept many strong, conservative companies, which were governed by well trained and experienced oil men, out of the field and brought in many operators who had the oil business to learn, and some stock companies who had to get production.

The Big Sinking area is a remarkable oil pool. The depths of the wells vary from 800 to 1,200 feet, dependent upon the topography; there are two, and in some places three, pays with an aggregate thickness of 10 to 30 feet; much of the pay sand is very porous; the oil in parts of the field is under considerable pressure; the gravity of the oil is around 40 degrees Baume and the gasoline content above 30 per cent;* the cost of drilling and equipping a well varies from $3,000.00 to $5,000.00. However, these advantages do not warrant, in the writer's opinion, the payment of such high prices for acreage and additional royalty when the *average* size of the initial production is considered. On account of the porosity of the pay sands the production will decline rapidly and the average life of the wells in

*Some tests are reported as high as 45 per cent.

the Big Sinking field will not be long. This fact should be of first consideration in determining the amount which can be paid as bonus per acre, to which should be added the cost of development of the property, interest on the invested capital, and operating expenses during the estimated life of the property, so that the operating owner may realize a profit commensurate with the risk taken.



Ross Creek School House Lot.
View shows three wells drilled in on a single school yard in Estill County, Ky. Photo by R. L. McClure, March, 1919.

The Big Sinking pool is so young and in the older Irvine pool such poor records of production were kept that it is difficult to get many accurate figures from which depletion can be computed. Some leases that were located on favorable geologic structure and had average sand conditions were producing about 10 per cent as much oil at the end of the first year as they were producing at the point of maximum flush. Some have declined considerably more where the wells were put too close together. However, a few of the properties in the older Irvine field have held up remarkably well, a fact which may be due to a thicker pay and tighter sand, or inability of the pipe line to take all the oil.

The oil sand in the best parts of the Big Sinking pool is so porous that wells should not be spaced too closely. One well to

five acres should be sufficient, but on many leases one will see wells 300 feet apart and not infrequently one well to the acre. Under such conditions the wells must decline rapidly unless there is an unusually thick pay sand. The writer has estimated that on properties where wells are properly spaced and where there is an average thickness of pay, a well that is continuously pumped would be producing about 10 per cent of its initial capacity at the end of a year. This figure must be further decreased where wells are closely spaced, or where the pipe line does not take all the oil produced, or where protracted shutdowns are experienced, these estimates must be changed proportional to the lengths of the unpumped periods. Further, the average well which will have an average thickness of pay in the very porous sand areas of the Big Sinking pool that is pumped regularly to its capacity will probably produce as much in the first six months as during the remainder of its life. Where the pay is unusually thick it will take longer. In tighter sand areas, it will probably take a year to produce half the oil under regular pumping conditions and to get the maximum recovery the wells should be spaced closer than in the porous sand areas. What has been said of the individual well may be applied collectively to a lease. Where new wells are being drilled and production being added all the time, the decline in the producing wells is not as noticeable as when the property is fully developed. Production and decline records of wells and lease should be carefully kept so that the owner may profit by the depletion allowance and can claim exempt from taxation.

A concrete example of the above may be given. A company purchased a small lease which was producing and only partially drilled up paying at a specified rate per barrel of production which figured at a rate of approximately $30,000.00 per acre. With a very porous sand and 20 feet of pay, probably 15,000 to 20,000 barrels per acre should be recovered, if the pay is as thick as claimed. At the end of about five months of regular pumping 7,000 barrels per acre was removed, which is between one-half and one-third the calculated recoverable oil. At the end of two or three years the property will be practically exhausted. A small profit will be shown on the investment if depletion is charged off each year at a rate commensurate with the

decline of the property. The importance of correct estimates of depletion of properties in the Big Sinking pool and in other pools of similar character in Kentucky cannot be too forcibly impressed upon the operators.

There are exceptions to the rates of decline for the average well as given above. Some wells have flowed for several months and pumping has failed to lower others to any great extent, but in all calculations, such as these should be considered as exceptions.

The producing area north and northeast of Beattyville is but a southern extension of the Big Sinking field and the remarks made are applicable to it. Drilling is a little deeper and the wells are smaller, but there is room for expansion of the area. Care, however, should be taken in drilling to avoid the salt water. The Ross Creek pool is Big Sinking on a small scale. It has been greatly overdrilled and must, necessarily, have a short life. The area is rather limited but there are possibilities for a small extension southward. Prospects for a few smaller areas of production in this general region are good.* The Irvine field has been pretty fully exploited, and only drilling up of proven territory remains. This field has now been extended eastward several miles beyond Torrent, the eastern entrance to the producing areas. Efforts to carry production north of the fault of this field have failed.

Kentucky was a poor man's field during the early stages of its recent oil development, and many have made comfortable fortunes. To get acreage anywhere near the proven fields today requires capital. Wildcat acreage can be gotten cheap but the chances of success are commensurately lessened. There are opportunities for consolidation today that did not exist even a short time ago. Many local organizations could be handled much more economically and efficiently if they were under larger managements.

Conservation in the Kentucky oil fields is a pertinent question at this time. Mismanagement and waste can be seen in many places and must cause injury to the field. Considerable

*Since this article was written, in the Fall of 1918, a pool has been opened on Buck Creek, Estill County, about four miles north of Ross Creek. The area is one of the prospects referred to above and promises to furnish a number of small producing wells.

gas is being produced with the oil, which should be rich in gasoline and which is allowed to go to waste by the thousands of cubic feet per day. However, the field is young and such conditions are remedied with time.

Conclusion.

The object of this paper is to call attention to the probability that the area of production from the Irvine sand in eastern Kentucky is a function of the distance from the outcrop of the oil formation and from the major faults. The results of many wells drilled to the south, southeast, and east of the producing Irvine sand pools uphold this theory. However, the writer does not wish to discourage prospecting in the deeper areas as there are possibilities of opening up small, isolated pools. Prospecting should also be carried on with a view to opening up production in sands higher than the Corniferous limestone. Southeast and east of the Irvine District the Berea, the Big Injun and sands higher than the "Big Lime" may be found to contain oil in commercial quantities. In Knox, Floyd, Magoffin and Lawrence counties there has been small production from these higher sands for a number of years.

A number of wells have been drilled below the Corniferous in the Irvine District, but no oil formations were found. Sands are reported but oil shales apparently are absent. The possibility of finding a deeper pay is not very promising.

Manuscript received April 1, 1919.

Relation of Private Forestry to the Economic Development of the State.

BY J. E. BARTON,

Commissioner of Geology and Forestry.

While the subject herewith presented is not strictly scientific in all its phases, nevertheless the conditions of which it treats are of such grave importance at the present time that I feel this opportunity is a most excellent one to set forth the ramifications of the problem involved. No one single event has served to concentrate the attention of the country upon the serious condition of the timber supply in the United States so acutely as has the demands of the war which has just closed, and it is to meet this very plain situation that I am presenting to you today these facts as they especially relate to Kentucky.

There are certain outstanding features with regard to the ownership of Kentucky forests which are essential to a complete understanding of the difficulties presented in handling the situation and these may be summarized as follows: (1) All the forest lands of the state are privately owned.* (2) There are no state forest lands nor are there within the boundaries of Kentucky and federal National Forests which might tend to modify the conditions herein set forth. Kentucky is at the present time one of the few southern states in which purchases of land for National Forests under the Weeks' Law have not been made. (3) The ownership of private forested lands may be roughly classified under three heads: (a) those owned by large coal corporations; (b) those owned by large timber and lumber companies; (c) those owned by private individuals where the forested areas bear more or less a relation to lands cultivated. By this I mean that they are what has been recently termed—for lack of a better designation—farm woodlands. In this latter classification there is a distinction between the farm woodlands in the eastern part of the state and those in the western and

*Kentucky has recently acquired by gift from the Kentuckia-Cartron Corporation, a state forest of 3,400 acres on Pine Mountain, in Harlan County. J. E. B.

south central parts of Kentucky. In Western Kentucky the forests form usually a more or less definite area (as a rule a small percentage of the entire tract), while in the eastern part of the state the cultivated areas are really an insignificant part of the area owned or controlled. A survey of these brief facts of ownership will make it clear just how difficult it is going to be to form some plan of management of all forest areas looking to a fixed and continuous timber supply and how improbable it is that in the immediate future any clear and well-defined policy, looking to the ultimate benefit of the state, is likely to be evolved. unless a strong centralized effort is made in this direction.

In dealing with this whole proposition, the biggest handicap is the lack of an adequate recent survey of the forest resources. The only real attempt which was ever made to arrive at a clear evaluation of the forest resources of Kentucky was that begun in 1906 and continued in two subsequent years under a cooperative agreement between the then Bureau of Agriculture, Labor and Statistics and the United States Forest Service, when the small sum of $8,000.00 was made available for this specific work. While, under the conditions in which this first survey was made, it was not possible to gain complete and accurate statistics of the available forest resources of Kentucky, nevertheless the work done at the time serves as a fair index for future comparisons and studies. The result of this survey shows that there was in the state about the year 1910 a stand of 24,115,796 M feet of timber board measure and that the land on which this forest stood represented an area of about 35% of the land area of the state. However, it is plain that the development and exploitation of the timber resources of Kentucky had at that time hardly begun any more than had the development of the coal areas. Previous timber operations had served to do little else with regard to Kentucky forests than to cull out the best trees of certain particularly desirable species, and for the most part species which were easily floated, because the transportation of timber at that time was largely confined to the streams. The species which received most attention in these early days were black walnut and yellow poplar (the tulip tree) and to some extent white oak and cherry. The result of this exploitation was that the poplar and black walnut were rapidly removed from the

stand so that today these two extremely valuable species have largely disappeared from the forests of the state. The big timber operations have come into existence mainly within the last five years and a rapid survey of such operations at the present time shows that in many instances all the merchantable timber on large areas has been completely removed and marketed. In 1916, it was figured that 40% of the original stand included in the estimate of 1906, 1907, 1908 has been cut off and removed, leaving that much timber land upon which there was no growth at all or relatively inferior growth. In 1919, it is estimated that approximately 66% of the original stand had been cut. In a measure, this stand has in the meantime been replaced by the growth of a certain amount of young timber, but by no such amount as to replace appreciably that already cut. The cut of lumber from 1899 to 1917, as obtained from the figures from the United States Bureau of Census and other sources, is as follows:

1899—774,651 M. ft. B. M.
1908—658,539 M. ft. B. M.
1909—860,712 M. ft. B. M.
1910—753,556 M. ft. B. M.
1911—632,415 M. ft. B. M.
1912—641,206 M. ft. B. M.
1913—541,531 M. ft. B. M.
1914—596,392 M. ft. B. M.
1915—560,000 M. ft. B. M.
1916—525,000 M. ft. B. M.
1917—360,000 M. ft. B. M.

It will be noted that from 1909 to 1917 the production fell away about 60%. The steady decline in the amount of lumber annually cut from the forests of Kentucky is a sure indication of the decline of the forest resources under the extensive operations which have been going forward, although lumber is only one of many products cut from the Kentucky forests. It is an actual fact that there still remain very few large bodies of timber in Kentucky of such large size as to warrant the erection of large and expensive mills and the expenditure of the necessarily large outlay in transportation facilities, etc., for the undertaking of major operations. Already Kentucky is beginning to see that definite change from large permanently located sawmill plants to small minor operations, the main feature of which is in most

instances a mill of the capacity of 50,000 feet per day or an even smaller portable mill. Of course, the interpretation of this whole situation is that the virgin forests have for the most part disappeared or will be gone in the immediate future. It is safe to say that the next ten years will see the end of a great many grades of timber with which we are at the present time familiar and which can only be cut from timber or large growth such as occurred in the original forest stand. In speaking of the decline of timber resources, I do not want to imply—as has frequently been done—that utter exhaustion of timber supplies stares us in the face, because the timber cut is in some measure replaced by the natural reproduction and the growth of the small stuff which remains on the ground after the major operations are completed. And yet in a large measure this natural yearly accretion pays tribute in no small part to those demands for timber which are able to make use of trees of small dimensions. One of these, which may be mentioned, is the tie industry and another, particularly in the eastern part of the state, is the coal mining industry. To depend on this volunteer annual accretion, precarious and undependable under present conditions, is little short of suicidal.

As I stated early in this paper, Kentucky has no state-owned forest areas nor any National Forests under federal control within its borders which would serve as a nucleus from which a future supply of timber might be expected.* This is in itself a serious situation since the state and the federal governments are undoubtedly the two agencies in the best position to insure a stablizing influence and to point the way to a regulated condition where a reasonable production of timber might be expected annually as part of the state's contribution to the economic life of the nation and particularly to the industrial development of the people of the state. We have, then, to deal with the exceedingly difficult proposition of private ownership and to evolve some directing influence whereby a stable condition in the growth and production of timber resources and the exploitation and marketing of these resources may be gained. As the matter stands now the production is too erratic, too much affected by abnormal conditions due to the financial stresses of

*This statement was true when this paper was written, May 1, 1919. J. E. B.

private concerns and too little subject to the real necessities of supply and demand.

I have already stated that three kinds of private ownership naturally present themselves, and I shall deal with these in order. (1) The large timber landowners are chiefly concerned (and in most cases entirely so) in the cutting and logging of the timber. They have little or no interest either in a second growth of timber or in the ultimate disposal of the lands which have been logged off. These owners have bought the land solely for the market value of the timber thereon and naturally they are mainly occupied with the marketing of the timber at the most advantageous time and under the most advantageous conditions. They are influenced by many factors, among which may be mentioned the market value of their timber at the time of cutting, means of transportation, questions of overhead, such as taxes, protection of their timber, insurance, etc., and a combination of all these influences will almost inevitably result in the rapid logging off of all these large tracts within a comparatively short time. One of the particular features in this connection is the effect of the recent taxation laws in their relation to timber lands. The laws in relation to taxation passed by the 1916 and 1918 sessions of the General Assembly aimed at land classification and in a measure this classification has been carried out. The classification has, however, served to increase decidedly the burden of taxes on timber lands since timber lands are taxed as such without regard to situation, character of the stand or any other modifying feature and no attempt is made at assessing the timber separate from the lands. The tendency under these laws is against the holding of timber lands as such for long continued periods and results in the evident desire to cut the timber off as rapidly as possible under the most advantageous market conditions obtainable and to disregard any problem with relation to the future timber supply or the disposal of land. Urged on by these facts and by favoring market conditions, some of the largest timber tracts now remaining in Eastern Kentucky will be logged off within the shortest possible space of time.

(2) The coal companies, in view of their expectation of long time operations upon their coal lands, and the necessity of a

supply of timber for the operation of their mines, are in the best position to carry on a farsighted and an intelligent management of their timber areas than any other character of timber landowners in the state. But they are seriously handicapped in undertaking any adequate program of this character by many things. Among these may be mentioned the very evident reluctance of the coal mining interests to engage in any activity or to evolve any policy which does not clearly relate to coal mining in its strictest sense. This results in a narrow-gauge policy which precludes any broad attempt to manage the forest areas so as to secure therefrom the maximum benefit and to insure the greatest future usefulness and productivity of the land surface controlled by them which should, in most cases, be maintained in forest growth. Local questions of pasturage and cultivation of farms by tenants also influence the situation.

(3) The third class of owners are those whose chief interest is in agriculture and whose woodlands, as a part of their holdings, are more or less a side issue. And yet the woodland holdings of this class in the aggregate form no very small part of the wooded area of the state and include in a large measure land which will be indefinitely devoted to the growing of trees. The management of this last character of timber land holdings and the aims of such management differ very materially from the two preceding and the stimulus to a careful management of these tracts is necessarily considerably at variance with the general aims of any forest policy in the state relating to private holdings. Chiefly these landowners look to their woodland as a source of domestic and farm supply or as a means of obtaining ready cash by the sale of the products therefrom.

We come, then, to this point that the chief interests who own the timber lands of the state and hence control any movement looking to a unification of a forest policy within Kentucky must be reconciled so far as possible with the economic needs of the situation. The crux of the situation is the desirability—even the necessity—of having a cheap, nearby supply of timber for various industrial needs. Transportation is here largely the controlling factor. Freight rates since the beginning of the war and some time previous thereto have been constantly increasing, with a resulting increase in the price of the lumber and

timber to the consumer. Moreover there has been recently as regards timber itself a very decided advance in stumpage value. For instance, heretofore, in the state (to cite one class of products) ties have sold at prices f. o. b. the railroad track ranging from thirty to fifty cents. The price of ties has increased at the present time so that they are now selling at from one dollar to one dollar and a half. Other timber commodities are increasing in the same proportion. The day of cheap lumber has definitely passed. Our chief concern, then, is to retard this increase in timber values for local consumption as much as possible and to have available the greatest supply for the needs of the various industries of Kentucky. The history of the lumber industry has been that as soon as the timber was cut out of one region the lands would be permitted to lie idle and unprotected and eventually sold. The mills were moved to other fresh fields and no attention whatsoever was paid to the result so far as the deterioration of the land itself was concerned or any future crop of timber which might be harvested therefrom. A hasty survey of this situation seems to point to a very definite state control of the cutting of timber and a detailed investigation of the timber industry within the state as a means of remedying the situation and placing it on a sane basis. Any study and investigation which adequately covered the ground would involve, among other things, these features: (1) A complete and accurate inventory of the remaining timber resources of the state. (2) Extensive investigations in the matters of yield and growth upon which at the present time there is little or no satisfactory data (3) A thorough study of the tax situation which at the present time makes not only undesirable, but in most cases impossible. the holding of timber lands by private individuals with a view to maintaining such lands in forest crops. (4) A very definite plan for the purchase of lands by the state to be retained as a nucleus for extensive state forests for the future. (5) Adequate appropriations for carrying on this kind of work. (6) The establishment in selected advantageous situations of a limited number of forest experiment stations where many forest problems might be worked out under field laboratory conditions. There is no doubt but that if the state would commit itself to a policy involving these features that the awakened conscious-

ness of the federal government in this same direction will make possible additional funds which could be used in cooperation with the state toward the ends above outlined in the same manner as funds for agricultural extension work heretofore appropriated by the federal government. Such steps are seriously contemplated at the present time so far as the federal government is concerned and the interest of Kentucky should be focused upon the possibilities in this direction with the idea of being able to meet the situation when it arises. We need to share in the benefits of any federal appropriations which may become available and to have a definite program under which any sums placed at the disposal of the state may be intelligently and continuously expended looking toward the amelioration of the present grave situation.

The Status of the Mauch Chunk in Southeastern Kentucky As A Producer of Petroleum and Natural Gas.

BY WILLARD R. JILLSON,

Kentucky State Geologist.

Introductory.

During the past year with the steady increase in oil and gas prospecting in Johnson, Martin, Floyd, Knott, Perry and Knox counties there has developed considerable interest in the number and sequence of the oil and gas producing "sands" in this section of Kentucky. Because of the variability of the Lower Pottsville sediments and the great unconformity between them and the underlying Mauch Chunk, much uncertainty has arisen in the correlation of producing sands. Since the principal oil production of this area comes from the basal Pottsville and Mauch Chunk the interest chiefly centers about these horizons. It is the purpose of this paper to bring together the data of both new and old drilling in this section and offer by such means an interpretation of the actual conditions existent in the subsurface stratigraphy. The field work upon which these conclusions are based was carried on intermittently over a period of two years—1917 and 1918—during which time all the principal producing and wild catting localities of this part of the state were visited.

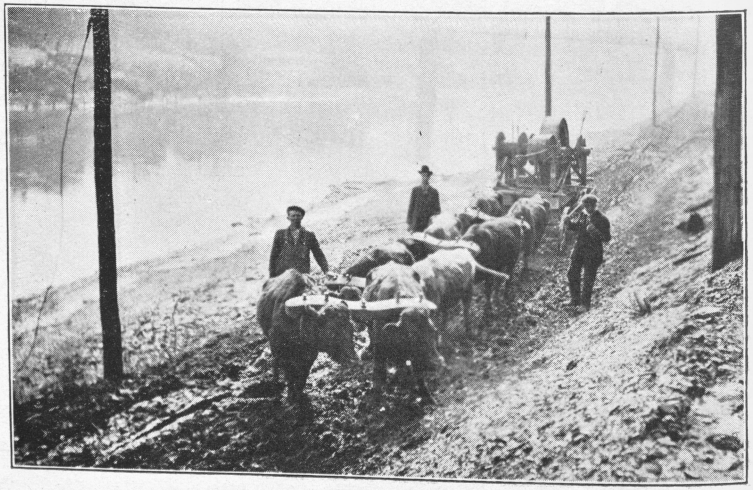
Stratigraphy.

The surficial rocks of Johnson, Martin, Floyd, Knott, Perry, and Knox counties, Kentucky, are of Pottsville age. The same is true of Pike county with the exception of that portion along the Pine Mountain Fault, where through over-thrusting the underlying Mississipian formations are brought to the surface. Johnson county shows Middle Pottsville or representatives of the Norton Formation in the western and northwestern portions. The eastern and southern parts of this county, due to the pronounced dip in these directions, show only the upper Pottsville

or Wise Formation. This formation is commonly known in West Virginia as the Kanawha. The Upper Pottsville rocks are also surficially exposed in Floyd, Martin, Knott, Perry, Knox and also in Pike, with the exception of the Pike Mountain locality.

Oil and gas operators in this field generally spud into rather thin creek or river bottom soil of the Coal Measures. All drill records that are carefully kept will show from two to four and sometimes six coal seams of varying thicknesses before the bit strikes the first limestone. This first limestone—sometimes only a calcareous shale and therefore often recorded as a shale—is generally an upper member of the Mauch Chunk. It represents the break or change from the heterogeneity of conglomeratic sands and shales and overlying coal seams of the Pottsville, to the more uniform alternation of sands, shale, and limes of the Mauch Chunk. In a way it anticipates a growing limy condition as the bit goes down, which culminates within a short distance in that well known drilling horizon the "Big Lime" of the Mississippian System.

Drillers operating in the Upper Big Sandy Valley have definitely determined four separate and generally distinct sands



Hauling A Rig in the Big Sandy Valley.

Eastern Gulf Oil Company moving its heavy National rig over very poor roads from Bull Creek to Left Middle Creek, Floyd County Ky. Photo by W. R. Jillson, March, 1918.

above the Big Lime. These have all been correlated as belonging in the Pottsville.* They are regarded as a splitting up of the thinner Pottsville of the northeastern part of the state and are named in descending order, Beaver, Horton, Pike and Salt Sands. Three Pottsville sands are also listed in the Knox county, Little Richland Creek section. These in descending order are the Wages, Jones, and Epperson. The following table of this upper portion of the Paleozoic Sediments of Kentucky has until recently been considered correct:

KENTUCKY SERIES AND CORESPONDING OIL SANDS.*

System.	Series.	Sands	Remarks
Pennsylvanian	Conglomerate Measures Shales, Coals Massive	Beaver, Horton, Pike, Salt } of Floyd Pike etc. — Wages, Jones, Epperson } of Knox	Corresponds in part to Pottsville Conglomerate of Ohio, West Virginia and Pennsylvania.
Mississippian	Chester Group. Shales, Limestones and Sandstones.	None known as yet.	Corresponds to Mauch Chunk of West Virginia and Pennsylvania.
	St. Louis Group. Mostly. Limestones.	None known except where broken by an intervening sand in Pike and Martin Counties.	Corresponds to Mountain Lime, Big Lime and Green Briar Lime.

(Lower part of the original table omitted because of irrelevancy.)

*J. B. Hoeing, Oil and Gas Sands of Ky. Bull. 1, Ky. Geol. Surv., 1905, p. 12.

The Mauch Chunk.

According to this correlation it can be readily seen that the principal production of this portion of Kentucky is ascribed to the Pottsville. A consideration of the facts revealed by the somewhat extensive recent drilling of this section does not apparently substantiate this view any longer. It has been found by constructing a detailed section of six new and carefully kept well logs from a point on Mud Lick Creek, west of Paintsville, central Johnson county, to Wheelright, on the head of Otter

*J. B. Hoeing—Oil and Gas Sands of Kentucky. Bull. 1, Ky. Geol. Surv. 1905, pp. 12 and 13.

Creek of Left Beaver Creek, in the southern nipple of Floyd county, that the true Mauch Chunk is present at all points south of Prestonsburg. Furthermore in this region the Mauch Chunk shows a very striking resemblance to its described typical occurrences in the adjoining state of West Virginia. These recent wells, which show such splendid representation of the Mauch Chunk, are, going south in Floyd county, the Joseph Gray No. 1, Bull Creek, J. M. Akers, No. 1, Left Beaver, Frazier No. 1, Left Beaver and the Elkhorn Coal Corporation No. 1, Wheelright. Each of the logs shows a sandstone varying from 50 to 100 feet thick overlain by red shale from 10 to 50 feet thick and underlain by an impure limy shale —the Pencil Cave.

In a letter to the writer under date of March 4, 1919, Prof. I. C. White, State Geologist of West Virginia, says in part:

> "I would say that nearly everywhere in West Virginia we have a well-defined sand in our Mauch Chunk Series. It was first discovered near Sistersville, Tyler County, West Virginia and named the "Maxton" Sand from its discovery on the land of a farmer named Maxton. It has proven productive over a considerable area and always occurs a short distance below the top of the first Red Beds below the Pottsville conglomerate while the Pencil Cave is practically universally present below the Maxton Sand and immediately on top of the main Green-briar or Mountain limestone. Hence, if you find a productive sand in eastern Kentucky section at the horizon in question and Red Beds above and Pencil Cave below, it would represent our Maxton Sand of the Mauch Chunk Series of Chester Group."

A further inquiry into the records of a large number of very old wells, many of which were drilled into this section before it was as well known as at present, reveals the rather startling fact that the Mauch Chunk sequence of (1) Red Rock, (2) Sandstone, (3) Limy shale was encountered in widely separated places. It shows great variability both in known thickness ranging from 9 feet in Floyd county to 274 feet in Martin. The shallowest depth at which the red rock was encountered is 872 feet in Floyd and the deepst 1566 in the same county—southern part. These old records as excerpted* are presented herewith for individual study.

*J. B. Hoeing—Oil and Gas Sands of Ky. Bull. 1, Ky. Geol. Surv., 1905, pp. 84-93, 161-179, 80-84, 94-97, 180-182, 103, 107.

Floyd County.

LESSOR	Waters.	Depth to Red Shale.	Known* Thickness.
Joseph Gearhart	Salt Lick Creek	1,158	14
Susanna Gearhart	Right Beaver—Salt Lick	1,053	49
James Prater	Brush Creek	931	228
G. T. Kendrick	Cow Creek	1,143	267
Joseph Gray	Bull Creek	900	130
Marion Rice	Brush Creek	1,020	13
Jack Allen	Salt Lick	1,126	9
George Allen	Right Beaver—Salt Lick	1,045	134
R. S. Elliott	Mud Creek	1,566	195
A. S. Crisp	Buck's Branch	930	131
T. J. Webb	Henry Branch—Beaver Creek	872	253

Martin County.

Jack Cassidy	Hardin Branch—Coldwater Fork	1,050	140
Burning Well	Tug Fork—Big Sandy	764	274
Sam Munsey	Big Branch—Wolf Creek	1,010	225
J. M. Stepp	Wolf Creek		160

Pike County.

Schomberg Well	Caney Fork—Johns Creek	1,336	164
	Cedar Creek	1,211	139
May	Bear Fork—Robinson Creek	1,490	102
Flem Maynard	Brushy Fork—Johns Creek	1,312	254

Knox County.

Madeline Gray	Gray's Station	910	268

Whitley County.

L. E. Bryant	Pine Knot	807	93

In order to show the stratigraphic sequence of the Pottsville-Mauch Chunk Sediments in the Big Sandy Valley and the rapid thickening of these upper formations to the east, two well kept logs have been selected and are presented. The first is a

*The bit in all of these instances probably did not pierce the entire Mauch Chunk and therefore the thinnest thicknesses given may involve slight error.—W. R. J.

rather recent drilling near Prestonsburg, Floyd county, the second a very much older drilling on Big Branch of Brushy Fork of Johns Creek, Pike county.

Log No. 1. Illustrating the Pottsville-Mauch Chunk. Joseph Gray No. 1. Bull Creek, Floyd County, Kentucky.

Stratum.	Thickness.	Depth.
Soil, 10" Casing	14	14
Pennsylvanian System.		
Sand and shale	26	40
Coal, water	4	44
"Pottsville" conglomerate	211	255
Shells, shale	55	310
Sand	90	400
Shale, shells	100	500
"Beaver" sand	200	700
Small gas at 625.		
Slate and coal	24	724
Slate, and sandy shale	118	842
Water at 756.		
Sand	78	920
Mississippian System.		
"Red Rock" shale	30	950
Shale	41	991
"Maxton" sand—Gas small	93	1,084
"Little" lime	24	1,108
Pencil Cave (Black slate)	15	1,123
"Big Lime," St. Louis	152	1,285
"Big Injun" sand and shale. Gas production 1,300	40	1,325
"Waverly" shale	255	1,580
Brown shale	20	1,600
"Berea" or "Weir" sand shell (gas and oil show)	80	1,680
Devonian System.		
Brown shale	120	1,800
Gray slate	15	1,815
Brown shale	595	2,410
"Corniferous" limestone	30	2,440

National Rig. T. M. King, Driller.

Log No. 2. Illustrating the Pottsville—Mauch Chunk. Flem Maynard No. 1. Big Branch of Brushy Fork of Johns Creek, Pike County, Kentucky.

	Thickness.	Depth.
Drift	9	9
Sand	4	13
Light slate	27	40
Gray sand	54	94
Dark slate	11	105
White sand	37	142
Dark slate	62	204
White sand	30	234
Black slate	16	250
Coal	3	253
Light slate	7	260
Gray sand	105	365
Dark slate	31	396
Coal	4	400
Dark slate	10	410
Gray sand (salt water)	18	428
Light slate	15	443
White sand	21	464
Dark sand	28	492
Black slate	70	562
White sand	21	583
Slate	208	791
White sand (gas and salt water)	251	1,042
Black slate	13	1,055
Blue sand	12	1,067
Black slate	68	1,135
Sand (gas and salt water)	88	1,223
Dark sand	8	1,231
White sand	56	1,287
Coal	1	1,288
Base of Conglomerate Measures.		
Sand	24	1,312
Red shale	12	1,324
Sandy slate	15	1,339
White sand "Maxon"	61	1,400
Lime	12	1,412
Slate	8	1,420
White sand "Maxon"	49	1,469
Dark sand	28	1,497
Sandy slate	24	1,521
Gray sand	18	1,539
Sandy slate	27	1,566
Lime (red shale at base)	214	1,780
Blue sand	20	1,800
Slate	410	2,210
Dark-brown slate	47	2,257

Summary.

In conjunction with the above data, which removes any doubt as to the presence of the Mauch Chunk in more or less typical expression in this part of Eastern Kentucky, there are a large number of wells in this section that do not show a red rock cap. These same wells, however, generally show a dark drab to black cap shale over a white sand which seems to be identical with that beneath the regular red rock cap. This white sand, which has been called the "Salt Sand" of the Pottsville, is productive of both oil and gas. It is the writer's opinion that this sand is not Pottsville at all, but the "Maxton" (Maxon of Drillers), as recognized in West Virginia. The chief proof substantiating such a view is the widespread distribution in this southeastern section of the state of the typical Red Rock—Sandstone—Pencil Cave sequence. The variation in thickness of the Mauch Chunk, as far as known, gives the clue to the proper explanation of the absence of the red rock cap at some places and the presence of darker shale. This explanation is the great unconformity at the top of the Mauch Chunk. Had this unconformity not become developed to the degree in which we now know it there is no reason to doubt but that the red cap of the Mauch Chunk sand would have been more widely and uniformly distributed. North and west of Prestonsburg the Mauch Chunk is recognized with difficulty as a very thin remnant or is entirely missing. South, east and west of the same town the "Maxon Sand" is generally well developed as well as the red cap rock. In the Beaver Creek section of Floyd county the "Maxon Sand" is both an oil and gas producer. About sixteen old and new wells are producing crude from this horizon, and about fourteen are now producing gas from the same sand.

Conclusions and Corrections.

Occasionally a section is found where four distinct and separate sands are developed in the Pottsville. Such a case is the Maynard well, of Pike county. Usually, however, there are only four separate sands above the "Big Lime." The lowest of these which has been considered Pottsville and called "Salt Sand" must in most cases be reclassified as "Maxton" of the Mauch Chunk. Such definite conclusions then give the following strategraphic table:

CORRECTED SEQUENCE.

South Eastern Kentucky Series and Correlated Oil Sands

System	Series	Sands	Correlation
Pennsylvanian	Coal Measures Conglomerates Shales, Coals Massive Sandstones.	Beaver, Horton, Pike } of Floyd Pike. Wages, Jones, Epperson } of Knox.	Pottsville Conglomerate of Ohio, West Virginia and Pennsylvania.
		Great unconformity.	
Mississippian	Chester Group Shales, Impure Limestones and Sandstones.	Maxton:—Of Martin, Floyd, Pike and Knott. The principal producer of oil and gas in this section.	Mauck Chunk of West Virginia and Pennsylvania.
	St. Genevieve St. Louis	"Big Lime Gas Sand"	Mountain Lime. Green Briar Lime.

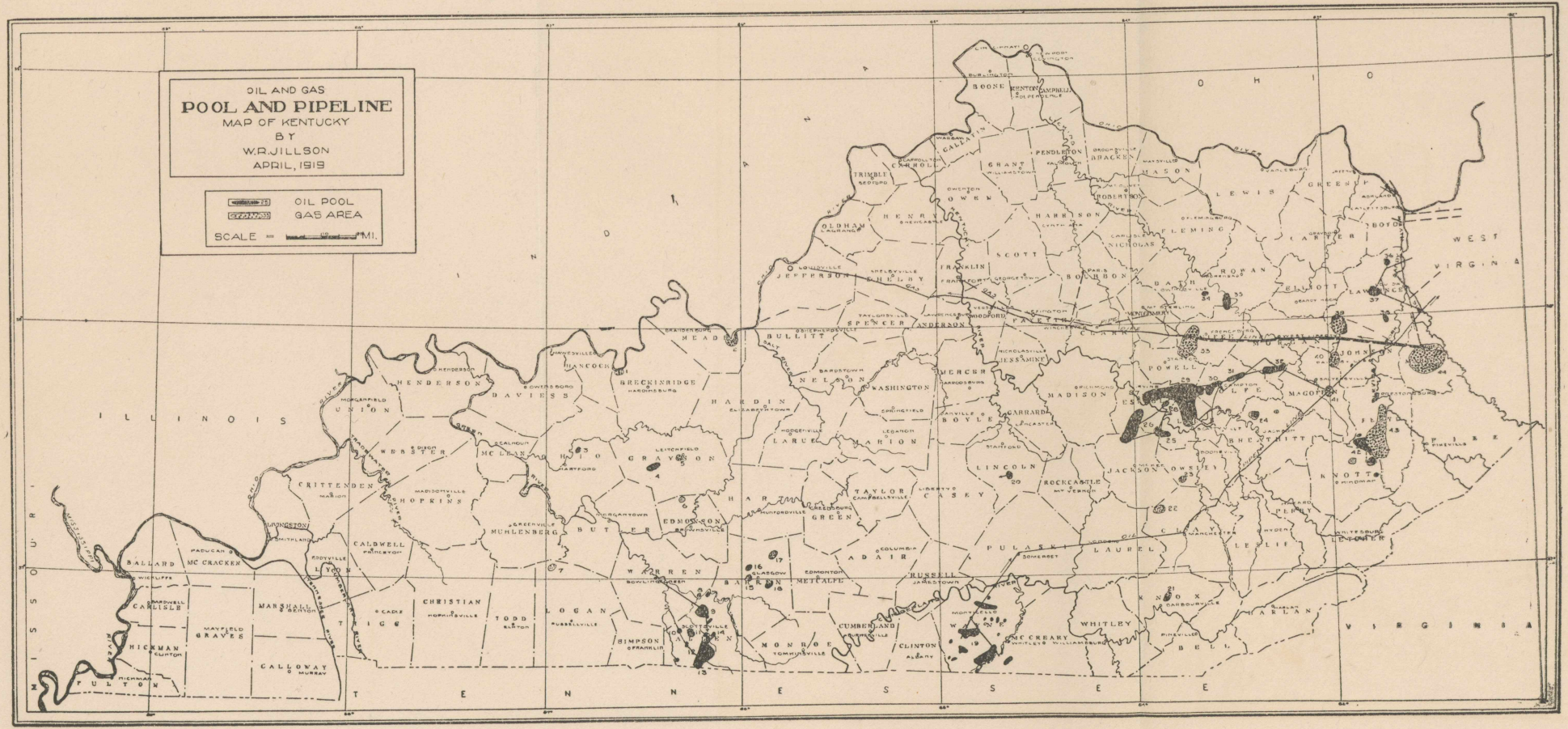
(Lower section omitted because of irrelevancy.)

Whether future drilling will ever demonstrate the practicability of a correlation of the "sands" of the Pottsville of the Floyd-Pike section with that of Knox remains to be seen. As far as the "Maxton" is concerned it is doubtful if it can ever be recognized as far to the west as Knox county, as the Mauch Chunk, though typically represented by the red shales, is rapidly losing its sandy phase and taking on the characteristic of the limy and shaly Chester of central, southern and western Kentucky.

Local Name Key to Oil and Gas Pool and Pipe Line Map of Kentucky.

BY WILLARD R. JILLSON,
Kentucky State Geologist,
June, 1919.

No.	Field Name.	Producing "Sands"	County.
1.	Cloverport Gas Field.	"Warsaw"	Breckinridge.
2.	Rock Haven Gas Field.	"Black Shale"	Meade.
3.	Hartford Oil Pool.	"Niagara"	Ohio.
4.	Caneyville Oil Pool.	"Waverly"	Grayson.
5.	Leitchfield Gas Field.	"Onondaga"	Grayson.
6.	Bear Creek Gas Field.	"Waverly"	Edmonson.
7.	Diamond Springs Gas Field.	"Cypress" "Waverly"	Logan.
8.	Jewell Oil Pool.	"Onondaga"	Warren.
9.	Gainesville Oil Pool.	"Onondaga" or "Niagara"	Allen.
10.	Butlersville Oil Pool.	"Onondaga"	Allen.
11.	Halfway Oil Pool.	"Onondaga"	Allen.
12.	Rodemer and Petroleum Oil Pools.	"Onondaga" or "Niagara"	Allen.
13.	Adolphus Oil Pool.		
14.	Scottsville Oil Pool.	"Onondaga" or "Niagara"	Allen.
15.	Steffy Oil Pool.	"Onondaga"	Barren.
16.	Oil City Oil Pool.	"Onondaga"	Barren.
17.	Hiseville Gas Field.	"Onondaga"	Barren.
18.	Oskamp Oil Pool.	"Onondaga"	Barren.
19.	Wayne County Oil Pool.	"Stray" "Mt. Pisgah" "Beaver" "Otter" "Cooper" "Slickford" "Trenton"	Wayne and McCreary.
20.	Buck Creek Oil Pool.	"Onondaga"	Lincoln.
21.	Little Richland Creek. Barbourville Oil and Gas Field.	"Pottsville"	Knox.


OIL AND GAS
POOL AND PIPELINE
MAP OF KENTUCKY
BY
W.R.JILLSON
APRIL, 1919
OIL POOL
GAS AREA
SCALE = MI.
OHIO
INDIANA
ILLINOIS
MISSOURI
TENNESSEE
WEST VIRGINIA
VIRGINIA
BOONE
KENTON
CAMPBELL
GALLATIN
CARROLL
TRIMBLE
GRANT
PENDLETON
BRACKEN
MASON
LEWIS
GREENUP
BOYD
OWEN
HENRY
OLDHAM
HARRISON
ROBERTSON
FLEMING
CARTER
NICHOLAS
SCOTT
FRANKLIN
BOURBON
BATH
ROWAN
ELLIOTT
LAWRENCE
JEFFERSON
SHELBY
SPENCER
ANDERSON
WOODFORD
FAYETTE
CLARK
MENIFEE
MORGAN
JOHNSON
MEADE
BULLITT
NELSON
WASHINGTON
MERCER
JESSAMINE
MADISON
POWELL
MAGOFFIN
HENDERSON
DAVIESS
HANCOCK
BRECKINRIDGE
HARDIN
LARUE
MARION
BOYLE
GARRARD
ESTILL
LEE
BREATHITT
FLOYD
PIKE
UNION
WEBSTER
MC LEAN
OHIO
GRAYSON
LINCOLN
ROCKCASTLE
JACKSON
OWSLEY
KNOTT
CRITTENDEN
HOPKINS
MUHLENBERG
BUTLER
EDMONSON
HART
GREEN
TAYLOR
CASEY
PULASKI
LAUREL
CLAY
PERRY
LESLIE
LETCHER
LIVINGSTON
CALDWELL
LYON
WARREN
BARREN
METCALFE
ADAIR
RUSSELL
BALLARD
MC CRACKEN
CARLISLE
MARSHALL
TRIGG
CHRISTIAN
TODD
LOGAN
SIMPSON
ALLEN
MONROE
CUMBERLAND
CLINTON
WAYNE
MC CREARY
WHITLEY
KNOX
BELL
HARLAN
HICKMAN
GRAVES
CALLOWAY
FULTON

No.	Field Name.	Producing "Sands"	County.
22.	Burning Springs Gas Field.	"Big Injun?"	Clay.
23.	Island Creek Oil and Gas Field.	"Onondaga?"	Owsley.
24.	Frozen Creek Oil and Gas Field.	"Onondaga"	Breathitt.
25.	Ross Creek Oil Pool.	"Onondaga"	Estill, Lee and Jackson.
26.	Station Camp Oil Pool.	"Onondaga"	Estill.
27.	Irvine Oil Pool.	"Onondaga"	Estill.
28.	Big Sinking Oil Pool.	"Onondaga"	Lee.
29.	Ashley Oil Pool.	"Onondaga"	Lee.
30.	Campton Oil Pool.	"Onondaga"	Wolfe.
31.	Stillwater Oil Pool.	"Onondaga"	Wolfe.
32.	Cannel City Oil Pool.	"Onondaga"	Morgan.
33.	Menifee Gas Field.	"Onondaga"	Menifee and Powell.
34.	Olympia Oil Pool.	"Onondaga"	Bath.
35.	Ragland Oil Pool.	"Onondaga"	Bath, Rowan and Menifee.
36.	Fallsburg Oil Pool.	"Berea"	Lawrence.
37.	Busseyville Oil Pool.	"Berea"	Lawrence.
38.	Georges Creek Oil Pool.	"Berea"	Lawrence.
39.	Laurel Creek Gas Field.	"Berea"	Johnson and Lawrence.
40.	Paint Creek Gas Field.	"Wier" "Berea"	Johnson and Magoffin.
41.	Ivyton Gas Field.	"Pottsville"	Magoffin.
42.	Beaver Creek Oil Pool.	"Beaver" "Horton" "Pike" "Maxon"	Floyd and Knott.
43.	Beaver Creek Gas Field.	"Beaver" "Horton" "Pike" "Maxon" "Big Lime" "Big Injun" "Berea" "Black Shale"	Floyd and Knott.
44.	Inez Gas Field.	"Big Lime" "Big Injun"	Martin.
45.	Moulder Oil Pool.	"Onondaga" "Niagaran"	Warren.

The Kendrick Shale—A New Calcareous Fossil Horizon In the Coal Measures of Eastern Kentucky.*

BY WILLARD R. JILLSON,

Kentucky State Geologist.

Introduction.

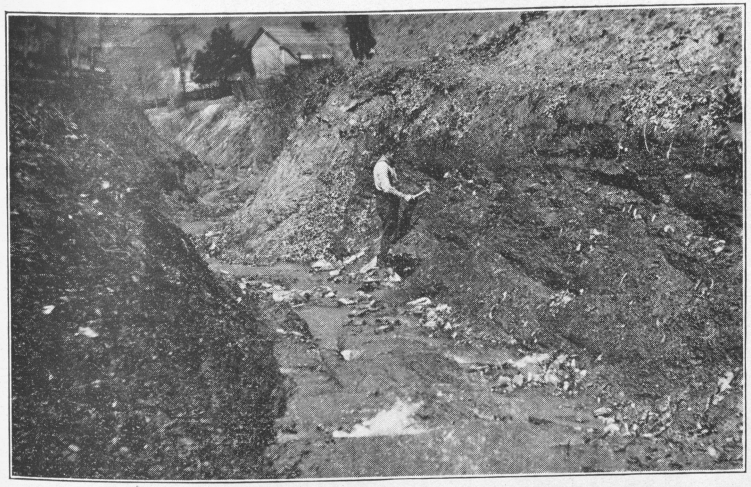
In August, 1918, while engaged in doing oil and gas structural geology in Kentucky, the writer discovered a new fossiliferous limestone shale horizon on the head waters of Cow Creek, Floyd County, Kentucky. A rapid reconnoissance of the typical outcrop in this locality led to immediate conclusions that the horizon presented features of paleontologic value worthy of more extended study. Subsequent field investigations carried on by the writer have more than justified this decision. It definitely appears now that, besides opening up new avenues of paleontologic investigations, this limy shale horizon, which has been called the Kendrick shale, may when coupled with other similar horizons known to exist in this section, and certain definite coals, come to be regarded as of fundamental importance in determining the unmapped stratigraphic geology of this part of Kentucky.

The work already done and the results herewith presented are therefore to be considered simply as preliminary to a more exhaustive investigation which is now under way. There is no published literature which may be regarded as having any direct reference to this Kendrick limy shale horizon or its fossil content. The fossils are new and unmatched as a collection either in or outside of the State of Kentucky. The determinations and conclusions herewith presented may therefore be taken as independent of the influence of contemporary investigations. The nearest fossiliferous limestones anywhere receiving mention are from thirty to fifty miles distant. A reference list of the literature relevant to these closest limestone occurrences as well as other geological and paleontological features is appended.

*This paper presented in abstract before the Ky. Acad. Sc., May 3, 1919.

The Type Locality.

The type fossiliferous outcrop of the Kendrick shale is one hundred and fifty yards above the yellow farm house (Kendrick homestead) on the head waters of Cow Creek, Floyd County, Kentucky. The horizon which has been named the Kendrick shale for this outcrop, is a generally soft blue-gray calcareous shale carrying many calcareous and magnesium nodules.



Kendrick Fossil Bed.

This is the original fossil outcrop located on the headwaters of Cow Creek, just above Bear Branch, which forks just below the Dr. G. T. Kendrick house seen in the central background. The view is down stream and to the northwest. Photo by W. R. Jillson, April 6, 1919.

These nodules, which fall into two classification of, (1) hard, compact, and smoke gray; and (2) soft, easily disintegrated and neutral gray, may or may not carry fossils. The second or softer nodules possess in addition the unique lithological and formative characteristic of what may be called a cone-in-cone or a budding-cone structure (Fig. 1). Chemical analyses of these two types of nodules have been made under the direction of Dr. A. M. Peter, State Chemist, and are presented herewith:

(1) Hard, Compact, Smoke Gray Nodule—Lab. No. G-3842.

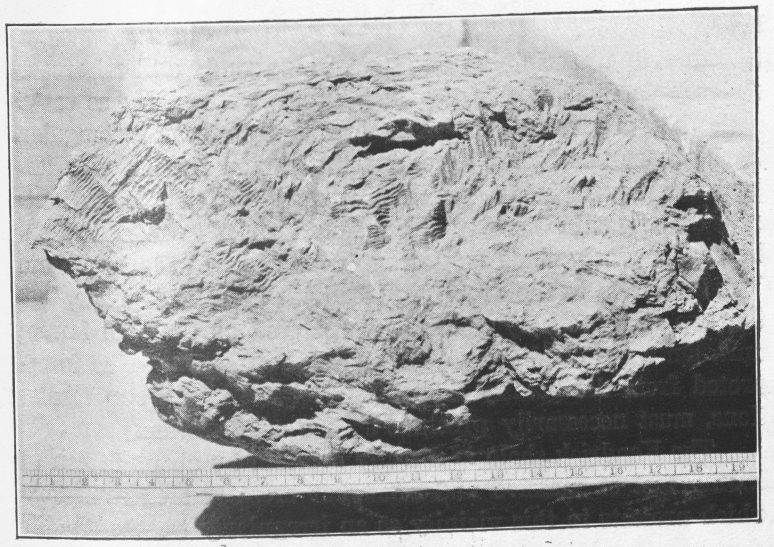
Moisture	0.37
Ignition	34.52
Silica	12.94
Ferric oxid	2.64
Alumina	4.96
Titanium dioxid	.36
Calcium oxid	36.28
Magnesium oxid	4.89
Potassium oxid	1.34
Sodium oxid	0.16
Total	98.46
Calcium carbonate equivalent to the CaO	64.75
Magnesium carbonate equivalent to the MgO	10.16
Manganese and phosphorus	trace
Zinc	present
Sulphur of sulphids	present

(2) Soft, Neutral Gray, Cone-in-Cone Nodule—Lab. No. G-3843.

Moisture	0.42
Ignition	35.62
Silica	12.34
Ferric oxid	1.20
Alumina	4.66
Titanium dioxid	.40
Calcium oxid	41.30
Magnesium oxid	1.03
Potassium oxid	1.29
Sodium oxid	0.21
Total	98.47
Calcium carbonate equivalent to the CaO	73.71
Magnesium carbonate equivalent to the MgO	2.15
Manganese and phosphorus	trace
Zinc	present
Sulphur of sulphids	present

The iron in both samples is in the ferrous condition, probably mainly carbonate, with some pyrite.

Besides their inclusions in the nodules, the fossils are distributed generally through this limestone-shale horizon, but are rarely preserved as well outside as within the nodular formations. Although more than ninety per cent of the collections



"Cone-in-Cone" Nodule.

The radical distribution of the "Cone-in-Cone" "growth ripples" is well shown in this photograph of a calcareous nodule taken from the Kendrick shale of the coal measures of Eastern Kentucky. The locality of occurrence is the Dr. G. T. Kendrick farm, Cow Creek, Floyd County, Kentucky. Collected and photographed by author, April 6, 1919.

have been secured from the above described type exposure, a few have been taken from two adjoining places on a continuous outcrop of the same calcareous shale bed. One of these is at the mouth of Bear Branch and the other a hundred yards below Bear Branch on the main Cow Creek. All three of these localities (and these are the only ones now locally known) may be placed within a circle having a diameter of 250 yards. At no place on the outcrop of the fossiliferous horizon are the fossils prolific in number or found in a typically good limy state of preservation. This is probably largely due to the robbing by the shale itself of a part of the original calcareous content of the embedded shells, and not, as has often been inferred, entirely to the exceptional paucity of lime in the shell of the living organisms. As a result of this condition these fossils are never secured without considerable difficulty, due to their marked tendency to crumble under the slightest pressure or strain.

The Kendrick shale lies about one hundred and seventy feet above the well known Prestonsburg, Miller's Creek, or Van

Lear coal, which is at this point that distance below drainage. It is directly underlain by two feet of blue sandy and calcareous shale. This shale is slightly fossiliferous, principally as casts. Following exposure, this shale breaks into semi-rectangular blocks about two feet square, and these upon further weathering, distintegrate into a typical blue marl—which was undoubtedly the original character of the deposit prior to consolidation. Later this marly shale may come to be shown to have a close faunal relation to the overlying Kendrick limestone—shale, but the two will probably never be considered as a single faunal unit, since the conditions of attending sedimentation as interpreted from the greatly differing lithology of the two formations, must necessarily preclude such a construction.

The Kendrick shale is directly overlain by about fifteen to twenty feet of massive and somewhat cross bedded sandstone which projects in this vicinity as an irregularly weathered cliff or ledge. Overlying this sandstone and about thirty feet above the fossil bearing horizon lies a thirty inch coal seam which for lack of more definite determination may be called the Kendrick coal, as it outcrops and is worked for domestic consumption on the J. C. Kendrick farm. Whether this coal is the same as the "Whitesburg" coal or the same coal as that which is called the No. 2 seam at Prestonsburg is not known. Certainly it is the next and only coal of commercial importance here above the Prestonsburg coal which in this locality goes under drainage on Cow Creek a short distance above its junction with the Levisa Fork of the Big Sandy River.

Invertebrate Record.

From a collection of several hundred invertebrate fossil specimens, taken from this locality and submitted to him for comparison, Professor Charles Schuchert, Curator of the Peabody Museum, has submitted the following tentative list of identifications:

Corals—Number of Species, 1.
- Lophophyllum proliferum (index.) *

Crinoids—Number of species, 1.
- Basal plates of a calyx—Undetermined.

Brachiopods—Number of species, 7. All rare.
- Glossina nebraskensis.
- Orbiculoides convexa.
- Orbiculoides manhattensis.
- Productus cora—small.
- Spirifer rockymontanus (index.)
- Spirifer cameratus (index.)
- Seminula subtilita

Pelecypods—Number of species, 11
- Nuculana belliostriata.
- Nuculana, species undetermined—rare.
- Nucula ventricosa (index.)
- Clinopistha radiata.
- Schizodus, species undetermined.
- Solenonga, species undetermined. A.
- Solenonga, species undetermined. B.
- Modiola subelliptica.
- Astarella, species undetermined (index.)
- Allorisma, species undetermined (index.)
- Aviculopecten, species.

Gastropods—Number of species, 11. Six rare.
- Bellerophon, species undetermined (index.)
- Patellostium, species undetermined.
- Pleurotomaria, cf. Larii—rare.
- Pleurotomaria, species rare. 3 specimens.
- Pleurotomaria tabulata. Rare. (index.)
- Pleurotomaria depressa.
- Soleniscus medialis.
- Soleniscus gracilis—rare.
- Soleniscus texanus—rare.
- Polyphemopsis peracuta—rare (index.)
- Zygopleura nodosa—rare.

Cephalopods—Number of species, 7. Two rare.
- Orthoceras rushensis.
- Orthoceras, species undetermined.
- Orthoceras, species undetermined—rare.
- Nautilus, species undetermined—rare.
- Nautilus, species undetermined—rare.
- Goniatites, species undetermined.
- Goniatites, species undetermined.

*These indexes refer to Pennsylvanian System.—W. R. J.

Fanual Characteristics.

A review of the above incomplete determinations shows there are now at least thirty-eight separate species present in the Kendrick limestone-shale horizon. Further work may reasonably be expected to show not less than a total of forty-five and possibly fifty different forms. Of these about ten are new species, and between sixteen and twenty are rare in the coal measures as now understood in Eastern North America. Moreover the entire collection is new to Kentcuky, no paleontologic work ever having been done before in this horizon.

The Kendrick fauna is clearly early Pennsylvanian—that is, Pottsville. This is shown by the presence of the Brachiopod, Spirifer rockymontanus. Knowledge of the local stratigraphy suggests that the Kendrick fossil horizon should be placed in the lower part of the Wise formation or Upper Pottsville, with the Norton formation just below it corresponding to the middle, and the Lee formation further below it correlating with the earliest Pottsville sediments.

Altogether the Kendrick fauna is a peculiar Pennsylvanian one, a condition which in all probability is due to the clear exhibition of mud facies. Brachiopods usually so common in the Coal Measures are here rare. On the other hand practically all the common guides are absent. Mollusca are revealed as the common fossils and all appear to be mud lovers to some extent. The fauna is particularly interesting and unique because of the many specimens of Cephalopods, especially the Gonitites. These are usually very rare or entirely absent in the Appalachian Coal Measures. So far no trace of Trilobites, which are rare in the Pennsylvanian System, or of Fusilina which are usually present, if not prolific in this system, has been found. These two groups, however, may possibly later exhibit representatives as a result of more intensive collecting work in the field .

Stratigraphic Interpretation—Conclusion.

In summation, then, the Kendrick fossil shale horizon, though lacking the safest or commonest Pennsylvanian index guides, presents the true Pennsylvanian characteristic of a cosmopolitan, long range fauna. Such a fauna necessarily lived under peculiar, shallow, semi-marine conditions. These conditions may be truthfully represented as continually changing and aggrading through rather rapid sedimentation into swamp land areas. The waters may hardly be considered as having been typically marine at any point even for a very short period. The widespread absence of marine fossils generally throughout the Coal Measures, and the extreme paucity of lime in the shells where they are found indicate the very trying environmental conditions presented to marine invertebrates endeavoring to migrate into these inconstant muddy Pottsville seas.

Along what line, whether broad or narrow, and from what local direction the Kendrick fauna progressed in its invasion of this Eastern Kentucky region may as yet only be inferred. It has been held by Girty and David White that the general Pottsvillian migration was from a west or southwesterly direction from a Central Gulf embayment which encroached rapidly east, west, and north over the Mississippi River valley during and following the early Pottsville. These correlations which are stratigraphic and chiefly based upon White's floral determinations coupled with somewhat meager faunal data from Girty, may not hold, however, for each and every one of the several fossiliferous limestone horizons which are now known to exist in Eastern Kentucky. The character of the sediments of the Eastern Kentucky Pottsville indicate a certain and impassable barrier between this area and the marine Atlantic. Assuming that the fauna did come from the west, as there seems to be good reason to believe, it must have passed through the relatively shallow seas lying on or about the Cincinnati-Nashville arch which, if not a unit insular land area in this later Pottsville time, undoubtedly acted as a very definite barrier to the great majority of the invading species. The wonder that there is found any marine invertebrate life at all in this semi-isolated Pottsvillian pocket is further increased by a realization of the fact that these hardy pioneering faunas were continually subject to and repeatedly suffered from total extinction, when only partially established in their new environment through the rythmic grading up process of Pottsville sedimentation.

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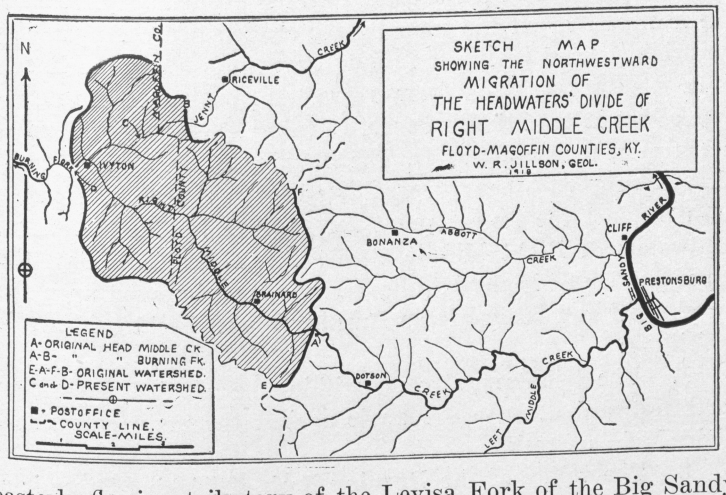
The Migration of the Headwaters Divide of Right Middle Creek, Floyd County, Kentucky.*

BY WILLARD R. JILLSON,

Kentucky State Geologist.

The headwaters divides of many streams rising in the foothills of the Appalachian mountains have experienced horizontal shifting or migration. That such movements have taken place in the eastern part of the Cumberland plateau is apparent upon inspecting the Prestonsburg, Paintsville and Salyersville, Kentucky, topographic sheets, the first two of which have recently been issued by the United States Geological Survey. Middle Creek in Floyd county, Kentucky, presents uncommonly plain evidence of migration, and the results of a study of the drainage basin of this stream are considered worthy of record.

As shown on the accompanying map Middle Creek is a large



easterly flowing tributary of the Levisa Fork of the Big Sandy River, which it joins at the town site of Prestonsburg. About 3 miles from its mouth Middle Creek branches and the Right Fork of Middle Creek, or, as it is locally called, Right Middle Creek, extends westward about 14 miles.

*Am. Jour. Sc., Vol. XLVII, pp. 60-64, Jan. 1919.

The present watershed of the upper part of Right Middle Creek is indicated by the western, northern and eastern edges of the shaded area. The lowest pass, or "gap," is found at a quarter of a mile west of Ivyton, Magoffin County, at D, and is about 960 feet above sea level. The "gap" is flat and swampy on the Burning Fork side; but on the Ivyton side it is perfectly drained, and erosive forces are active. At C, within the shaded area, is another low pass. These two passes indicate points of movement of the shifting divides. The upper part of Right Middle Creek basin is bounded on the west by the basin of the Burning Fork of Licking River, on the north by the basin of Jenny Creek, a tributary of the Levisa Fork of the Big Sandy River, on the east by the basin of Abbott Creek, which is also tributary to the Big Sandy River.

From a combined study of the field geology, the drainage courses and the topography, it is apparent that Right Middle Creek has shifted its divide 8 to 10 miles northwestward and has captured the headwaters of the Burning Fork of Licking River. The extent of the captured area is about 20 square miles and is indicated on the map by the shaded area. Apparently the original head of Right Middle Creek was along the line E to A. Capture resulted from a gradual pushing to the northwest of the Right Middle Creek, Burning Fork "gap" from A to the present location at D. The Burning Fork, already somewhat entrenched when the shifting began, offered in its own main channel the lowest point for capture by the advancing headwaters of Right Middle Creek. As a result, today the upper portion of Right Middle Creek is superimposed upon the old channel and basin of the Burning Fork. Field evidence is as follows:

1. The tributary streams within the shaded area flow northwestward at an acute angle against the main current of Right Middle Creek.

2. The valley of the Burning Fork of Licking River is a broad, open, flat basin, with low rounded hills and imperfect headwater drainage. The Burning Fork itself is a very small stream and out of proporton to the size of its valley. Aggradation is in progress.

3. The valley of Right Middle Creek from Ivyton to a point one mile below Brainard presents the physiographical opposite

to the valley of the Burning Fork. The Right Middle Creek valley is V-shaped and in some places the walls of the creek are nearly vertical. There is scarcely any "bottom land," the hills are high and steep, and the drainage is perfect. Erosive forces are actively engaged.

4. Between Ivyton and Brainard, Right Middle Creek is bordered by imperfect terraces developed on a strong sandstone member of the Pottsville series, through which the Right Middle Fork has cut. Probably this sandstone formed at one time the floor of the headwaters of the Burning Fork which were too feeble to cut through it and meandered back and forth across it, carving out a wide, flat valley at a high elevation. Toward Brainard the terraces gradually becomes less distinct and finally disappear.

5. Within the shaded area the channel of Right Middle Creek is choked with gravel and bowlders. The stream is still degrading rapidly.

6. The topography of Middle Creek changes abruptly 1½ miles below Brainard. At A the valley broadens, the hills become lower, the wagon road comes up out of the creek to find bottom land on either side, and the stream meanders back and forth in a slightly aggraded valley floor of sandy loam.

7. From A to the mouth of the stream, all tributaries come into the main channel at an acute angle with the current. The hills have an older, round-off, and worn-down appearance, and the broadened, level, slightly aggraded floor indicates an excess of eroded material from the headwaters. No trace of terracing remains.

Migration has also taken place near the headwaters of Jenny Creek. From Riceville southwestward Jenny Creek has cut through a thick sandstone member of the Pottsville and has developed a box canyon known locally as "The Narrows Fork." By so doing Jenny Creek tapped and appropriated one of the minor tributaries of the former head of the Burning Fork of Licking River. This captured tributary is seen on the map just to the east of the "gap" at C within the shaded area. According to field observation the "gap" at C is now shifting very slowly as a balance in elevations of the headwaters of the two competing creeks has almost been reached. Jenny Creek carries about

the same amount of water as Right Middle Creek and has a lower average elevation. The question therefore arises: Why did not Jenny Creek capture the head tributaries of the Burning Fork? The answer involves a consideration of local structures as given below.

1. *Difference in Elevation.* Right Middle Creek is a tributary of the Levisa Fork of the Big Sandy River. At its mouth, Middle Creek has an elevation of about 580 feet at low water. The elevation at the mouth of Burning Fork is about 880 feet at low water. This difference of 330 feet is slightly increased when a comparison is made, as between the headwater tributaries of the Licking River where they adjoin the tributaries of Right Middle Creek. It was this difference in elevation which gave the first "push" to the northwestward migration of the divide between Burning Fork and Right Middle Creek.

2. *Difference in Structure.* But equally as important as the difference in altitude of the main channels of these two competing drainage systems were the structural and lithological features of the area, which, perhaps, may be considered the real cause of the rapid shifting of the Middle Creek-Burning Fork divide. The slight difference in the structure and lithology also may explain why Jenny Creek possessing the advantage of a somewhat lower stream channel could not overtake Right Middle Creek in the race for the headwaters of the Burning Fork.

The village of Ivyton is near the center of a region of local uplift—a structural dome. This dome sends off rather high limbs to the west, to the north, and to the southwest. A somewhat lower limb extends to the east, and it is up this limb that the headwaters of Jenny Creek progressed westward. But the lowest and steepest dipping limb extends to the southeast, almost in the course of Right Middle Creek, and there is a structural drop in this direction of over 100 feet in a very short distance. The strong sandstone member of the Pottsville series, through which both Right Middle Creek and Jenny Creek have had to cut, has a somewhat softer texture in the lower courses of Middle Creek than on Jenny Creek. In these two factors, then, all others being excluded, lies the key to the situation. Right Middle Creek with a somewhat softer rock to cut and a much steeper structural limb to ascend was more favorably situated

than Jenny Creek, although Jenny Creek possessed the initial advantage of a somewhat lower channel. Right Middle Creek, a veritable giant, has removed a mountain 10 miles long, has captured the headwaters of its indolent neighbor, the Burning Fork, and as a penalty for the theft must for the rest of geologic time run backwards and "uphill" throughout its upper course.

The migration of the Burning Fork divide, or "gap," is still in active progress, though it is probable that now having reached the top of Ivyton structure the rate of the recession will decrease materially. After progressing a little farther northwestward down the fixed course of the Burning Fork, the Right Middle Creek "gap" will soon come to a more or less stationary position, because the "gap" will have passed over the crest of the Ivyton structure, where the factor of reverse dip may be expected to operate negatively upon further northwestward recession. The influence of this reverse dip may reasonably become so strong as to counteract the positive forces still operating which favor migration and are still maintained by the difference in the initial surficial elevation of the waters of this locality which are tributary to the Big Sandy and Licking rivers.

The Cumberland Falls Meteorite.

BY ARTHUR M. MILLER,

Professor of Geology, The University of Kentucky, Lexington, Ky.

The meteor, which on April 9, in its fall to earth over northeastern Tennessee and southeastern Kentucky, so startled the people living in that section, appears to have landed in the vicinity of Cumberland Falls. At least four of the fragments of the meteorite fell close to Sawyer post office, only a few miles distant from these Falls.

These fragraments, weighing respectively: 398.2 grams (13.7 ounces), 568.8 grams (1 pound 4 ounces), 878.4 grams (1 pound 14 ounces), and 2203 grams (4 pounds 12 ounces), were secured by the writer from Mr. W. H. Morgan, postmaster at Sawyer. Their meteoric character is beyond question. They have the characteristic pittings on the surface and the glaze which forms the coating of all meteorites. Moreover the chemical analysis by Dr. Alfred Peter of the Agricultural Experiment Station establishes the celestial source of these fragments.



McCreary County, Ky. Aerolite.

Fell April 9, 1919 about 12:21 p. m. near Sawyer, P. O., McCreary County, Kentucky. Weight, 2205 grms. Collector: W. H. Morgan. Photo by W. R. Jillson, May 24, 1919.

More convincing even than the foregoing, at least to Mr. Morgan, is the fact that the largest of these pieces whizzed past his head and was picked up by him in his front yard. This meteoritic fragment, the largest now known, is now in the possession of Prof. W. R. Jillson, Curator of the State Museum of Kentucky.

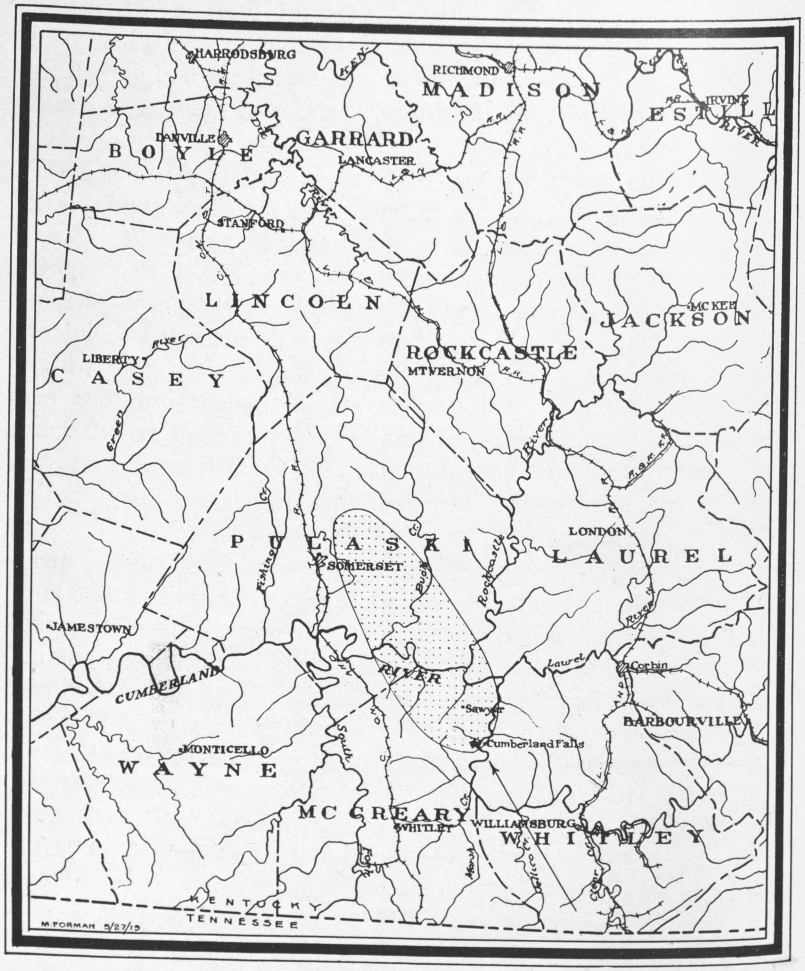
All the fragments are uniform in structure and composition. They are light gray in color and blotched, presenting a brecciated appearance. They are parts of an *aerolite* (stony meteorite) of the variety known as "chondrite." In composition they consist largely of the mineral *enstatite*—a magnesian silicate. Through this stony matter is disseminated in microscopic particles a very small amount of nickel-iron, this, with a sulphide of iron, amounting to about two-tenths of one per cent. Other elements found to be present in small amounts are calcium, potassium and sodium. The specific gravity of the whole is 3.18, which is practically the specific gravity of the mineral enstatite.

As soon as the announcement appeared in the newspapers of southeastern Kentucky and northeastern Tennessee that that region had been visited by some sort of a catyclysm—earthquake or meteor—the writer, through the same channels sent out an invitation calling for more detailed information, and because he was convinced it was a meteor, asked for reports which would give the compass bearings of the point of the explosions as seen or heard from different places.

He also made a visit into the region traversed by the Cincinnati Southern Railroad, going as far as Cumberland Falls Station.

From the replies received by letter from various observers, and from what he learned on this trip, it would appear that this meteor was seen in northeastern Tennessee and southeastern Kentucky throughout an area of at least 14,000 square miles: the range in latitude and longitude being each about two degrees. It was seen as far south as Neubert, Tennessee, latitude 35 degrees 48 minutes, and as far north as Pollard, Jessamine county, Kentucky, latitude 37 degrees and 48 minutes. East-

ward it was seen near Rogersville, Tennessee, west longitude about 83 degrees and westward at Jamestown, Russell county, Kentucky, about west longitude 85 degrees.



Map of a Portion of Southeastern Kentucky.

The strippled oval area is that in which probably all of the fragments of the Cumberland Falls Meteorite fell. The arrow indicated the direction taken by the meteorite just prior to its fall, and the star shows the point from which the main unit body of this meteor was recovered.

The observer at Neubert, Mr. J. W. White, describes the meteor as becoming visible at an altitude of about 60 degrees

and as traveling in a direction 35 degrees west of north till it disappeared by bursting. It left a "trail of blue smoke" behind it.

The observer near Rogersville, Hawkins county, Tennessee, Mr. C. M. Brannan, of Greenville, Tennessee, while traveling in an automobile, saw the meteor descend steeply toward the north. He describes it as resembling an "elongated bag" of a smoky red color. Suddenly to his gaze the lower end "burst into flame" more brilliant than the brightest electric light he ever saw, even though it was mid day and the sun was shining. It disappeared by descending below the horizon, though to Mr. Brannan it appeared to drop between him and the next knob.

The other observer in Tennessee, from whom we received a circumstantial report, is Mr. J. F. Layne, the day telegraph operator of the Southern Railroad at Coal Creek. He saw the meteor descending to the northwest, leaving a "trail of smoke behind." He states that it disappeared at 12:21 p. m.

None of the observers in Tennessee report any accompanying sounds. From the time it became visible to observers in southeastern Kentucky, however, it also advertised its presence to the ear by terrific detonations. These seemed to have been especially marked along a belt paralleling a little to the east the Cincinnati Southern Railroad. Indeed it is in this way only that its course in that region can be traced, as the sky was obscured by clouds in this section. All report the sound as like a rushing storm accompanied by violent claps of thunder or exploding dynamite blasts. An interesting incident in this connection is that the telegraph-telephone operators in the stations and signal towers along the Cincinnati Southern Railroad immediately put the unknown visitor on a schedule, something like an "extra," and heralded its coming ahead. The operator in the Tatesville signal tower, noting the detonations and the shaking of his tower at 12:27, called to the operator in the tower at Waynesburg telling him what had just happened, only to hear him say that he was hearing the same thing coming. From here it was passed on to the Danville operator, who heard the sounds at 12:30. The distance from Tatesville to Danville is 53 miles by rail, about 48 miles in an air line. It took the meteor sounds, therefore, 3 minutes to travel these 48 miles from Tatesville to Danville.

How much of this was due to rate of sound propagation in air and how much to rate at which the meteor was traveling north cannot at present be stated.

That the meteor never crossed to the west of the Cincinnati Southern Railroad seems now pretty well established. It also seems probable that its path in Kentucky was somewhere west of the Knoxville-Cincinnati branch of the Louisville and Nashville Railroad.

That it crossed the Louisville-Livingston line of the Louisville and Nashville Railroad seems improbable. Sawyer post-office lies at about west longitude 84 degrees 20 minutes, and latitude 36 degrees 53 minutes. All the indications now are that the main mass of this meteorite, if a main mass there is, should be found in a direction slightly west of north of this point, and within the boundaries above indicated. Steps have been taken by the writer to get the compass bearings of the explosions of this meteor as heard from points all around this area in the hopes that the point where the main mass should have fallen may be disclosed. However, as this area lies in the "conglomerate strip"—the most rugged and sparsely settled region of the Eastern Kentucky mountains—the prospects for actually finding the main mass do not seem to be very promising.

The Low Sulphur Coals of Kentucky.*

BY WILLARD R. JILLSON,

Kentucky State Geologist.

Within the last ten years Kentucky has become celebrated for its low sulphur bituminous coals. Prior to this time many practical investigators had already made this important discovery, but it remained unknown to the general public until the last extension of Kentucky's mountain railroads was completed. The coals of Kentucky are broadly separated into two geographic units—the Eastern and the Western coals fields. On a basis of their sulphur content these coal fields, however, really fall into three units. As indicated on the accompanying map (Fig. 1), these are designated by numbers, 1, 2 and 3. No. 1, the very southeastern part of the state, shows the lowest sulphur—all coals averaged. In this field the maximum is 1.04 and the minimum as low as .68—both averages and not individual analyses, which would of course show much greater variation. Included in this group are the following counties: Lawrence, .87; Martin, .75; Johnson, .73; Magoffin, .87; Floyd, .88; Pike, .68; Knott, 1.04; Perry, .77; Letcher, .80; Leslie, .70; Harlan, .79; Knox, .86; and Bell, .92. The total average sulphur content for these thirteen counties is 0.82.

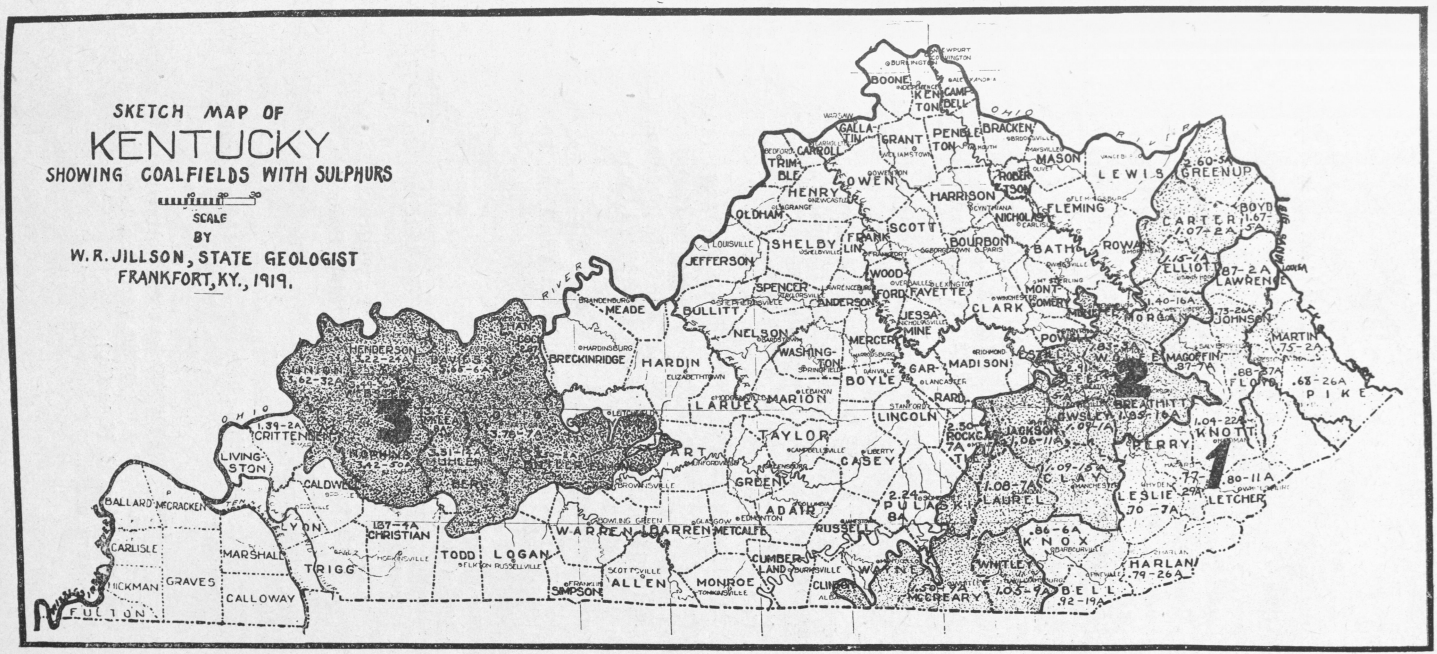
Bordering the restricted low sulphur field of Eastern Kentucky is the No. 2 belt (slightly darker), which is commonly known as the western border of the Eastern coal field. Here the maximum sulphur is 2.91 and the minimum 1.05. Again these are averages and not individual analyses. The counties in this group are: Greenup, 2.60; Boyd, 1.67; Carter, 1.07; Morgan, 1.40; Wolfe, 1.83; Lee, 2.93; Breathitt, 1.85; Owsley, 1.09; Jackson, 1.06; Rockcastle, 2.30; Clay, 1.09; Laurel, 1.08; Pulaski, 2.24; Whitley, 1.05; McCreary, 1.50; and Wayne. The sulphur percentage average for this No. 2 area including fifteen important counties is 1.65.

*Pub. contemporaneously Aug., 1919. Bull. No. 1152, A. I. M. M. E.

In the Western Kentucky field the great increase in the percentage of sulphur is at once apparent. Ohio County with 3.78 is the highest and Hancock with 2.87 is the lowest. The percentages by counties are as follows: Hancock, 2.87; Henderson, 3.22; McLean, 3.27; Muhlenberg, 3.31; Hopkins, 3.42; Webster, 3.49; Butler, 3.50; Union, 3.62; Daviess, 3.65; Ohio, 3.78. The sulphur percentage average for the No. 3 area including ten counties and all of the Western Kentucky coal field is 3.41. In arriving at the above averages upon which the boundaries of the three districts were determined, 514 selected air dried analyses were used out of a total of about 750, which were reviewed. These analyses were made by two agencies, the U. S. Bureau of Mines and the Kentucky State Chemist. The number of analyses used per county may be found by referring to the map. Fig. 1, e. g. Floyd, 0.88—37 A., which is Floyd County per centage of sulphur 0.88 secured as an average from 37 analyses. In the following table of the important low sulphur coals of Eastern Kentucky access was had to over 250 additional analyses of the same character, out of which 160 were selected and used in compilation of the data presented below.

Tentative Sequence of the Important Commercial Coals of Eastern Kentucky.

The following table is not intended to be considered in the light of a definite correlation. Work towards such a correlation is now under way, but final results have not yet been obtained. The arrangement given, however, is correct within broad lines and will serve the purposes of this paper. Many small coals have been omitted and a number herein given as separate coals will eventually be co-ordinated. The coals here listed are found only in sulphur districts numbers 1 and 2, as indicated on the map. See Fig. 1.


SKETCH MAP OF
KENTUCKY
SHOWING COALFIELDS WITH SULPHURS
SCALE
BY
W. R. JILLSON, STATE GEOLOGIST
FRANKFORT, KY., 1919.
OHIO RIVER
BOONE
KENTON
CAMPBELL
GALLATIN
GRANT
PENDLETON
BRACKEN
MASON
LEWIS
GREENUP
CARROLL
TRIMBLE
OWEN
HENRY
OLDHAM
HARRISON
ROBERTSON
FLEMING
BOYD
CARTER
SHELBY
FRANKLIN
SCOTT
BOURBON
BATH
ROWAN
ELLIOTT
JEFFERSON
WOOD-FORD
FAYETTE
MONTGOMERY
MORGAN
LAWRENCE
JOHNSON
SPENCER
ANDERSON
JESSAMINE
CLARK
MEADE
BULLITT
NELSON
MERCER
POWELL
MARTIN
WASHINGTON
GARRARD
MADISON
ESTILL
MAGOFFIN
FLOYD
PIKE
HENDERSON
DAVIESS
BRECKINRIDGE
HARDIN
BOYLE
LEE
BREATHITT
LARUE
MARION
LINCOLN
ROCKCASTLE
OWSLEY
KNOTT
TAYLOR
JACKSON
PERRY
CASEY
CLAY
LIVINGSTON
CRITTENDEN
CALDWELL
BERRY
GREEN
LAUREL
LESLIE
LETCHER
BALLARD
MCCRACKEN
ADAIR
PULASKI
RUSSELL
CHRISTIAN
WARREN
BARREN
METCALFE
KNOX
LYON
TODD
LOGAN
CUMBERLAND
WHITLEY
HARLAN
CARLISLE
MARSHALL
TRIGG
SIMPSON
ALLEN
MONROE
CLINTON
MCCREARY
BELL
GRAVES
CALLOWAY
HICKMAN
FULTON
3
2
1

ALLEGHANY.

Coals.
Stamper—Very High—Small Area.
Hilton —Very High—Small Area.

POTTSVILLE.

Wise—Kanawha—Upper Pottsville.

Coals.
Hindman—High Splint—1.45 (2A-Perry Co.) .675 (2A-Letcher Co.)
Cornett (Cannel)—.59 (1A-Letcher Co.)
Francis.
Flag—.906 (4A-Leslie Co.)—.80 (5A-Perry Co.)—.55 (1A-Letcher Co.) —.75 (1A-Letcher Co.)—.67 (11A-Letcher Co.)
Hazard—.80 (5A-Perry Co.)—1.28 (4A-Leslie-Knott Co.) .70 (1A-Letcher Co.)
Haddix—.816 (Breathitt and Perry Co.)—1.06 (1A-Letcher Co.)
Hamlin—.87—(1A-Letcher Co.)
Pardee—1.14—(1A-Letcher Co.)
Fire-Clay Rider (McGuire Cannel)—.69 (1A-Leslie Co.)
Fire Clay—Hyden (No. 4)—Lower Hignite—.87 (Perry Co.) .72 (10A-Perry Co.)—.765 (4A-Letcher Co.)—.413—(3A-Bell Co.)
Whitesburg—Mills (?)—1.318 (1A-Letcher Co.)—.79 (1A-Letcher Co.)
Amburgy—.613 (Leslie Co.)—.98—(1A-Letcher Co.)
Elkhorn-Taggart—Moss (?) (No. 3)—.58 (6A-Letcher and Knott Cos.)—.654 (15A-Letcher Co.)—.971 (10A-Floyd Co.)
Howard—Ivel (No. 2.)
Van Lear—Prestonsburg—(No. 1—Millers Creek—.593 (10A-Johnson Co.)—.698 (17A-Floyd Co.) Av. at Van Lear .50.
Straight Creek—.902 (8A-Bell Co.)
Collier.
Blue Gem—.8766 (1A-Knox Co.)
Bacon Creek (Lower Blue Gem.)
Harlan—Shelby Gap—Lily (?)—.805 (2A-Letcher Co.)—.776—(12A-Harlan Co.)

Norton—New River—Middle Pottsville.

Imboden—1.33 (1A-Letcher Co.)
Many unimportant coals.
Dorchester.
Manchester—Wide variation between—.47 (Low) and 2.65 (High) (Clay Co.)

Lee—Pocahontas—Lower Pottsville.

Beattyville—2.33 (7A-Lee Co.) wide variation between—1.041 (Low) and 3.991 (High) (Lee Co.)
Many unimportant coals.

Although considerable stratigraphic work has been done on the Western Kentucky coals—Map No. 3 area—no attempt is made here to portray the sulphur characteristic of these coals, since the district is without what may be called a commercial low sulphur coal. It is interesting from a stratigraphical standpoint to note the result of the plotting of the sulphurs of the coals of Kentucky, especially since to date, the Pennsylvanian System in this state has never been mapped, except in outline. Within broad limits then it may be said that sulphur district No. 1 corresponds with the Wise-Kanawha or Upper Pottsville, which forms the main body of the Kentucky commercial coals. Sulphur district No. 2 corresponds roughly with the Norton-New River or Middle Pottsville, and the Lee-Pocahontas or Lower Pottsville. It is relatively of much less importance. Sulphur district No. 3—The Western Coal Field—is probably Middle and Lower Pottsville.

The summation of averages of these sulphur percentages shows quite as much of a difference between districts 2 and 3 as between 1 and 2. It must be concluded then, that great and striking differences of sedimentation attended not only each division of the Pottsville, but that within any one unit of Pottsville time due to geographic location and proximity of continental or insular masses the same variations in point of size probably existed. It may be significant to point out in this connection that lowest sulphured coals of Kentucky are found farthest removed from the principal Pottsville marine sea—the Lower Mississippi embayment. Progressing toward this typical marine sea from east to west, the Pottsville sulphurs rise rapidly, and after one crosses the shallow channeled area on and just west of the Cincinnati anticlinal barrier in Central Kentucky the maximum is reached. Here then in the certain westward movement of these Pottsville waters out of the long arm extending northeast into Pennsylvania, may lie the logical solution to the problem of the distribution of the low sulphur coals of this period.

The New Oil and Gas Pools of Allen County.

BY WILLARD R. JILLSON,

Kentucky State Geologist.

Location and Topography.

Allen county, one of the "Pennyrile" counties of Kentucky, lies in the central southern part of the state adjoining the Tennessee line. It is bounded by Warren and Barren counties on the north, Monroe on the east, Macon and Clay of Tennessee on the south, and Simpson of Kentucky on the west. The altitude of the surface of the county varies from 825 above sea level in the southeastern part of the county to about 500 along the lowest portion of the Big Barren River on its northwestern border. Allen county is essentially an imperfectly dissected gently northwestward sloping table land in which the topography while certainly not excessively rugged is rough enough to cause a constant change in the scenery in every direction. The relief

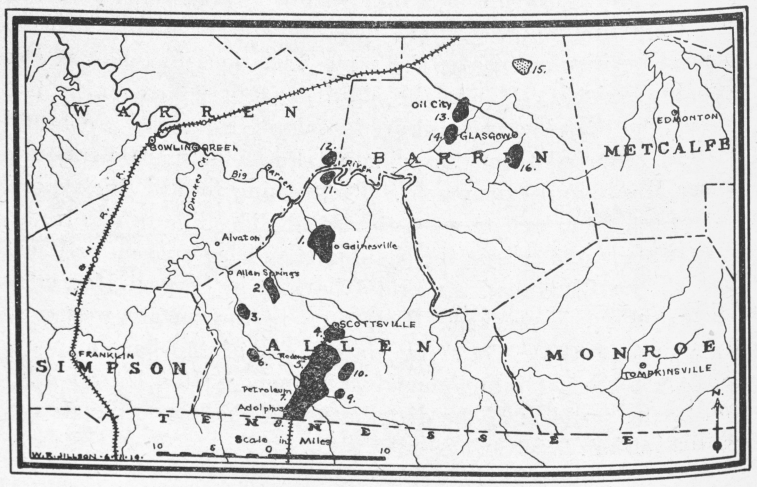


Fig. 1.
Sketch Map Allen and Adjoining Counties.

As shown above the principal Oil and Gas Pools of Allen County are: 1. Gainesville; 2. Bays Fork; 3. Butlersville; 4. Scottsville; 5. Rodemer; 6. Trammel Creek; 7. Petroleum; 8. Adolphus; 9. Rough Creek; 10. East Rodemer; 11. Jewell; and, 12. Moulder.

varies from 150 to 300 feet. The main roads of the county are located on the rounded ridges to avoid the imperfect drainage of a large number of the sink holes which in various parts, especially the northwestern, are well developed in the soluble surface Mississippi limestones. There is approximately 400 square miles within the county borders. Scottsville—see Map, Fig. I—is the county seat. The drainage is that of the Big Barren River and its tributaries; of these Trammel Creek and Bays Fork are the largest.

Acknowledgments.

The data herewith presented represent a combination of such information as could be gleaned from the publications of the former Geological Surveys of Kentucky, together with many personal notes collected by the writer during various visits to Allen county prior to the spring of 1919. In March, 1919, the writer spent ten days in Allen, Warren and Barren counties, and it is upon this general reconnoissance that this paper is chiefly based. The oil and gas development in this portion of Kentucky is now going forward so rapidly—twenty-two completions were reported for the week ending May 31—that it is quite impossible to present any report that is thoroughly up-to-date. However, standing within the limit of reason, it is the purpose in offering this paper to advance the main facts of the geology of the oil and gas of Allen county leaving the wealth of attending detail to a more comprehensive report. Thanks are due to Mr. C. A. Phelps and Dr. E. R. Riggs, Mr. J. C. Kirby, Mr. W. H. Giltner and many other oil men in and about Bowling Green, Scottsville, and Glasgow, for their many helpful suggestions and assistance.

Stratigraphic Geology.

The principal surface rocks in Allen county belong to the Mississippian System or Sub-carboniferous. They are chiefly limestones, St. Louis—the Big Lime of drillers—in the western part, and the underlying formations, Warsaw, Keokuk, and Burlington in the central and eastern part. Small areas of the Devonian Black Shale and Onondaga (Corniferous) Limestone have been exposed along the Big Barren River on the north-

east border and a few of the main creeks, especially Trammel, in the central southern section. Underlying the Onondaga (Corniferous) Limestone and occurring as very restricted outcrops due to stream erosion there may be found some patches of the limestone and shales of the Niagaran group, which belong to the Upper Silurian. As in Allen county, the principal surficial rocks of the counties adjoining are Mississippian. It is a matter of twenty-five miles to the border of the western coal field and double that to the first Pennsylvania rocks in the east. While there is a river valley outcrop of Ordovician rocks along the



Site of the Big Oil Tank Fire.
Burned area on Johnson farm on Difficult Creek, New Gainesville Pool, Allen County, Ky. Note charred tank bases at right and dead trees in foreground. Photo by W. R. Jillson, Mar. 19, 1919.

Cumberland fifteen to twenty miles to the east, the real Kentucky Blue Grass is distant by 55 miles in an air line to the northeast, and the corresponding area surrounding Nashville in Tennessee is fifteen to twenty-five miles away to the southwest. The real reason for this distribution of the surface rocks is found in the major structural features of the region. Allen county lies on the western limb of the great Cincinnati Anticline, almost in the saddle between the Lexington and Nashville domes. It is situated, however, slightly more upon the Nashville dome than otherwise, and for this reason the strata in this section find their normal dip to the northwest. The simplicity of this ar-

rangement may be readily seen by reference to Plate I, the Geologic map of Kentucky. Allen county lies just north of the dot in the state line under the first "E" in Burkesville. A generalized section of the exposed and unexposed rocks and the oil sands of the Allen county section is as follows:

MIDDLE PALEOZOIC SERIES IN ALLEN COUNTY AND CORRESPONDING OIL SANDS.

System.	Series.	Producing Sands.	Notes.	
Mississippian	Chester.	Big Lime	Exposed — Not a producer	Limestones
	Waverly.	Berea Grit	Exposed partly Possible producer	Limestone
	Chattanooga	Stray Sands	Occasionally gas	Black Shale
Devonian	Onondaga	Gainesville Corniferous Rodemer Boyds Creek Scottsville	The principal oil and gas producing horizons in Allen county and vicinity.	Cavernous Limestone
Silurian	Niagara			Sandy, impure Limestones
	Clinton	Deep Sands	Occasional producer	Limestones and Shales
Ordovician	Cincinnatian	Upper Sunnybrook Deep sand.	Very occasional producer.	Mostly Limestones
	Mohawkian	Trenton Deep sands	Very occasional producer.	Mostly Limestones

The Producing "Oil Sands."

There are a number of oil and gas producing formations with their included "sands" in Allen county, but the principal amount of the oil production may be narrowed down and referred to two—the Onondaga or "Corniferous" of the Devonian, and the Niagaran of the underlying Silurian. It is estimated that ninty-five per cent of the production of this section is now being recovered from these two horizons and the indication is plain that these two horizons will continue to be the important ones of the future. Above the Onondaga or Corniferous the amount of either oil or gas production from the uncommon "stray sand" of the Black Shale is trivial. There is perhaps a very small amount of what is known as "Amber oil" production that may be referred to the lower part of the Waverly in a few unimportant isolated wells in Barren county. The total amount of all of this production is hardly worth considering from a commercial standpoint. Below the Niagaran the production again rapidly dwindles—for two reasons. One of these is that very few deep wells have been drilled in this section and

the other is that practically all of the deep wells have been dry. Evidently the production is not present in the deeper "sands" in any except in occasional instances.

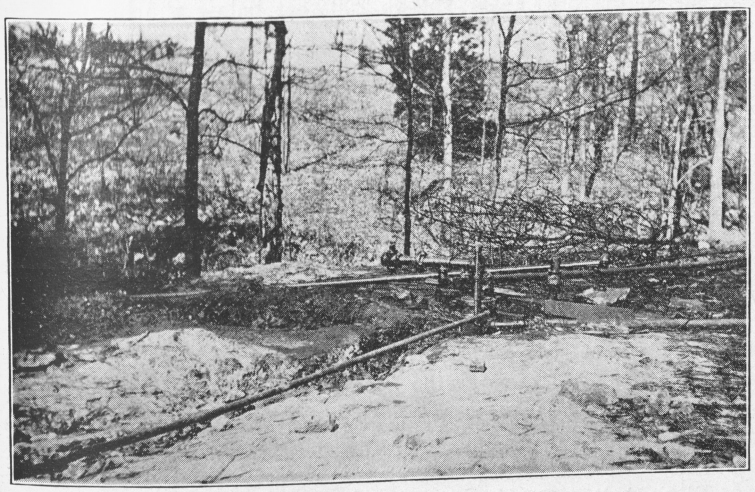
The Onondaga (Corniferous) and the Niagaran are the formations upon which the attention of all oil men is justly focused. The situation with respect to these two "sands" even today with all the study they have received is one that still lacks a great deal of being clear. A number of obvious facts cause this. Field observations have determined definitely that a rather large unconformity occurs not only at the top of the Niagaran but also at the top of the Onondaga (Corniferous). This break has been observed by the writer to be so extensive in places that the entire Onondaga has been removed and what is considered the Niagaran or Upper Silurian was found to be resting unconformably directly beneath the Black Shale of the Devonian. The result of this has been to introduce a large element of uncertainty into the establishment of the production horizon in practically all wild cat wells. The first production, however, comes generally just below the Black Shale and may or may not be followed at from 50 to 150 feet deeper by a second or third pay.

Nature of the "Pay Sands."

While it is not easy to accurately and quickly determine whether the producing sand of any well is Onondagan or Niagaran, practice and the microscopic study of the drillings will tell much. From all observations it appears that the Onondaga (Corniferous) Limestone of this section—generally unfossiliferous—is a true limestone, which is slightly to considerably cavernous due to solution. The cavernous characteristic is not a general or regular occurrence, but apparently is widely distributed as a local condition. What is regarded as the true Onondaga is dark and pitted on exposure but is gray with a brown tinge upon fresher surfaces. A comparison of a number of well records indicates that it may vary (probably due to its unconformable upper surface) from 5 to 50 feet in thickness. In some cases it may exceed this amount, but there exists some question in these instances as to the exact base of the formation, and it may be that in certain of these instances the bit had already pierced the underlying Niagaran lines. The absence of the

Onondaga in some places and its apparent tendency to thin down in many others seem to indicate that it might always be safer to assign less thickness rather than greater ones to it.

Though the Onondaga is sometimes absent, and the Niagaran is always present, it is a fact that the latter sediments are much more difficult to determine than the former. Generally it seems that Silurian has a much higher fossil characteristic than the overlying Onondaga. But this does not help in the well records—when they are to be studied separately from the drillings. When



The Spectacular Johnson No. 2 Well.

This well at the time it was drilled in probably attracted more attention than any other in the new Gainesville Pool, Allen County, Ky. It is reported to have flowed 1,300 barrels in the first 32 hours. At the time this picture was taken it was still flowing. Photo by W. R. Jillson, Mar. 19, 1919.

the drilling sample sands are at hand the matter is somewhat simplified in so far as lithology goes, for the Silurian will quite usually present the notable characteristic of sandy—real sand grains—lime body. This seems to be the case also to a greater degree towards the top of the Niagaran than lower down. If closely compared with drillings from the Onondaga (Corniferous) the Niagaran drillings will be seen to be really quite different. And it is a fact at no place does the Onondaga exhibit the real siliceous sand grain.

Conclusions then must place the Niagaran as the better of the two formations from an oil reservoiring standpoint. Perhaps

this statement would not be without dispute if a generally more widespread porous or cavernous condition had been tested out and found to be existent in Allen county. It has been the experience of many producers and almost innumerable instances could be cited where the tightness of the Onondaga apparently was the only cause of a dry hole offsetting production. Due to the characteristics of changing porosity—which the bit alone can determine—drillers in Allen county failing to secure production have found it a good rule to continue their drilling to salt water or to at least 150 to 200 feet below the base of the Black Shale. Frequently by so doing a change in porosity has been encountered and with the change—production. However, experience to date does not justify a general prospecting for productive sands deeper than 200 feet below the Devonian Shale.

A comprehensive idea of the stratigraphy of the unexposed rocks and the depths to various oil and other horizons may best be secured from a study of a number of representative logs. These logs are presented by pools and are unaltered in figure from the original copy which is given in feet.

WELL RECORDS.

Gainesville Pool Map No. 1.

J. R. Johnson No. 1.	Thickness.	Depth.
Soil	7	7
Limestone	184	191
Black shale	47	238
Blue limestone	6	244
Lime sand	36	280

J. R. Johnson No. 2.		
Soil	5	5
Limestone	177	182
Black shale	45	227
Blue limestone	7	234
Lime sand	1	235

J. R. Johnson No. 3.		
Soil	6	6
Limestone	166	172
Black shale—Devonian	49	221
Blue limestone	71	292
Lime sand	4	296
Limestone	14	310

J. R. Johnson No. 4.	Thickness.	Depth.
Soil	6	6
Limestone	166	172
Black shale	42	214
Blue limestone	5	219
Lime sand	28	247
Limestone	7	254

J. R. Johnson No. 5.		
Soil	4	4
Limestone	234	243
Black shale	44	287
Blue limestone	5	292
Lime sand	60	352
Black limestone	94	446

J. R. Johnson No. 7.		
Soil	8	8
Limestone	234	242
Black shale	46	288
Blue limestone	5	293
Lime sand	83	376

J. R. Johnson No. 8.		
Soil	18	18
Limestone	254	272
Black shale	46	318
Blue limestone	6	324
Lime sand	57	381
Black limestone	70	451

J. R. Johnson No. 9.		
Soil	6	6
Limestone	265	271
Black shale	46	317
Blue limestone	5	322
Lime sand	13	335
Black limestone	75	410

J. R. Johnson No. 10.		
Soil	18	18
Limestone	268	286
Black shale	44	330
Blue limestone	5	335
Lime sand	15	350
Black limestone	50	400

Andy Smith No. 2.	Thickness.	Depth.
Limestone	274	274
Black shale	46	320
Blue limestone	19	339
Lime sand	30	369
Limestone	6	375

Andy Smith No. 3.		
Limestone	276	276
Black shale	50	326
Blue limestone	23	349
Blue limestone	12	361
Lime sand	31	392
Limestone	4	396

Scottsville Oil Pool, Map No. 4.

Ocala Oil Co. No. 4.

Frost Farm, 3 Miles S. of Scottsville.

Top of black shale at	(Devonian)	210
Base of black shale at		257
First oil show at		271
Oil		282
Bottom of well at		287

Ocala Oil Co. No. 5.

Top of black shale at	(Devonian)	223
Base of black shale at		269
First pay at		294
Salt water at		308

Ocala Oil Co. No. 6.

Top of black shale at	(Devonian)	209
Base of black shale at		256
Oil and water at		283
Oil at		298

Rodemer Pool, Map No. 5.

Keen Well No. 7.		
Lime and shale	120	120
Black shale (Devonian)	43	163
Blue lime	11	174
Brown sand (lime?)	3	177
Light lime	6	183
Brown sand (lime?) Pay sand	9	192
Hard lime	2	194
Light blue lime	9	203
Dark lime	2	205
Gray lime	1	206
Dark lime	6	212
Blue lime	10	222
Light-blue lime	3	225

Rosa Holder Farm.	Thickness.	Depth.
Soil	28	28
White lime	158	186
Black shale (Devonian)	41	227
Lime-Gas show at 245. Water at 320	98	325

Settles Well No. 3.		
Casing	81	81
Limestone	119	200
Green shale	3	203
Black shale (Devonian)	45	248
Dark lime (Oil smell)	5	253
Hard lime	10	263
Brown oil-sand (lime?) Gas	13	276
Oil show at		276
Shaly lime	14	290
Dark brown sand (lime?) Oil show	5	295
Hard blue lime	6	301
Sandy lime—Oil show	7	308
Hard blue and shaly lime	20	328
Hard sand (?)	1	329
Salt water	5	334

Trammel Creek Pool, Map No. 6.

Well on Big Trammel Creek.

Five Miles Southwest of Scottsville.

Soil	12	12
Blue limestone	90	102
Black shale (Devonian)	13	115
Black rock—Oil at 127	12	127
Blue limestone	40	167
White sand (lime?)	20	187
Black rock—Gas at 193	6	193
Soft sand rock (lime?)	10	203
Yellow flinty sand (lime?) Salt water	2	205
"Trenton" rock*	600	805
Blue limestone	200	1,005
"Trenton" (light)	85	1,090

*"Trenton" is driller's distinction.

Petroleum Pool, Map No. 7.

Well at Petroleum.		
Soil	10	10
Blue limestone	30	40
Black shale (Devonian)	9	49
Light gray sandstone (lime?) Oil at 132	83	132

Adolphus Pool, Map No. 8.

J. H. Carter Farm, Northeast of Adolphus

	Thickness.	Depth.
Top of black shale (Devonian)	at	152
Base of black shale (Devonian)	at	195
Sulphur water	at	196
Oil sand (lime?)	at	200
Lime	at	221
Sand (lime?)	at	225
Blue clay	at	253
Sand (lime?)	at	257
Slate	at	271
Lime	at 281 to	823
Sand (?)	at 823 to	899

Widow Lane Farm, Near Tennessee Line.

Soil	5	5
Lime	65	70
Sand	20	90
Blue lime	40	130
Slate	5	135
Sand	10	145
Slate	5	150
Black shale (Devonian)	55	205
Gray lime	30	235
Oil-sand (lime?)	10	245
Blue lime	20	265
White lime	3	268

Well was dry.

Various Locations.

George Jewell Well.

Soil and limestone	193	193
Black shale	50	243
Blue limestone	7	250
Lime sand	28	278
Broken limestone	14	292
Lime sand	4	296

Wood Jewell Well.

Soil and limestone	188	188
Black shale	50	238
Blue limestone	2	240
Lime sand	10	250

T. Y. Oliver Well No. 1.

	Thickness.	Depth.
Soil	37	37
Limestone	274	311
Black shale	43	354
Lime sand	65	419

1st sand 5 ft.
2nd sand 10 ft.
3rd sand 14 ft.

B. T. Williams Well.

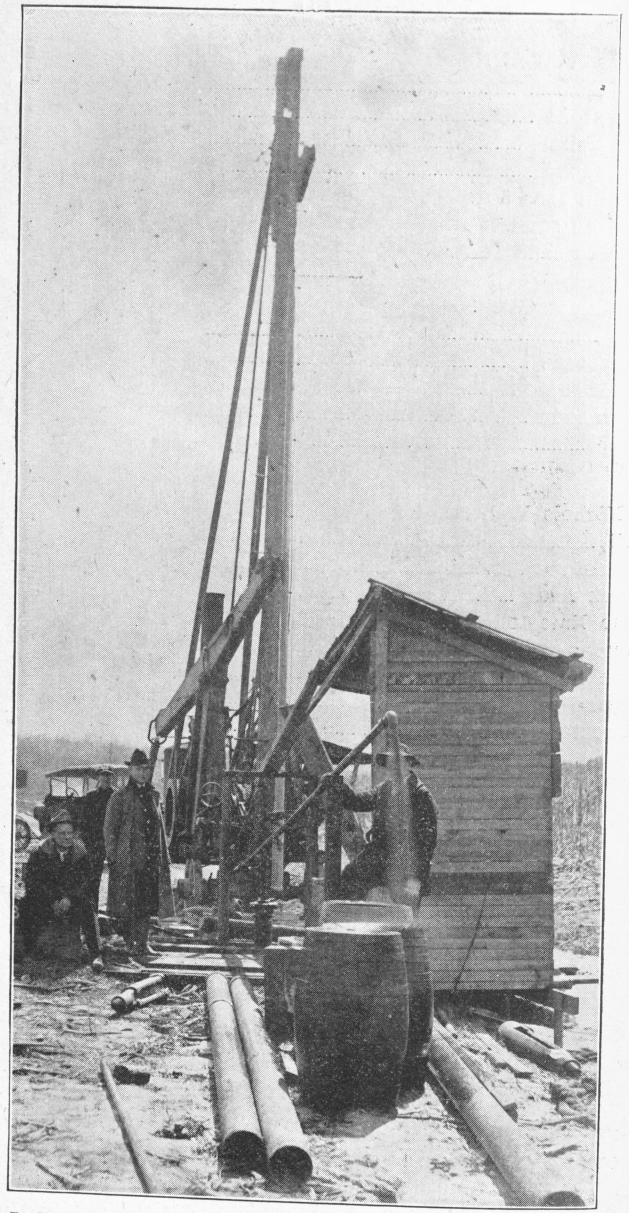
Soil	30	30
Limestone	272	302
Black shale	48	350
Lime sand	98	448
Slate	54	502

L. W. Nichols Well No. 1.

Soil	13	13
Limestone	250	263
Black shale	57	320
Blue limestone	5	325
First sand	5	330
Blue limestone	12	342
Second sand	20	362
Limestone	20	382

Structural Geology.

As has been stated the normal dip of the strata underlying the Allen county section is to the northwest, and this fall will average about thirty feet to the mile. However, this dip is far from uniform and it is this lack of uniformity which is, in part at least, responsible for the accumulation in commercial quantities of the Allen county petroleum. The deviation from the normal dip to the northwest has resulted in producing in a roughly parallel arrangement a large number of small, somewhat localized minor folds, domings or terraces. The smaller folds or anticlines may generally be considered as lying with their major axis extending in a northeast and southwest direction. Roughly the progress of development has delimited two groups of these small folds which are extremely productive. See map Fig. I. The Gainesville No. 1, Bays Fork No. 2, and Butlersville No. 3 pools may be considered the western group, with



The J. R. Winlock No. 3 (Flowing) well drilled in by the J. M. Karl Oil Company, March 14, 1919. Located on the northward extension of the Steffy Pool on the lower road to Bowling Green, three and one-half miles southwest of Glasgow, Barren County, Ky. This well flowed light green oil 44.6 Baume during an half hour gauge by the writer, one barrel every five minutes. The well made considerable gas, but no water. Photo by W. R. Jillson, March 31 1919.

the Steffy No. 14, Oil City No. 13, and Hiseville No. 15 pools, further to the northeast in Barren county a possible extension. The second group of pools and really the older of the two in point of development is the Scottsville No. 4, Rodemer No. 5, Petroleum No. 7, and Adolphus No. 8, Rough Creek No. 9, and East Rodemer No. 10, and possibly the old Oskamp No. 16 in Barren county, again a northeastward extension.

No attempt has been made as yet to map these separate structures, but it is planned to map some of them during the present field season. The work will be done on the sub-surface structure—that is the first oil pay. It is the writer's conclusions based upon field observations, that while many structural indications are to be found at the surface, none of them may be used to advantage in preparing a working map. The reason for this is found in the unreliability of the continuity of the sub-surface structure. It is definitely known for instance in the Gainesville pool that the structure of the surface worked on a thin key bed in the shale is not exactly true to that of the oil pay which is developed into at least two rather restricted domes. However, prior to any large amount of drilling in a given locality, surface structure is all that one may go by and should not be discounted where the absence of a soil mantel makes it possible to use it.

It is not intended that the reader shall infer that these two above outlined lines of minor folding are the only ones and that production will be confined to them. On the contrary the writer believes that there is very good evidence now developing which will go to show that another line of these producing structures will be brought in somewhat along the Warren county line from the Big Barren River southwestward into the eastern part of Simpson county. Furthermore these conditions may well persist to the east and extend not only over the Long Creek section but across the Allen line into Monroe county.

Structure vs. Porosity.

Any discussion of an oil field in Kentucky and especially the shallow limestone fields would be thoroughly inadequate that did not make some attempt at least to portray the real condition existent as regards porosity. In these oil fields either Appalachian, Mid-Continent or elsewhere that produce petroleum

from genuine silicious sandstones—porosity does not enter as quite as vital an issue, since all sands are more or less porous. However, when the producing horizon is known to be a limestone, porosity becomes at the same time a very important thing, for most limestones that are protected from surface exposure or rapid water percolation are or should be "tight." The "loose" or porous cavernous limestone then is not the rule, but rather the exception at protected depths below the surface. The term protected here means something more than simply out of sight too. It implies an essentially impervious cap rock of some discription. In Allen county this protecting cap rock is of course the Devonian Black Shale.

Reference has already been made to the cavernous condition of the Ononodaga limestone, and the sandy phase of the impure limes of the upper part of the Niagaran has also been pointed out. It is the writer's opinion that the Onondaga (Corniferous) where "loose" forms an almost ideal oil "sand" reservoir. It is hard to see, with large interlocking interspaces, such as this limestone frequently shows, how a much better reservoiring medium could be designed. However, the great fault with Onondaga (Corniferous) porosity is not with the porosity at all, but with the amount and the irregularity of it. There seems to be no guiding rule to go by and as has been instanced splendid producers have been offset one location again and again with absolutely dry holes due simply to a sudden tightening or compacting of the limestone. The result of this characteristic has been to prematurely condemn much territory that may eventually be redrilled to pay. Due to its irregularity in porosity therefore the Onondaga cannot be said to be quite as good a reservoiring "sand" as the actually sandy limes and associated beds of the Niagaran. These sands present a truly sandy phase and the knowledge of this fact should always—unless oceans of waters are met—encourage the prospecting driller to test them out.

In summation then the outstanding facts as revealed by the actual development are that structure—anticlines, terraces, etc.—certainly control the accumulation of petroleum in Allen county. But porosity is a vital feature and any anticline that has no porous bed developed within it below the Devonian Black Shale may be looked upon as a failure. Petroleum can not and

does not accumulate under very "tight" sand structures. Water conditions, however, being generally present serve always to segregate the petroleum in all porous places, and where tightening "sands" on the flanks of structures have prevented the upward climb of the petroleum it is conceivable that it should collect at some lower—possibly even the lowest—structural point. Thus it is logically conceivable in the peculiar limestone that the petroleum may be synclinal even in the face of ample water pressure and adequate structure. Of course this is a condition that could not possibly obtain in a true siliceous sand. But it is nevertheless a not uncommon occurence in Allen county and it is confidently expected that structural mapping in this section will show some synclinal production.

The theoretical development of the actual cause of the cavernous or porous condition of the Onondaga may not be attempted in this brief paper, but the suggestion may not be out of place that temporary subaerial conditions of leeching in post Onondaga times may have been quite as responsible for this porous condition, as the same conditions are well known to be now in many other limestones. This view is strengthened by the knowledge of the unconformity and disconformity above the Niagaran and the base of the Black Shale. Conditions favorable to rather rapid solution of the hardly consolidated young Ononodaga were certainly existent. This view point is substantiated by the fact that the Onondaga is frequently cut down to a very thin remnant and is in a few places at least entirely removed.

Sources of Allen County Petroleum.

Much has been said on the subject of the ultimate origin of petroliferous hydrocarbons and the end of the discussion is not yet in sight. Many statements have been made that had better never been advanced. Literature on this subject is rich in theories and original ideas but poor indeed in actual proof. However, some certain progress has been attained and the minds of most professional oil and gas geologists have become clarified and united in support of—in the great majority of instances—an original organic source for petroleum and natural gas. According to some it is animal, according to others

vegetable, but the rank and file take the more reasonable middle course and ascribe both plant and animal origin.

Assuming then in concensus with the general professional opinion the organic source of petroleum—it really could not be otherwise in the undisturbed sediments of Allen county—the decision does not settle the matter, but on the contrary provokes the question as to the orginial hydrocarbon bearing formation or group or rocks. And here it is that the writer believes that many who have interested themselves in this subject, and subscribed their approval to the Devonian Black Shale as the indigenous source of the principal amount of Kentucky petroleum, are in error. Plainly, the writer has no sympathy with this view or the fallacious philosophic conceptions which are put forth to uphold it.

It may not be too plain a statement to say that apparently the reason why Kentucky's petroleum—always speaking of the major portion generally found just beneath the Black Shale—is ascribed in indigenous origin to the Devonian Black or Chattanooga Shale, may be found in the fact that such reasoning follows the line of least resistance. The Devonian Shale is a very carbonaceous formation. It will burn under some conditions spontaneously* and always ignite with a little kindling. The writer has many times distilled both oil and gas from the shale. The oil—a tarry substance—may be produced, when normally severe destructive distillation tests are imposed upon the shale at the rate of between twenty and thirty gallons to the ton.** While this is not really as high as the run of some of the celebrated Colorado† and Utah petroliferous shales which it has been stated reach as high as fifty and even eighty gallons to the ton, it is nevertheless a very highly petroliferous condition, and very much higher than the average shale.

However, it does not follow that because a rich oil bearing, chiefly limestone series is overlain by a very unusually rich carbonaceous shale of considerable thickness that this lime series must or probably did secure its oil from that shale. Such

*An interesting case of spontaneous combustion—P. C. Bowers. Resources of Tenn.; Vol. VI, No. 1. Paper No. 3, pp. 37-40, Tenn. Geol. Surv., Jan. 1919.

**Author's unpublished experimental notes.

†Oil shale in Northwestern Colorado and adjacent areas. D. E. Winchester. U. S. G. S. Bull. 641. F.

an assumption might and probably does hold good in a section where shales and sands alternate with small limes but the conditions in Kentucky are special and an inquiry into them disallows the above conception. The proofs which may be considered both positive and negative are as follows:

In the State of Kentucky: (1) The petroleum recovered below the base of the Devonian Black Shale exhibits a wide chemical variation indicating varying conditions of ultimate source. A Black Shale group of petroleums might be expected to show uniformity comparable to their source. (2) The petroleum is generally found one or more "pays" beneath a very compact cap rock at the top of the lime series, which it is believed would have held any migratory gravity inspired petroleums above it much more easily than it now holds them below under water pressure. (3) The Black Shale directly overlies the lime under its cap. Under no conditions, except that of absolute dryness, could the therein contained petroleums have moved downward through the hard cap rock and into the cavernous limestones beneath. It cannot be shown that the Black Shale has ever been dryer than it is at present, if as dry. (4) Slight moisture would certainly have nullified the gravitative force, and capillarity would reasonably in any event have been a strong retaining factor against downward movement of petroleum. With any considerable degree of water present it is hardly conceivable according to physical laws of differential gravity how the isolated petroleums (if indeed they were isolated and free to move) could have done other than move slowly upwards.* At higher levels they would have been trapped by the overlying shales, limes and sands of the Waverly group. (5) Assuming that some part of the Black Shale hydrocarbons in some as yet unexplained way got down into the underlying limestone, it would be a very much one-sided arrangement if an equal amount did not in some locality at least move upward according to natural laws and find lodgment in the fine reservoiring strata towards the base of the Waverly. Yet the large amount of drilling in Kentucky has not demonstrated this to be the case. (6) Assuming that the larger part of the indigenous Black Shale petroleums have been free to move (never been

*The Role and Fate of the Connate Water in Oil and Gas Sands. R. H. Johnson, Am. Inst. Min. Engr. Trans., Vol. 51, pp. 587-610, 1916.

shown to be a fact) it would only be safe to infer that any stray sand lenses in the shale would be very highly impregnated with oil containing dissolved gas. Sand lenses in the Black Shale are not common but they do occur in Kentucky. And experience has shown that where they do, these sands are always gassy and never commercially petroliferous at all. This well known condition apparently precludes a further tolerance of the groundless theory of the Black Shale source.

Many other arguments quite as logical and destructive could be brought to bear on this subject, but the limits of this paper will not allow of their detailed presentation. Suffice it to say that the writer feels there is ample proof at hand to demonstrate that the Kentucky crude petroleum recovered from below the Devonian Black Shale is a strictly lime and shale oil derived indigenously from the Onondaga (Corniferous) and underlying Niagaran and possibly lower formations. As such it is probably of varying original animal and vegetable constituency, which readily accounts for the great variation in the bacterial sulphur component of analyses of samples from producing wells located within the same field and producing from the same horizon or horizons. Furthermore in the light of existing field conditions taught by the drill it seems unnecessary to suppose that any considerable amount of the Black Shale hydrocarbons have ever been freed for migration. It seems much more reasonable (since they may now be recovered at the rate of from twenty to twenty-five gallons to the ton) to consider them all still locked within the shale awaiting the day when they shall be released through mechanical means as a great reserved mineral oil resource.

Present Development and Futurity.

Beginning with a single producing oil well on Bays Fork* considerably less than a hundred feet deep and drilled shortly after the close of the Civil War, probably in 1865 or 1866, Allen county has come to the front rank as an oil producer in Kentucky. Today it is probably only exceeded by Lee county in point of actual production. A number of factors have favored this turn of affairs. Firstly Allen county is easy of access—

*Note on the Geological Position of Petroleum Reservoirs in Southern Kentucky and Tennessee. Am. Jour. Sc., 2d Series Vol. 42, pp. 104-107, 1866.

that is as compared to the other mountain counties. Secondly, the drilling fortunately is shallow—generally less than 350 feet—and therefore dry holes are less expensive and hazardous to the prospector of limited means. Thirdly, production has been secured in very commensurate proportions to the amount of drilling done. It is this third point that has really made Allen county a success. Fourthly, commercial outlet for the Allen county oil has been practically maintained from the first which has quickened field activity.

The present season is witnessing the zenith of Allen county development. There are at present at least 200 rigs at work in this county and more will be on the ground before the end of the summer. Weekly completions are steadily increasing and with them the amount of production. Two short pipe lines—both of which have recently become inadequate to move the crude—serve the Allen county fields. These are the American Pipe Line Company (2-inch), Gainesville Pool to Bowling Green, and the Indian Refining Company Pipe Line (4-inch) from the Gainesville Pool to Scottsville. Both of these lines end at tank car stations on the Louisville and Nashville Railroad. The Rodemer, Petroleum and Adolphus pools feed directly to gathering lines of the Indian Refining Company with outlet at Rodemer, Kentucky.

The tank car shipment totals of the Indian Refining Company in Allen county for the years 1915 to 1919 are as follows:

Tank Car, Allen County Crude.

Year.	Barrels.
1915	191.26
1916	27,616.23
1917	31,936.94
1918	20,990.86
1919 (2½ months)	1,774.57
Total barrels	82,509.86

The pipe line runs of the Indian Refining Company in Allen County during the year 1918 and January and February and half of March, 1919, is as follows:

Pipe Line Runs, Allen County Crude.

Year.	Scottsville.	Rodemer.	Total.
1918	28,233.25	9,886.63	38,119.88
1919 (2½ mo).	38,455.56	17,906.71	56,362.27
Total barrels			94,482.15

The total amount of crude taken out of Allen county by the Indian Refining Company from 1915 up to March 16, 1919, would be the sum of the above totals or 176,992.01 barrels.

In addition to the above figures there is an increasingly large amount of crude oil from the Scottsville, Rodemer, Petroleum and Adolphus pools being shipped by tank cars to various smaller purchasers in and outside of Kentucky. Because of the scattered nature of these customers, it has been impossible to secure figures which would be at all representative of their aggregate purchase. It is believed, however, that 30,000 barrels for 1918-1919 and 50,000 for the period 1915 to 1919, inclusive, would be a very conservative estimate of the total amount of this scattered crude.

The American Pipe Line Company—Gainesville Pool to Bowling Green, 2-inch—has been such an uncertain factor in the transportation of the Gainesville crude that it has been impossible to obtain figures showing what runs have been made. This line is now in the hands of receivers and out of service. Altogether it probably never ran more than 20,000 barrels and wasted almost as much as this with old leaky pipe. Adding this figure to the one of the Indian Refining Company and the independent tank car purchasers a total production figure from 1915 to March 16, 1919, of 246,992.01 barrels is obtained.

The crude of Allen county coming from any one of the three pay "sands" below the base of the Devonian Black Shale is a mediumly dark green oil. It is opaque—except in films less than one-eighth of an inch in thickness. Its base is paraffin. The gravity of this oil by the Baume scale will vary from 26.0 to 45.0, the latter of which is exceptional, and as taken from the records of the State Chemist, Dr. A. M. Peter, is the highest of any Kentucky crude oil. The average crude oil from this horizon in Allen county will run about 35 to 38 Baume. Unfortunately these Allen county limestone crudes exhibit, except

in some special instances, rather high sulphurs, 1.15% to 1.95%, which renders them difficult of refinement. All high sulphur oils are classed as "sour," and command in the open market a present day price somewhat less than $2.60, the generally uniform price for the bulk of Kentucky "Somerset" grade. The gasoline recovery of these crudes is, however, very good following a somewhat longer "treatment" than the oils of Eastern Kentucky. The following distillation record gives a fair idea of how the Allen county crudes run in commercial test.

Distillation Record of Scottsville, Allen County Crude.

Tank
Initial Boiling Point 300
Temp. Condenser 80
Gravity Baume 26.0
Maximum Boiling Point 650

Per Cent Off.	Temp. "F"	Gravity Be.	Per Cent Off.	Temp. "F"
10	350	42.8	-----	212
20	425	38.4	3.0	300
30	522	35.5	10.0	350
40	580	33.0	13.0	365
50	620	31.6	15.0	375
60	640	30.6	19.0	400
70	650	30.5	22.0	460
80	-----	-----	26.0	500
90	-----	-----	68.0	650
98	-----	-----	-----	-----
			Per Cent Total Recovery	-----
			Loss in Gravity	-----

32% Bottoms. 15.8 Grav.

Various ingenious methods have been devised by operators, geologists and promoters to estimate the amount of oil contained in the Allen county lower than Black Shale "sands." The writer's experience does not lead him to believe that any of these estimated—generally reckoned upon uncertain cubic space—are reliable. If any dependence could be placed in the regularity of porosity or quantity of oil per under-surface unit of 1000 square feet, some reliance might be placed upon the results thus obtained. But the chief characteristic of the producing sands of Allen county is their irregularity in porosity and productivity. It is believed that the old time-honored method of accurate well gauging over an extended period of time and considerable area

will prove to be the only safe guide as to the life of the wells of this section of Kentucky.

Naturally in so youthful an oil field as this, however, figures of this kind are as yet hardly obtainable, and where they are operators realizing the vital nature of such figures have hestitated to give them out. General deductions must, therefore, for the time being be used. The best information obtainable on Allen county shows that many correctly drilled and managed wells have started in with an initial flow from the pump of from 30 to 100 barrels. A few wells have flowed, and flowing wells when active and open to a tank. can easily do from 200 to 300 barrels every twenty-four hours. A very select group of wells in Allen county have probably done as much as 250 or 300 barrels per day for the first twenty-four hours after being "drilled in." Such exceptional wells have usually secured their pay from a very porous streak generally 15 to 17 feet thick in the Onondaga (Corniferous) limestone. No one has ever published or boasted of a ten day test of any such well or group of wells, though their capacity is certainly known to their owners. This is significant, and it is thoroughly in keeping with the statement that these large capacity wells do not long maintain their high production record.

Allen county is essentially a shallow field—relatively easy and cheap to operate in. With these virtues it combines the feature common to all such fields of rapid and early decline of production. This decline is most notable in the larger wells. It may within practical limits of accuracy be figured at from 25 to 33 1-3 per cent by the end of the first month and with a gradually lessening decline during the second six months. This state of affairs need not cause undue concern either to the general public or the operators themselves for any group of fair size wells—30-150 barrels—will repay their initial cost and running expenses many times over before abandonment, providing they have the right kind of field supervision. Allen county wells as a rule are not well managed and this condition unless it is corrected will sooner or later militate against the production of the field.

In the small wells—5 to 20 barrels, and there are a great many of these in Allen county—the decline has shown itself to be very much slower and of course very much lower in proportion

to the total well production. While big production is what is always desired, it is a fact, that with low developing costs such as are now existant in Allen and rapid commercial outlet for the crude—small wells can and are being drilled generally over this area with a substantial profit. Humorously enough it is the small well or group of small wells that determine whether an individual or corporation is an actual "oil producer" or not. Any one can ride along on "pot luck," big production, but it requires real oil producing management to head the small producing property. The reason is plain for in the latter case the profit must come from the crude oil sales alone, and not from press agent stock inflation or Eldoradic speculation in the leases. Unfortunately Allen county—like the other producing sections of Kentucky—with its splendid bona fide record of recent new crude production has suffered much from this latter kind of unsound business.

Natural Gas Gasoline in Kentucky in 1917.

By JOHN D. NORTHROP.

U. S. Geological Survey

Although the contribution of Kentucky was only 1.8 per cent. of the natural gas gasoline produced and marketed in the United States in 1917, that contribution amounted to 3,818,209 gallons and was 426 per cent. greater than the state's output in 1916. This large gain is attributed chiefly to the absorption plants installed by the United Fuel Gas Co., in 1916, which, though located in Kentucky, operate to a considerable extent on natural gas from West Virginia. Other sources of natural gas gasoline in Kentucky include compression plants operated by the Wood Oil Co. and by the new Domain Oil & Gas Co. in the oil fields of Wayne county, and by the Morgan County Heat & Light Co. in Morgan county, as well as the drip stations on the gas mains in the state.

The average selling price of natural gas gasoline marketed in Kentucky in 1917 was 20 cents a gallon, and the market value of the entire output was $763,186, a gain of half a cent in average selling price and of $621,839, or 440 per cent., in total market value, compared with 1916.

The volume of gas treated in the production of the gasoline marketed in Kentucky in 1917 is estimated at 24,915,946,000 cubic feet, from which the recovery of gasoline per thousand cubic feet averaged 1.2 pints.

Reference: Mineral Resources of the United States, Part II, Natural Gas Gasoline (Kentucky), 1917. (John D. Northrop.)

Kentucky Mineral Waters in 1917.*

BY ARTHUR J. ELLIS,

U. S. Geological Survey.

The reports for 1917 show a decline in the sales of mineral water in Kentucky. There was a decrease of 20 per cent. in quantity and of 23 per cent. in value. The reported sales in 1917 were 301,748 gallons, as compared with 377,246 gallons in 1916, and the value of the output was $40,189, as compared with $52,305 in 1916. The average price decreased from 14 to 13 cents. One spring which marketed water in 1916 reported no sales in 1917; 2 springs active in 1916 were reported out of business in 1917; 1 spring active in 1916 could not be located in 1917; 2 springs idle in 1916 reported sales in 1917; and 4 new springs were added to the list: thus the total number of active springs was 13. Two resorts, accommodating 130 guests, exclusive of the capacity of Dawson Springs, and 2 mineral water bathing establishments were maintained. In addition to this 76,207 gallons of mineral water was used in making soft drinks—an increase of 121 per cent over 1916. Four new wells were added to the list, as follows: Doom's Well, H. & H. Water Well, Phillip's Well, and Redden's Well.

The 13 springs reporting production are as follows:

Anita Springs, LaGrange, Oldham County.
Avon-More Well, Dry Ridge, Grant County.
Blue Rock Spring, near Fisherville, Jefferson County.
Cole's Lexington Lithia Springs, Lexington, Fayette County.
Doom's Wells, Dawson Springs, Hopkins County.
Hamby's Well, Dawson Springs, Hopkins County.
H. & H. Water, Dawson Springs, Hopkins County.
Kentucky Mineral Well, Lorain, Taylor County.
Phillip's Well, Dawson Springs, Hopkins County.
Redden's Well, Dawson Springs, Hopkins County.
Robson Spring, Fort Thomas, Campbell County.
Royal Magnesian Spring, near LaGrange, Oldham County.
St. Patricks Well, Louisville, Jefferson County.

*Mineral Resources of U. S. for 1917. Part II; U. S. G. S., pp. 500-501. 1919.

DEPARTMENT OF GEOLOGY AND FORESTRY
OF KENTUCKY
FRANKFORT, KY.

J. E. BARTON, Commissioner
W. R. JILLSON, State Geologist

MAP OF ALLEN COUNTY

BASE BY

L. M. SELLIER

OIL AND GAS DEVELOPMENT

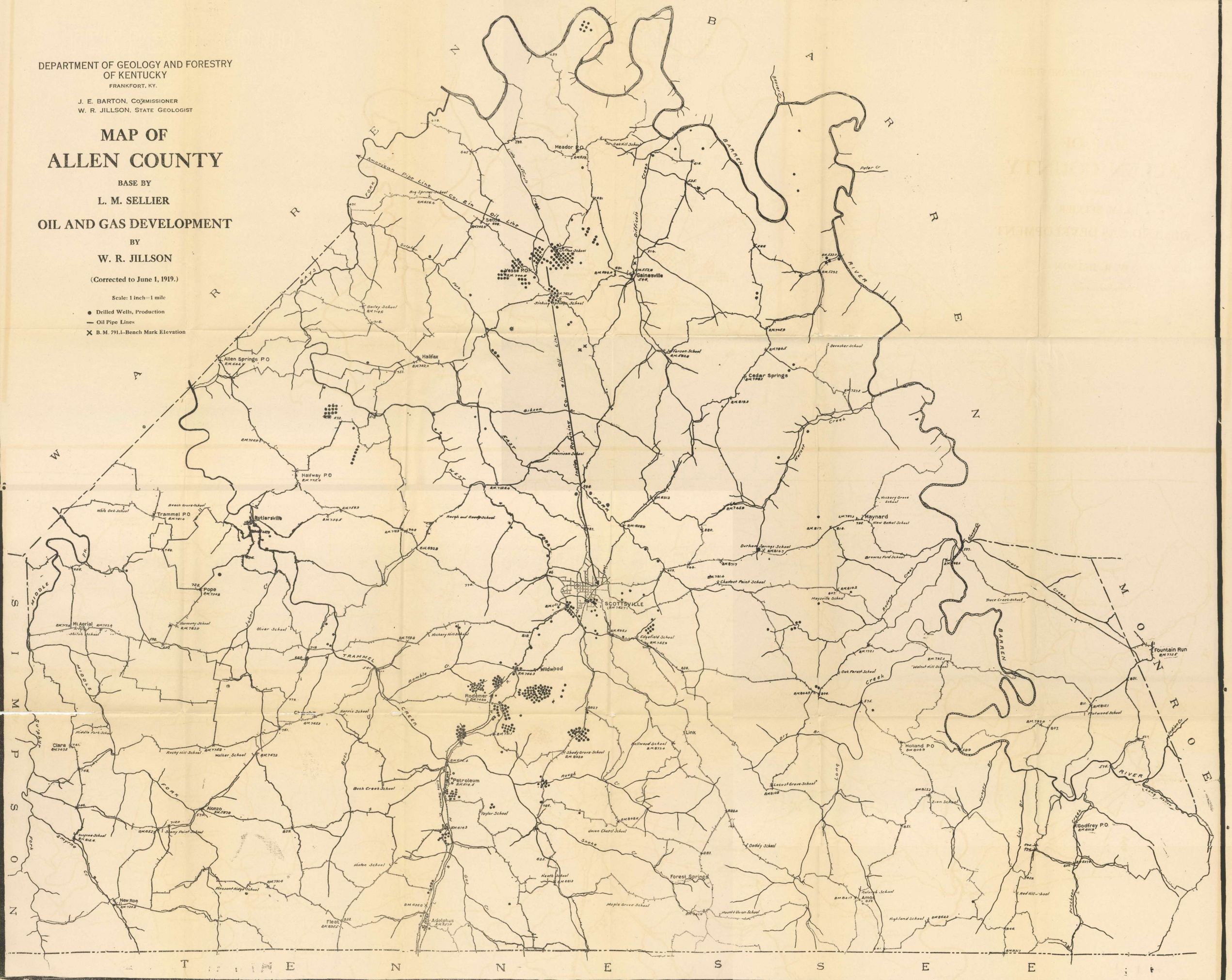
BY

W. R. JILLSON

(Corrected to June 1, 1919.)

Scale: 1 inch=1 mile

- Drilled Wells, Production
- Oil Pipe Lines
- B. M. 791.1--Bench Mark Elevation



Department of Geology and Forestry

J. E. BARTON, Commissioner
W. R. JILLSON, State Geologist

Oil and Gas Map of Barren County, Ky.

Compiled and Drawn by
H. R. MERRY, C. E.
Glasgow, Ky.

June 25, 1919

