STATE GEOLOGICAL SURVEY OF KANSAS

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OIL AND GAS IN MONTGOMERY COUNTY, KANSAS

By G. E. ABERNATHY
With chapters by R. P. KEROHER and WALLACE LEE

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OIL AND GAS IN MONTGOMERY COUNTY, KANSAS

By G. E. Abernathy

INTRODUCTION

Geographic features.—Montgomery county is situated in southeastern Kansas and in the southernmost tier of counties (fig. 1). Its dimensions are about 26.5 miles from north to south and 24 miles from east to west.

Montgomery county has a population of 50,593. The land is primarily devoted to agriculture, stockraising, and dairying. The principal crops are native hay, wheat, corn, and oats. Grazing lands comprise large areas in the rougher uplands.

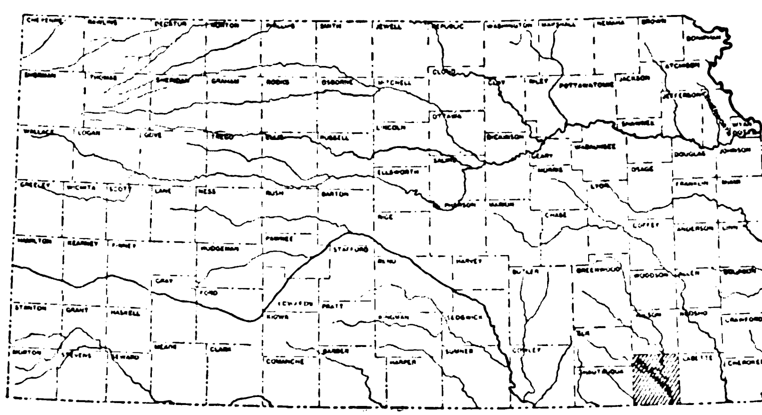

Fig. 1. Index map of Kansas, showing location of Montgomery county.

The principal towns in the county are Independence, the county seat, which has, according to the 1939 census, a population of 11,759; Coffeyville, with 17,838; Cherryvale, 4,251; Caney, 2,794; Elk City, 607; Havana, 289; Dearing, 324; Wayside, 159; and Sycamore, 187.

Railway tracks within the county exceed 160 miles in length. A main line of the Atchison, Topeka and Santa Fe Railway in the eastern part of the county runs from north to south through Cherryvale, Liberty, and Coffeyville. A branch line runs westward from Cherryvale to Independence, then turns southwestward to Havana, Caney, and Oklahoma points. Another branch line runs from Independence through Elk City in the northwestern part of the county. A main line of the Missouri Pacific Railway passes through Sycamore, Independence, and Coffeyville, and a branch line in the southern end of the county runs through Coffeyville, Dearing, and Caney. The Missouri-Kansas-Texas Railway traverses the extreme southeastern area of the county, the line running through Coffeyville. The St. Louis and San Francisco Railway crosses the extreme northeastern part of the county, the line running through Cherryvale. The Union Traction Electric Railway passes through the east-central and southeastern areas.

Three paved federal highways extend across Montgomery county; U. S. highway 75 traverses the county from the north-central part, through Sycamore and Independence, to the southwestern part through Havana and Caney; U. S. highway 160 extends from the eastern part of the county through Independence to the northwestern part, and U. S. highway 169 traverses the eastern part of the county from north to south. Most of the state and county roads are graveled, so that almost any of the towns and villages can be reached even in bad weather.

Topography.—Montgomery county lies in an area of somewhat deeply dissected rolling plains. The most striking topographic features are eastward-facing escarpments and broad intervening dip-slopes that are deeply dissected by erosion, and the flat flood-plain areas of Elk and Verdigris rivers. The escarpments are most prominent where hard, resistant beds of the Drum or Stanton limestones overlie thick shale. The strike of these escarpments is in general from north to south.

The altitude (Schrader, 1908)[1] of the surface of Montgomery county above sea level ranges from 690 feet near Coffeyville in the southeastern corner of the county, where Verdigris river crosses the Kansas-Oklahoma boundary line, to slightly above 1,000 feet in the northwestern part of the county.

Purpose of report.—This report, and the accompanying maps, is the second of a series[2] to be published by the Kansas Geological Survey describing the counties in southeastern Kansas.

The geologic investigation and the compilation of data relative to the oil and gas industry of Montgomery county were undertaken for the purpose of adding to the geologic knowledge of this section

1. References to publications are indicated in this report by the name of the author and date, as given in the list at the end of the report.

2. The first report was devoted to Labette county, which borders Montgomery county on the east. Map of Labette county, by G. E. Abernathy, Kansas Geol. Survey, 1939.

of the state and to assist in the development of the mineral industry of the county.

Field work.—This report and map contain the results of field work, compilation of drilling records, and other data obtained during 1938 and the summer of 1939.

Acknowledgments.—I express my appreciation for the generous coöperation given by many geologists and executives of operating oil and gas companies and to geologists, operators, and drilling contractors engaged in independent work. Special acknowledgment should be made to C. W. Studt and Thomas W. Lee, of the Sagamore Oil and Gas Company, for logs of deep wells and for advice and assistance. Vernon C. Palmer, of the Union Gas System, Inc., supplied data on gas production. The Consolidated Gas Company, the Roth Oil and Gas Company, Inc., and the Magnolia Petroleum Company permitted me to examine their log records. The logs of the Well Log Bureau of the Kansas Geological Society were also examined. Gene Abernathy very kindly assisted in obtaining many well records and checking the field location of wells. In addition I wish to express my appreciation to J. M. Jewett for information on stratigraphy.

SURFACE FORMATIONS

The rocks exposed at the surface in Montgomery county belong to the Pennsylvanian subsystem of the Carboniferous system. They include parts of the Des Moines series below and the Missouri series above.

DES MOINES SERIES (PENNSYLVANIAN)

Marmaton group.—The Marmaton group includes, in ascending order, the Labette shale, Pawnee limestone, Bandera shale, Altamont limestone, Nowata shale, Lenapah limestone, and Memorial shale. The upper boundary is the disconformity that marks the top of the Des Moines series. The Altamont limestone is the oldest rock formation exposed at the surface in Montgomery county. It consists of two limestone members separated by a bed of dark shale 5 to 15 feet thick. The lower member is a hard crystalline limestone 10 to 15 feet thick; the upper one is a dark-gray limestone containing fossiliferous chert nodules. The Altamont is exposed in the bed of Pumpkin creek northeast of Coffeyville. Upper Marmaton beds, including in upward order the Altamont limestone, Nowata shale, Lenapah limestone, and Memorial shale, crop out

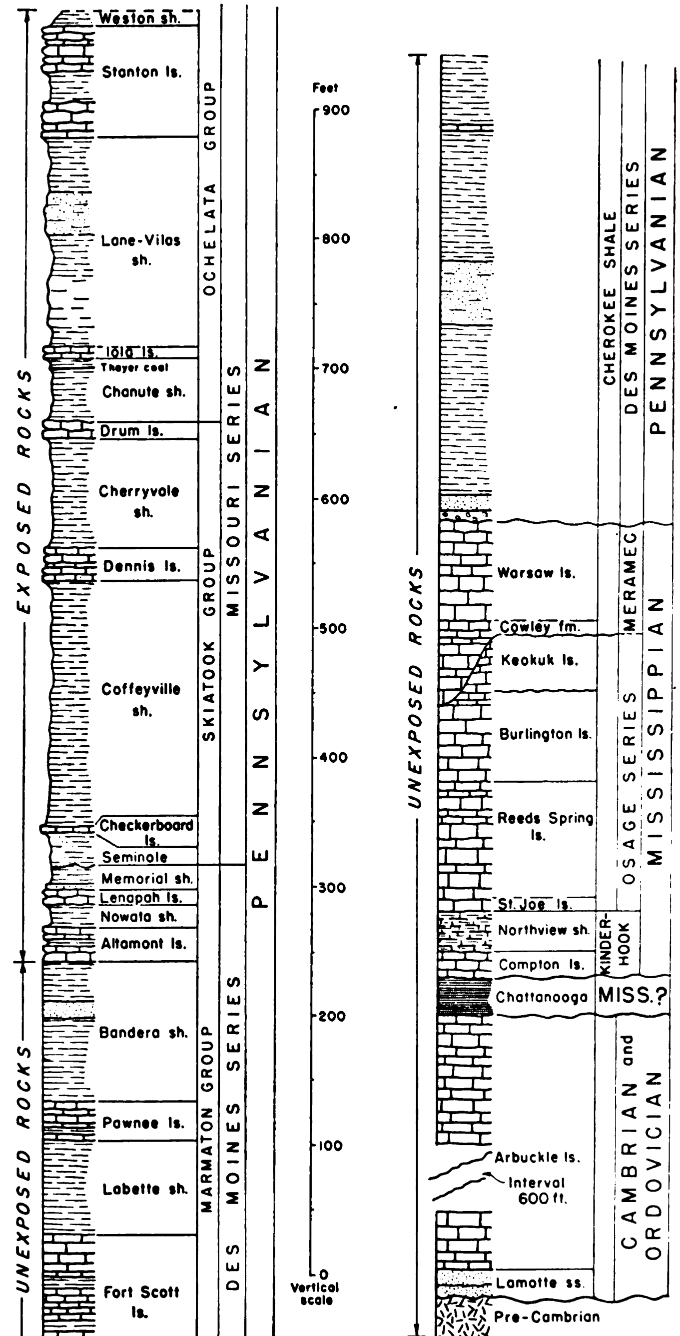

Fig. 2. Generalized rock section of Montgomery county.

in an area of about 25 square miles in the extreme southeastern corner of the county. The hard limestones do not form escarpments in this area but are exposed in the creek beds.

MISSOURI SERIES (PENNSYLVANIAN)

Skiatook group.—The exposed rocks of the northeastern, central, and southwestern part of Montgomery county belong to the Missouri series. The state geologic map shows the distribution of the Bourbon, Bronson, and Kansas City beds across the county. Because the limestones in the lower part of the Missouri series become thin and inconspicuous in the southern part of the county, it is convenient to use the northern Oklahoma classification for Montgomery county. This recognizes the Skiatook group at the base of the Missouri series, overlain by the Ochelata group. The Skiatook group includes, in upward order, the Seminole sandstone (mostly absent in Kansas), the Checkerboard limestone (or Hertha?), the Coffeyville shale, the Dennis limestone, the Cherryvale shale, and the Drum limestone. The group crops out in a band across the southeastern part of the county. The western limit of the band crosses the northern boundary near the northeastern corner of the county and extends southwestward to a point about 3 miles west of Cherryvale, then southwestward through Dearing to the Oklahoma line. There the band is about 5 miles wide. The Coffeyville shale is about 150 feet thick in the vicinity of Coffeyville. The Dennis limestone consists of 12 to 15 feet of dense, hard dark-blue flaggy limestone beds. It is separated from lower fossiliferous limestone beds 10 to 12 feet thick by 8 to 10 feet of dark shale. The Cherryvale shale, which is about 90 feet thick at Cherryvale, is not more than 10 feet thick in the area west of Coffeyville, owing to post-Drum erosion that brings the sandy base of the Chanute shale down nearly to the Dennis limestone. The Drum limestone varies greatly in thickness within a short distance. Near Independence the lower part is a bluish-gray fine-grained limestone about 5 to 20 feet thick. The upper part is a cross-bedded oölitic limestone that ranges in thickness from 2 to 70 feet. Near the Kansas-Oklahoma state line the Drum limestone is absent, owing to erosion.

Ochelata group.—The Ochelata beds comprise the upper Missouri deposits of Montgomery county. The lower boundary of the group is the base of the Chanute shale. This member is about 200 feet thick. The Chanute shale is normally overlain by the Iola limestone, a bluish-gray fossiliferous limestone about 6 feet thick. The beds of shale between the Iola limestone and the Stanton limestone are about 50 feet thick and are designated as Lane-Vilas shale. The Stanton limestone is variable in thickness and lithologic character. Eight miles southwest of Independence, in sec. 7, T. 34 S., R. 15 E., the Stanton limestone consists of 5 feet of thin-bedded limestone underlain by about 50 feet of gray shale, which is underlain by a few thin beds of limestone and shale. In the vicinity of Table Mound, a few miles northwest of Independence, the Stanton limestone consists of an upper bed of limestone 40 feet thick and a lower bed of limestone 44 feet thick separated by about 8 feet of shale. The weathering of the Stanton limestone produces escarpments that are in some places more than 200 feet high. In other places weathering produces isolated hills, which are locally known as mounds. The Weston shale overlies the Stanton limestone and is the surface formation over the northwestern part of the county. The Ochelata group crops out over the north-central part and all the western half of Montgomery county.

SUBSURFACE FORMATIONS

Rocks penetrated by drilling in Montgomery county are identified as belonging to the following major geologic divisions, named in downward order: Pennsylvanian subsystem and Mississippian subsystem, which belong to the Carboniferous system; Ordovician system; Cambrian system; and pre-Cambrian crystalline rocks. These divisions are described in order from oldest to youngest, the portion of the rock column below the Carboniferous being described by R. P. Keroher, and the Mississippian rocks being discussed by Wallace Lee.

PRE-MISSISSIPPIAN ROCKS

By R. P. Keroher

The name Arbuckle is used in Kansas to include rocks ranging in age from Upper Cambrian to Lower Ordovician. These rocks correlate approximately with part of those at the type locality of the Arbuckle limestone in Oklahoma and have been traced northward across both Oklahoma and Kansas.

The excellent exposures of Arbuckle rocks in Missouri and the advanced state of classification there make it desirable to correlate recognizable subdivisions of the Arbuckle in Kansas with corresponding beds in Missouri. That classification accordingly will be used here.

The maximum known thickness of Arbuckle rocks in Montgomery county is that in the J. B. Miller No. 1 well, sec. 33, T. 33 S., R. 17 E. The driller's log of this well shows 950 feet of "limestone", which is probably all Arbuckle. The driller's log of one other deep well in Montgomery county, the Hydraulic Oil Company No. 1 R. 17 E. The driller's log of this well shows 950 feet of "limestone", directly overlying the pre-Cambrian granite. Data from wells in adjacent areas show a thickening of the Arbuckle beds toward the south and west, and, accordingly, it is probable that the thickness is somewhat greater near the southwestern corner of the county than elsewhere in Montgomery county.

The very small amount of information available concerning the Arbuckle rocks in Montgomery county makes it impossible to do more than approximate the thickness and character of these beds. Comparison of the logs of the deepest two wells in the county with the Wert No. 1, sec. 16, T. 31 S., R. 21 E., in Labette county, however, indicates that the rocks encountered in these wells may be very similar. The following correlation and description of the rocks are taken from the Wert well and wherever possible are referred to deeper wells in Montgomery county.

Pre-Cambrian rocks.—According to the driller's log the pre-Cambrian surface was reached at a depth of 2,155 feet in the J. B. Miller well in sec. 33, T. 33 S., R. 17 E., and at 2,536 feet in the Hydraulic Oil Company's No. 1 Beal, in sec. 12, T. 33 S., R. 14 E. These logs show that red granite was penetrated to a depth of 5 feet in each well. Granite, containing an abundance of pink feldspar, has been found in other wells in southeastern Kansas. On the basis of the above logs it is reasonable to infer that it is also present in Montgomery county. Both Cambrian and Ordovician rocks are present in Montgomery county. These will be discussed in ascending order.

Cambrian rocks. — The Cambrian formations present in Montgomery county are the Lamotte, Bonneterre, and Eminence. The total thickness of Cambrian rocks penetrated in the Wert well is 344 feet.

The Lamotte sand in the Wert well is 58 feet thick. It is composed of large angular to subangular quartz sand grains.

The Bonneterre formation in the Wert well is 138 feet thick. It consists of dark-gray, very coarsely crystalline dolomite, which contains considerable glauconite near the base. A fine gray sand, which ranges from as much as 50 percent of the samples at the base to a very small amount in the upper part of the formation, is characteristic of this formation.

The Eminence formation is well defined at the top by the persistent Gunter sandstone of Ordovician age. In the Wert well it consists of 148 feet of light to buff crystalline dolomite. The rock is distinguishable because of the relatively small amount of chert and sand present and by its position above the readily recognizable Bonneterre formation.

Ordovician rocks.—The Ordovician rocks present in Montgomery county are correlated with the Gunter, Van Buren, Gasconade, Roubidoux, Jefferson City, and Cotter formations of Missouri. The total thickness of these beds in this part of southeastern Kansas is approximately 727 feet.

The lowest Ordovician rocks in Montgomery county are correlated with the Gunter, Van Buren, and Gasconade formations of Missouri, named in ascending order. The Gunter sandstone, at the base of the Van Buren, consists of about 20 feet of dolomitic sandstone. The shape of the sand grains ranges from subangular to rounded. Although the Van Buren and Gasconade formations are readily distinguishable at the outcrop, no attempt is made here to separate them on the basis of the few samples available. Both formations are characterized by a considerable amount of white, smooth chert. Some zones contain dolocasts (casts or impressions of dolomite crystals preserved in chert). The Van Buren formation is defined at the base by the thin but fairly persistent Gunter sandstone. The combined thickness of the three formations is approximately 147 feet in the Wert well.

The Roubidoux formation in the Wert well is approximately 320 feet thick. Lack of samples at the contact of the Roubidoux and Jefferson City formations justifies only an approximation of the thickness of these beds. The Roubidoux consists dominantly of buff to tan dolomite, which ranges in texture from dense to coarse-grained. Considerable chert is present in some samples. A considerable amount of sand is present throughout the entire thickness of the Roubidoux. Some samples near the middle of the formation are composed almost entirely of subangular to rounded quartz grains. The quartzose chert and relatively large amount of sand are characteristic of the Roubidoux. A thin cherty zone near the top of the Roubidoux in some wells contains large brown "oölites" very similar to those in the Jefferson City. The common type of chert, however, has a transparent, quartzose appearance.

The combined Jefferson City and Cotter formations in Montgomery county have a thickness of about 360 feet in the Wert well. The rocks are tan, buff, and gray dolomites, which range in texture from dense to very coarse-grained. A considerable amount of chert is present, which is dominantly white and smooth, and ranges from opaque to almost transparent. The translucent character and smooth fracture give the rock somewhat the appearance of paraffin. This peculiar chert and the abundance of large brown "oölites" in a matrix of lighter, translucent chert are characteristic of these formations. A minor amount of fine to coarse, angular to well-rounded, frosted quartz sand is present throughout most of the formation. Some samples consist almost entirely of this sand.

MISSISSIPPIAN ROCKS

By WALLACE LEE[3]

Rocks of Mississippian age are not exposed in Montgomery county and they are thus known only from the cuttings and logs of drilled wells. In general, the depth to the top of the Mississippian rocks, which depends on the relief of the surface and the structure of the rocks, is 900 to 1,000 feet on the eastern side of the county and 1,500 to 1,600 feet on the western side.

Chattanooga shale and Kinderhook beds.—The Chattanooga shale is the lowermost formation that is currently regarded as Mississippian in age, although it may possibly be Upper Devonian. In Montgomery county this shale unconformably overlies Ordovician rocks that are broadly classified as the Arbuckle limestone—the "Siliceous lime" of drillers. The angular unconformity between the Chattanooga shale and the Ordovician rocks in Montgomery county and other parts of eastern Kansas is not very striking in wells that are near one another, but it is apparent when the region is viewed as a whole. The pre-Chattanooga rocks were raised above the sea, gently folded and then eroded to a nearly flat plain before the deposition of the Chattanooga shale. Montgomery county lies on the crest of a broad westerly pitching anticline known as the Chautauqua arch, formed at this time, from which hundreds of feet of Arbuckle and younger rocks that originally had been deposited in Montgomery and adjoining counties were removed by erosion.

The Chattanooga shale is 35 to 45 feet thick in Montgomery county, but it may have been partly or completely eroded during a

3. Published by permission of the Director of Geological Survey, United States Department of the Interior.

later period of emergence in a small area in the extreme southwestern part of the county. The Chattanooga consists for the most part of slightly micaceous, pyritiferous, noncalcareous, black fissile shale containing irregularly disseminated plant spores. In the central portion of the county the shale in the middle part of the Chattanooga is gray. This gray shale thickens eastward, in which direction the black shales of the formation thin, and in some places all of the Chattanooga is gray. A widely distributed but erratically deposited sandstone, known to oil operators as the Misener sand, occurs in the base of the Chattanooga. Although the sandstone is absent or represented only by sandy shale in many localities, it is locally several feet thick and provides the reservoir rock of some oil pools.

The Chattanooga is overlain by the Compton limestone and the Northview shale of Kinderhook age, which together represent the Chouteau limestone of northeastern Kansas and northwestern Missouri. The Compton limestone, which directly overlies the Chattanooga, is a slightly greenish-gray, semigranular, noncherty limestone 2 to 5 feet thick. It is overlain by the greenish-gray silty calcareous shale of the Northview, whose thickness in Montgomery county is in most places less than 15 feet. Both formations have been removed by the erosion indicated by unconformity at places in the extreme southwestern part of the county.

Osage beds.—Rocks of Osage age, which consist in ascending order of the St. Joe, Reeds Spring, Burlington, and Keokuk limestones, overlie the Northview. The St. Joe limestone, which is probably separated from the Northview by an obscure unconformity, is a gray, noncherty or sparsely chert, semigranular limestone. In most localities it is only 6 to 10 feet thick, but in the Lyon well, in sec. 10, T. 33 S., R. 17 E., it has a thickness of 45 feet, the upper part of which includes pink limestone.

The Reeds Spring, Burlington, and Keokuk are composed of irregular zones of dolomite, dolomitic limestone, and limestone, and all of them contain abundant chert whose characteristics[4] serve to distinguish them. The St. Joe, Reeds Spring, and Burlington limestones seem to constitute a conformable sequence, but limestones believed to be of Keokuk age seem to be separated from the Burlington by an unconformity. The maximum combined thickness of the Osage limestones is more than 280 feet along the northern boundary of the county, but the thickness is less in other portions

4. Lee, Wallace, unpublished manuscript.

of the county because of the erosion of the uppermost formations in post-Keokuk time. Erosion at that time did not continue to peneplanation, but left an upland surface in most of Montgomery county that rose from a large basin in southwestern Montgomery and the counties adjoining to the south and west. Only the lower Osage formations survived in the southern part of the county, but the Keokuk limestone floored the upland surface in the northeastern part of the county, where the surface in some places was more than 300 feet higher.

Meramec beds.—The Meramec rocks are represented in Montgomery county by the Cowley formation and the Warsaw limestone, which were deposited in the basin and upland areas that have just been described. The more-deeply dissected areas were first filled with silty and cherty gray or dark-gray or buff to almost black dolomite or dark dolomitic silty shale in some places more than 300 feet thick, which I have named the Cowley formation.[5] The chert is dark colored and much of it contains the silicified remains of great numbers of broken microfossils. The Cowley formation contains also considerable glauconite, particularly in a zone a few inches to 30 or more feet thick, which forms a transgressive deposit at the base of the formations. The Cowley was followed conformably by the Warsaw limestone, which overlapped unconformably upon the still-exposed upland surface north and east of Montgomery county. Except the glauconitic zone at the base of the Warsaw, there is little local indication, in the upland area, of the unconformity indicated by the stratigraphic relations in the deep basin to the southwest.

The Warsaw limestone consists of gray and white semigranular limestone and sucrose dolomite and includes some disseminated glauconite and much gray chert. The chert of the Warsaw closely resembles the microfossiliferous chert of the Cowley formation, except that it is gray and white instead of brown or dark. The Warsaw has a thickness of about 50 feet, but considerably greater thicknesses of limestone, representing higher Warsaw and other younger Meramec rocks and possibly also some Chester rocks, have been eroded from this area.

Deformation and erosion of Mississippian rocks.—In post-Mississippian time further deformation of preëxisting northwest-trending folds took place in eastern Kansas, notably in Chautauqua

5. Lee, Wallace, unpublished manuscript.

county adjoining Montgomery county on the west, but deformation is not now known at this time to have formed northwest-trending folds in Montgomery county. The known post-Mississippian folds affecting the rocks of this age in Montgomery county trend north or northeast, the directions of the principal folds of eastern Kansas. Erosion that accompanied the post-Mississippian folding reduced the region to a nearly featureless plain. The rocks that had been raised into anticlines above sea level were worn away so that anticlines are generally marked by thin sections of Mississippian rocks. On account of this beveling of the folded Mississippian strata, their thickness varies irregularly according to the structure, but no very pronounced variations of thickness occur in Montgomery county. The Mississippian limestones are thinnest in sec. 11, T. 33 S., R. 14 E., where they are only 229 feet thick. In several other localities beneath anticlines the Mississippian limestones are less than 250 feet thick. They locally exceed 300 feet in thickness, but the extreme variation in the county is less than 80 feet.

After the peneplanation of the Mississippian rocks in eastern Kansas, the Cherokee basin, on the western side of which Montgomery county lies, was formed. Although a part of the folding that produced the basin probably took place during and after the deposition of the Cherokee rocks, the basin was probably already in existence before the deposition of the earliest Pennsylvanian deposits. The upper part of the Mississippian limestone was deeply weathered during the exposure that preceded the deposition of the Pennsylvanian. The resulting porous limestone provides the reservoir for the accumulation of most of the oil produced from Mississippian limestones.

PENNSYLVANIAN ROCKS

By G. E. Abernathy

Cherokee shale.—The Cherokee shale includes all the beds between the Mississippian and Fort Scott limestones. Its thickness ranges from 304 to 495 feet in Montgomery county. Variation in thickness of the Cherokee shale is due in part to the irregular erosion surface of the Mississippian, which directly underlies it, and in part to erosion interrupting deposition of the Cherokee series. In the outcrop area of the Cherokee in Crawford and Cherokee counties there are erosional unconformities that have a relief of more than 50 feet within a distance of 0.5 mile. Variation in the thickness of the beds was also caused by a structural buckling occurring before and during the deposition of the Cherokee. In Montgomery county the Cherokee is composed of light-gray and dark-gray shale, sandy shale, black shale, a few lenses of sandstone, several thin beds of coal, and a few thin beds of limestone. The Ardmore limestone is very persistent in distribution, whereas a similar bed about 40 feet below the Ardmore occurs only locally.

The base of the Cherokee is characterized by a conglomerate, composed principally of chert and smaller amounts of limestone and pyrite. The Burgess sand, where present, directly overlies the conglomerate. A bed of black shale, which ranges from 40 to 90 feet in thickness, is commonly present in Montgomery county and lies upon the Burgess sand, or, if the sand is not present, directly upon the Mississippian limestone. The sand bodies in the lower part of the Cherokee, about 140 to 200 feet above its base, are designated Bartlesville sand. The sand bodies are not continuous over large areas, but are lenses that occupy the same general stratigraphic position. At some localities these lenses are more than 100 feet thick. The Bartlesville sand accumulated on the shores of the Cherokee sea during its advance along a trough that extended northeastward from Oklahoma through southeastern Kansas. The southeastern part of Montgomery county represents an area that lay within this trough; therefore, the Bartlesville sand is commonly present in this part of the county. Another sand occurs in the Cherokee directly under the Fort Scott limestone and is known to drillers as the "Squirrel sand".

The Ardmore limestone is a massive fossiliferous dark-gray limestone that ranges from 3 to 5 feet in thickness. It lies about 450 feet below the surface in the southeastern part of the county and about 1,200 feet below in the northwestern part. The Ardmore is widespread in distribution and usually lies about 30 to 70 feet below the Fort Scott limestone.

Fort Scott limestone.—In Montgomery county the Fort Scott limestone is composed of at least three limestone members (locally four or five) separated by black shale members. The thickness of the upper and middle limestone members ranges from 25 to 50 feet, but that of the lower or third member is somewhat less, ranging from 10 to 30 feet. The black shale beds that separate the limestone members range in thickness from 2 to 20 feet. The total thickness of the Fort Scott ranges from 75 to 100 feet in Montgomery county. The Fort Scott is called "Oswego" by many drillers and operators, and it is designated as the "Brown lime" by some drillers.

The upper limestone member, called the "First lime" by many drillers, is a very hard, dense member; the middle and lower members, called the "Second lime" and "Third lime", are not so hard and in most places are composed of impure limestone.

Labette shale.—The Labette shale includes the beds between the Fort Scott and Pawnee limestones. Its thickness averages 70 feet and ranges from about 40 to 100 feet. There is a thin bed of coal in the upper part of the shale in southeastern Montgomery county. A bed of sand occurs locally in the Labette shale and is called the "Peru sand" by drillers and operators.

Pawnee limestone. — The Pawnee limestone lies between the Labette and Bandera shales. Its thickness ranges from 22 to 50 feet. It is a dense, hard light-gray fossiliferous limestone. Locally the Pawnee limestone consists of two beds of limestone separated by a few feet of black slaty shale. It is locally designated by drillers as the "Pink lime" or "Forty-foot".

Bandera shale.—The Bandera shale includes the beds of shale, sandy shale, sand, and one or more thin beds of coal lying between the Pawnee limestone and the Altamont limestone. A bed of sand 20 to 50 feet thick occurs locally in the upper part of the formation, and is known as the Weiser sand. In Montgomery county the thickness of the Bandera shale ranges from 60 to 150 feet.

Altamont limestone.—The Altamont limestone lies between the Bandera and Nowata shales. Over most of Montgomery county it consists of two beds of gray massive limestone separated by a bed of black shale. The total thickness of the Altamont beds ranges from 25 to 50 feet, and that of the black shale member from 5 to 15 feet. The Altamont is locally called the "Weiser lime" or "Weiser cap". Locally it occurs as one bed of massive limestone, ranging in thickness from 15 to 40 feet.

Nowata shale.—The Nowata shale lies between the Altamont and Lenapah limestones. It consists of beds of gray or yellowish shale, sandy shale, and sand. It ranges in thickness from 25 to 80 feet. Sandstone beds in the upper part of the Nowata shale are locally known as the "Wayside sand".

Lenapah limestone.—The Lenapah limestone overlies the Nowata shale and is overlain by the Memorial shale. It is a hard, massive light-gray limestone, and has a minimum thickness of about 7 feet in the southeastern part of the county and a maximum thickness of about 30 feet in the northern part.

Memorial-Coffeyville shale.—The Memorial shale includes an undetermined thickness of beds between the Lenapah limestone and a disconformity at the base of the Missouri series (Moore, 1936, pp. 67-69). The beds between the disconformity and the Dennis limestone belong to the Coffeyville shale. Because the lower boundary of the Coffeyville cannot be identified from well logs, the Memorial and Coffeyville shales are undifferentiated in most subsurface study. This zone comprises the beds of shale, sandy shale, and sandstone that lie between the Lenapah limestone and the Dennis limestone. In Montgomery county they range in thickness from 140 to 220 feet.

Dennis limestone.—The Dennis limestone lies between the Coffeyville formation and the Cherryvale shale. In Montgomery county the Dennis limestone is represented by one of its three limestone members, the Winterset. It ranges in thickness from 5 to 70 feet.

Cherryvale shale.—The beds between the Dennis limestone and the Drum limestone are called the Cherryvale shale. They consist of beds of blue shale and a few thin lenses of limestone. The thickness ranges from 10 to 90 feet.

Drum limestone.—The Drum limestone lies between the Cherryvale shale and the Chanute shale. It consists of two members, a lower light-gray fine-grained limestone 5 to 25 feet thick and an upper cross-bedded oölitic limestone that ranges in thickness from a few feet to more than 60 feet. Locally the Drum limestone is absent, owing to erosion.

Chanute shale.—The Chanute shale is composed of yellowish-brown sandy shale, dark-gray shale, thin-bedded sandstone, and at least one coal bed, which lie between the Drum limestone and the Iola limestone. The Thayer coal bed, in the upper part of the shale, ranges in thickness from a few inches to 2 feet or more and has been mined near Independence. The thickness of the Chanute shale in Montgomery county ranges from 10 to 100 feet.

Iola limestone.—The Iola limestone lies between the Chanute shale and the Lane-Vilas shale. It is a bluish-gray or yellowish thin-bedded limestone. In Montgomery county its thickness ranges from a featheredge to about 5 feet, but it is locally absent.

Lane-Vilas shale.—The beds of shale, sandy shale, and sand between the Iola limestone and the Stanton limestone are designated as Lane-Vilas shale. They are variable in lithologic character, but contain thick beds of sandstone in Montgomery county. The thickness of the Lane-Vilas shale ranges from 70 to 100 feet.

Stanton limestone.—The Stanton limestone is also variable in thickness and in lithologic character in Montgomery county, but is very persistent in its outcrop area. It ranges in thickness from 10 to 100 feet or more.

ECONOMIC GEOLOGY

The important mineral resources of Montgomery county are oil, gas, Portland cement, and clay.

OIL AND GAS

History of development.—Montgomery county was one of the first counties in Kansas to produce oil and gas in large quantities. Gas was found in small quantities at several places in Montgomery county as early as 1881. Gas was found in moderate quantities near Cherryvale in 1889 and about a year later at Coffeyville. Gas was piped to the city of Coffeyville in 1892; that city was the first town in southeastern Kansas to use natural gas. The largest gas field in the county reached its peak of production in 1904, at which time it had an open-flow capacity exceeding 700,000,000 cubic feet. Gas wells having an initial production of 10,000,000 to 20,000,000 cubic feet have not been uncommon, and the largest well, one reported by the Union Gas Company, had an initial production of 93,000,000 cubic feet.

Montgomery county first produced oil in 1903, the Bolton pool southwest of Independence being discovered in that year. The initial production of the wells in this pool ranged from 10 to 1,000 barrels per day. The pool is still producing some oil. Oil production in Montgomery county reached its peak of 1,136,654 barrels in 1925. Since that year there has been a gradual decline until 1938, when the production was 332,150 barrels.

Producing formations.—The formations producing oil and gas in Montgomery county include the Arbuckle limestone of Ordovician age, the Mississippian limestone of Lower Carboniferous age, and sands in the Cherokee shale, Fort Scott limestone, Labette shale, Bandera shale, and sands in the Lane-Vilas shales, all of Pennsylvanian (Upper Carboniferous) age.

The Arbuckle produces oil from a siliceous limestone zone near its upper surface. The formation is called "Siliceous lime" by drillers. Seven pools produce oil and one field produces gas from the Arbuckle in Montgomery county. The Arbuckle production is obtained from pools found on small but well-defined anticlinal folds; however, not all anticlinal folds that have been drilled have been productive. The Arbuckle has been penetrated by 221 holes in Montgomery county. Many of the wells had a showing of oil or gas, and perhaps many of them were not located upon anticlinal folds, but 86 have produced oil in commercial quantities and 6 have produced gas.

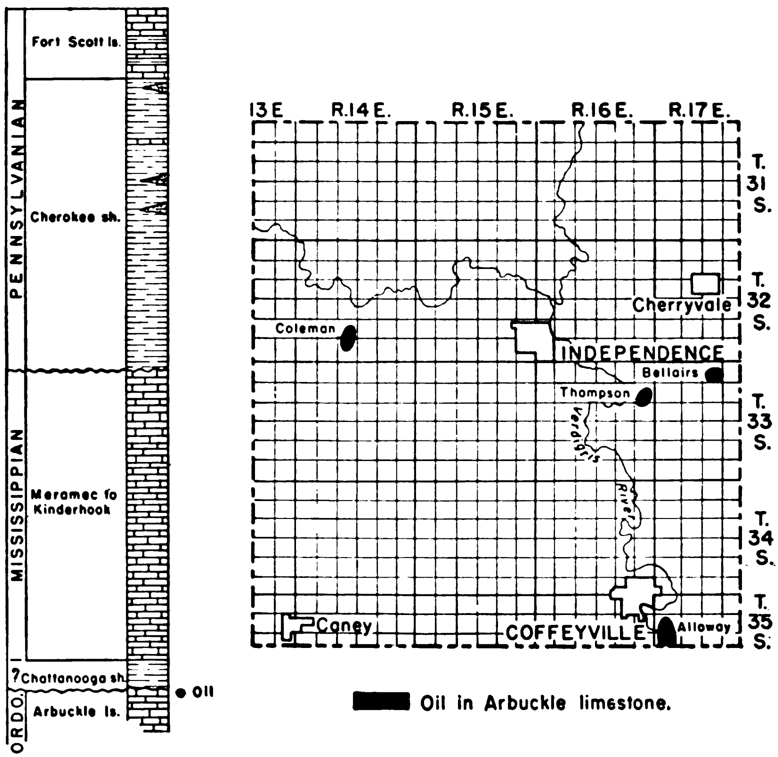

FIG. 3. Pool map of Arbuckle production.

The upper part of the Mississippian limestone contains porous beds that in places produce large amounts of gas. Another producing zone occurs in the "chat conglomerate" that lies at the contact of the Mississippian with the overlying Cherokee shale. This zone is composed principally of fragments of loosely cemented chert and is restricted in its distribution to the flanks of "Mississippi lime" hills. The Mississippian has been tested in Montgomery county by 358 holes, inclusive of those drilled to the Arbuckle. Of the total number drilled, 278 were dry holes, 103 produced gas, and 5 produced oil. The production of oil and gas from the Mississippian is controlled principally by structural folds. Many of the holes drilled to the Mississippian limestone were located without regard to structure. They were intended to be drilled only to the shallow producing sands, but when the upper zones were found to be dry the wells were deepened to the top of the Mississippian limestone.

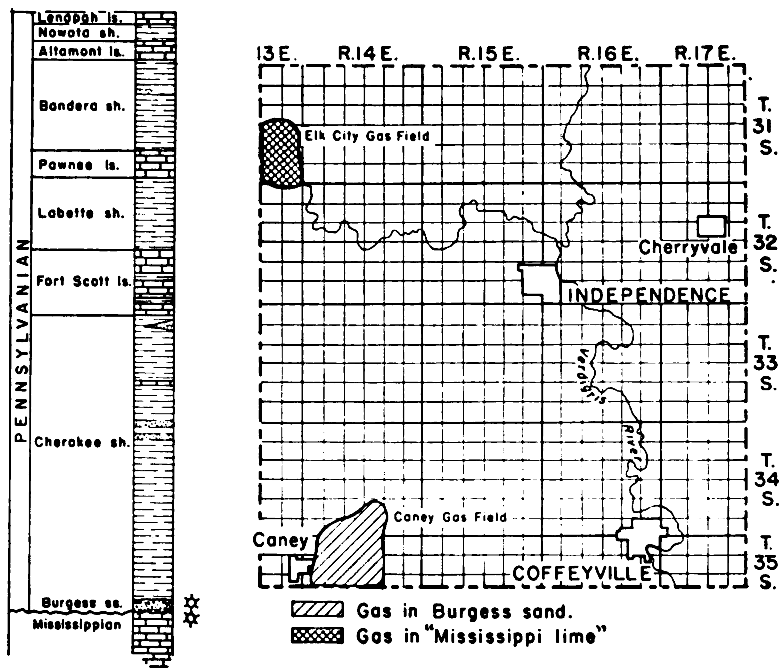

FIG. 4. Pool map of Mississippian production.

The Cherokee shale contains three important producing members. At or near the base of the Cherokee shale is the Burgess sand. This sand yields much gas. The Bartlesville sand occurs as lenses of sandstone, ranging from 10 to 100 feet in thickness. This sandstone is separated from the Mississippian limestone by 40 to 100 feet of shale. The Bartlesville sand produces both oil and gas in Montgomery county. The Squirrel sand occurs locally in the upper part of the Cherokee shale. It is separated from the Fort Scott limestone by 10 to 80 feet of shale. This sandstone produces small amounts of gas and some oil. Exclusive of those drilled deeper, 1,733 holes have been drilled into the Cherokee. Of these, 416 were dry holes, 901 produced gas, and 412 produced oil.

The Fort Scott limestone produces much gas from the beds of black shale ("shale-breaks") that separate the limestone members. No oil has been produced from this formation in Montgomery county. The Labette shale produces oil from a sandstone member known as the Peru sand. The thickness of the sand member ranges

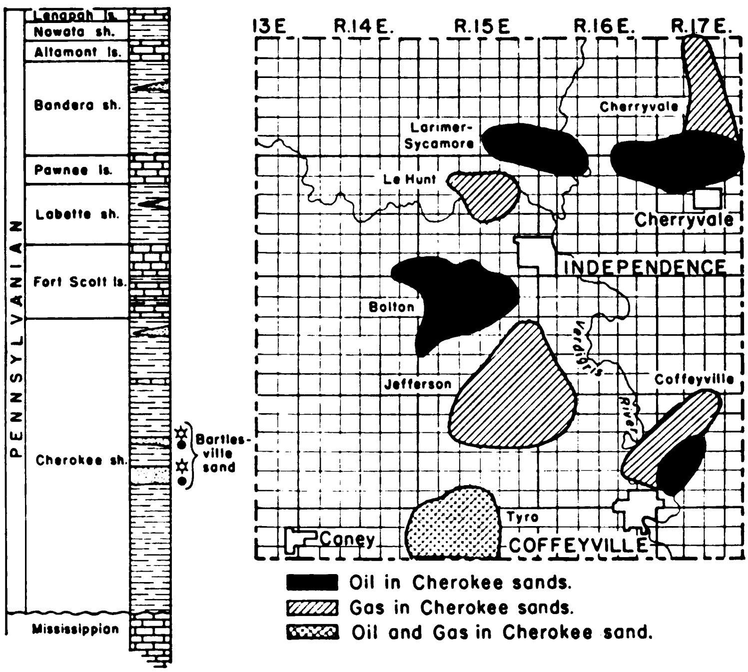

FIG. 5. Pool map of Cherokee production.

from 10 to 40 feet. In Montgomery county 239 holes have been drilled into the Labette shale and Fort Scott limestone, exclusive of those drilled deeper. Of the total number drilled, 55 were dry holes, 156 produced gas, and 28 produced oil.

The Bandera shale produces oil and gas from a sandstone member known as the Weiser sand, which ranges in thickness from 20 to 60 feet. The Nowata shale produces oil from the Wayside sandstone member, which ranges in thickness from 10 to 30 feet. The Lane-Vilas shale produces gas from at least three sandstone members in the northwestern part of Montgomery county. The upper sandstone is locally called "Bush-Denton" or "Ferguson", the middle member is called the "Longton", "Webb", or "Heck", and the lower sandstone is called the "Encill". In Montgomery county 293 holes have been drilled into the formations higher than the Pawnee limestone, exclusive of the holes drilled into formations below the Pawnee. Of the total number drilled, 63 have been dry holes, 70 have been gas wells, and 170 have been oil wells.

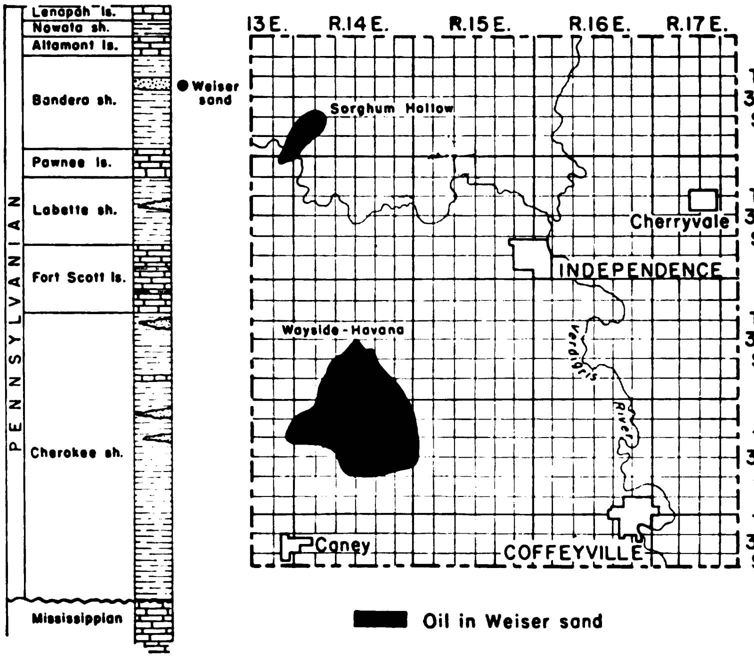

FIG. 6. Pool map of Weiser production.

The map shows the location of 7,707 holes drilled in Montgomery county (pl. 1). Holes have been drilled in 658 of the county's 788 sections; wells drilled in 471 sections have produced oil or gas, wells drilled in 265 sections did not produce oil or gas, and in only 52 sections in the county is there no record of holes having been drilled.

OIL POOLS

Bolton pool.—The Bolton oil pool was discovered in 1903 and was the first pool that produced oil in Montgomery county. The first oil well was drilled by McBride and Bloom in the SW¼ sec. 18, T. 33 S., R. 15 E. Oil sand was encountered at a depth of 1,180 feet, and at a depth of 1,195 feet the bit passed from sand into shale.

The initial production of this well was about 40 barrels per day (Haworth, 1908, p. 37). Initial production of many wells has exceeded 1,000 barrels. The pool is situated in secs. 4, 5, 6, 7, 8, 9, 16, 17, and 18, T. 33 S., R. 15 E. In this pool 450 oil wells have been drilled, and a small amount of oil is still being produced. The oil is obtained from the Bartlesville sand member of the Cherokee shale. The sandstone ranges in thickness from 10 to 30 feet and occurs at a depth of 1,150 or 1,200 feet below the surface and about 200 feet below the Fort Scott limestone.

Wayside-Havana pool.—This pool is situated in the southwestern part of Montgomery county. It represents the consolidation of two oil-producing areas in secs. 27, 28, 32, 33, and 34, T. 33 S., R. 14 E., and secs. 3, 4, 5, 6, 7, 8, 9, and 10, T. 34 S., R. 14 E. The pool was discovered in 1904 and is still producing a small amount of oil. More than 500 wells in this pool have produced oil. The oil is a high-grade paraffin-base oil having a specific gravity of 36 to 38 degrees A. P. I. (Moore and Boughton, 1920, p. 25). In this pool oil is obtained from at least three sandstone members. The Wayside sand, between the Lenapah and Altamont limestones, is the uppermost and occurs at an average depth of about 575 feet. The Weiser sand lies about 120 feet below the Wayside. The third zone is the Bartlesville sand, which lies at a depth averaging about 1,200 feet in this area. Its thickness ranges from 15 to 50 feet.

Tyro pool.—The Tyro pool is situated southeast of Tyro in secs. 3, 4, 5, 6, 7, 8, 9, and 15, T. 35 S., R. 15 E. The pool was discovered in 1904 and produces both oil and gas from the Bartlesville sand, which ranges in thickness from 20 to 60 feet. Its depth averages 1,250 feet.

Coffeyville pool.—The Coffeyville pool is situated in secs. 13, 24, 25, 26, 34, and 35, T. 34 S., R. 16 E., and secs. 17, 18, 19, 20, 30, and 31, T. 34 S., R. 17 E. It is the oldest field in the state and produces both oil and gas. The highest of the three producing zones is the Wayside sandstone, which lies at a depth of about 400 feet; the next lower is the Fort Scott limestone, at a depth of about 600 feet; and the lowest is the Bartlesville sand, at a depth of about 1,000 feet. The field never produced large quantities of oil or gas, but it still produces small amounts of both oil and gas.

Larimer-Sycamore pool.—The Larimer-Sycamore oil pool is situated in sec. 32, T. 31 S., R. 16 E., and sec. 5, T. 32 S., R. 16 E. About 45 wells produce oil from the Bartlesville sand, which ranges in thickness from 10 to 60 feet and lies at a depth of about 1,000 feet. The pool was discovered in 1920.

Cherryvale pool.—The Cherryvale pool is situated in secs. 5, 8, 9, 16, 21, 22, 27, 31, 32, 33, and 34, T. 31 S., R. 17 E. The pool was developed in 1904 and produces both oil and gas. The chief producing sand is the Bartlesville, which lies at a depth of about 800 feet. This field is now virtually exhausted.

Coleman pool.—The Coleman pool is situated in secs. 28 and 33, T. 32 S., R. 14 E. The discovery well was the Red Bank Oil Company No. 1 Coleman, completed on July 1, 1921. The initial production is reported to have been 4,100 barrels per day by natural flow. The oil is produced from the Arbuckle limestone (locally known as "Wilcox") at a depth of about 1,700 feet. The pool is still producing a small amount of oil.

Thompson pool.—The Thompson pool is situated in secs. 12 and 13, T. 33 S., R. 16 E. The discovery well was drilled in 1924 by Kors and Wilkinson on the Thompson farm. The oil has small gasoline content and zero cold test, and its gravity is about 28 degrees. The pool is still producing a small amount of oil.

Alloway pool.—The Alloway pool is situated in secs. 8 and 17, T. 35 S., R. 17 E. The pool was developed in 1924. More than 40 wells produced oil in this pool. The initial production ranged from 25 to 220 barrels per day. The oil is produced from the Arbuckle limestone at a depth of about 1,200 feet.

Bellairs pool.—The Bellairs pool is situated in secs. 3 and 4, T. 33 S., R. 17 E. The discovery well, Bellairs No. 1, was drilled in 1921. The producing formation is the Arbuckle limestone, and the depth is about 1,250 to 1,300 feet. Twenty-five wells have been drilled in this pool. During the early life of the pool, some of the wells flowed initially 220 barrels per day. Seven wells are still producing. The oil has very small gasoline content and 10-degree cold test, and its gravity is about 24 degrees. The oil is sold as Diesel fuel.

OIL PRODUCTION

Production statistics of petroleum in Montgomery county follow:[6]

Annual Production of Oil in Montgomery County

Year	Barrels	Year	Barrels
1921	293,444	1931	312,174
1922	257,425	1932	424,200
1923	58,351	1933	412,123
1924	347,601	1934	333,656
1925	256,116	1935	279,902
1926	721,252	1936	(not available)
1927	578,654	1937	(not available)
1928	537,648	1938	332,150
1929	544,625	1939	355,250
1930	488,014		

Oil production by districts in Montgomery county during 1938 is shown in the following table:

Montgomery County Oil Production in 1938, by Districts

District	Barrels
Bolton	73,000
Larimer-Sycamore, Cherryvale	21,900
Wayside-Havana	73,000
Independence, Coleman	73,000
Coffeyville, Jefferson Alloway, Tyro	73,000
Thompson, Bellairs	18,250
Total	332,150

GAS FIELDS

During the early history of the industry gas was produced from well-defined fields, such as the Elk City, Independence, Jefferson, Cherryvale, and Coffeyville fields. At the present time gas is produced in Montgomery county from wells that are widely distributed over the county. Development has been so widespread that any one field is almost continuous with the other fields.

In Montgomery county gas is produced principally from the Bartlesville sand member of the Cherokee shale; however, gas is produced from the "Bush-Denton", "Ferguson", "Longton", "Webb", and "Heck" sandstones within the Lane-Vilas shale. A small amount of gas is produced from the Weiser sand of the Bandera shale, from the Fort Scott limestone, from the Burgess sandstone at the base of the Cherokee, and from a chat and porous zone at the top of the Mississippian limestone. The lowest gas-producing formation is the Arbuckle limestone of the Ordovician.

6. Production data from 1921 to 1935 from *Oil and Gas Journal*.

Gas production in Montgomery county in 1938.—The estimated gas production in Montgomery county in 1938 was 1,271,746,000 cubic feet.

REFINERIES

Two oil refineries are operating in Montgomery county. The National Refining Company refinery at Coffeyville has a capacity of 6,000 barrels per day. The Sinclair-Prairie Oil Company refinery at Coffeyville has a capacity of 10,000 barrels per day.

OIL-FIELD EQUIPMENT

Several oil-field-equipment manufacturing companies and foundries are located in Coffeyville. This industry produced 14,625 tons of finished products in 1938 and employed 670 men.

CEMENT

Only one cement plant has been built in Montgomery county. The Universal Atlas Cement Company manufactures portland cement at Independence. The plant has a capacity of 2,500 barrels per day. Its total production was about 550,000 barrels in 1938, and about 610,000 barrels in 1939.

GAS AND OIL PIPE LINES

Oil and gas pipe lines in Montgomery county are shown on the map (pl. 1). The county has more than 250 miles of oil pipe line and about 200 miles of gas pipe line. About one-half of the oil pipe lines are gathering lines from oil pools in the county; the rest are trunk lines transporting oil across the county. About one-half of the gas pipe lines are gathering lines from gas wells within the county and pipe lines of supplying gas to cities and towns within the county; the rest of the gas lines are trunk lines for transporting gas through the county to other markets.

EXPLANATION OF MAP

The map, plate 1, gives the location of every well drilled in Montgomery county for which any record whatever could be obtained. The symbols designate the status of the well, whether it is now producing, has produced and is now abandoned, or was a dry hole; and, if a dry hole, if it had a show of oil or gas while being drilled.

Wells shown by black symbols are those for which no logs could be obtained; logs of wells shown in color are on file in the offices of the State Geoogical Survey. The color of the symbol designates the stratigraphic depth of the well, *i. e.*, wells shown in blue did not go deep enough to reach the base of the Pawnee limestone; wells shown in olive green went only deep enough to reach the base of the Fort Scott limestone; those shown in brown ended in the Cherokee shale; orange symbols designate Mississippian wells, and the wells shown in red penetrated the Arbuckle.

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