STATE GEOLOGICAL SURVEY OF KANSAS

RAYMOND C. MOORE, Ph.D., Sc.D.,
State Geologist and Director
(Absent on leave for military service, U. S. Army)

JOHN C. FRYE, Ph.D.,
Assistant State Geologist and Assistant Director, in charge

BULLETIN 57

OIL AND GAS IN EASTERN KANSAS

BY JOHN MARK JEWETT AND GEORGE E. ABERNATHY

Printed by Authority of the State of Kansas
Distributed from Lawrence

PRINTED BY UNIVERSITY OF KANSAS PRESS
LAWRENCE, 1945

UNIVERSITY OF KANSAS PUBLICATIONS
JULY, 1945

STATE OF KANSAS

ANDREW F. SCHOEPPEL, *Governor*

STATE BOARD OF REGENTS

LESTER McCOY, *Chairman*

JERRY E. DRISCOLL
FRED M. HARRIS
MRS. ELIZABETH HAUGHEY
WILLIS N. KELLY
DREW McLAUGHLIN
GROVER POOLE
LA VERNE B. SPAKE
OSCAR STAUFFER

MINERAL INDUSTRIES COUNCIL

JOHN ALLISON, *Chairman*
M. L. BREIDENTHAL
HOWARD CAREY
ANTHONY FOLGER
LESTER McCOY
J. E. MISSIMER
BRIAN O'BRIAN, *Vice-Chairman*
J. A. SCHOWALTER
CHESTER SCOTT
K. A. SPENCER
W. L. STRYKER
B. O. WEAVER

STATE GEOLOGICAL SURVEY OF KANSAS

DEANE W. MALOTT, M.B.A., LL.D., Chancellor of the University of Kansas, and ex officio Director of the Survey.

RAYMOND C. MOORE, Ph.D., Sc.D., Director and State Geologist†
JOHN C. FRYE, Ph.D., Asst. Director and Asst. State Geologist, in charge
EDITH HICKS LEWIS, Secretary

STRATIGRAPHY, PALEONTOLOGY, AND AREAL GEOLOGY:
Raymond C. Moore, Ph.D., Sc.D., Geologist†
John M. Jewett, Ph.D., Geologist
Walter H. Schoewe, Ph.D., Geologist
Arthur L. Bowsher, B.S., Geologist†

SUBSURFACE GEOLOGY:
M. L. Thompson, Ph.D., Geologist
Philip Kaiser, A.B., Geologist
Ethelyn B. McDonald, M.A., Well Sample Curator, Wichita Branch
June M. Kramer, Stenographer
Arden D. Brown, Assistant
Carrie Thurber, Assistant

MINERAL RESOURCES:
George E. Abernathy, E.M., Ph.D., Geologist
Robert M. Dreyer, Ph.D., Geologist†
Walter A. Ver Wiebe, Ph.D., Geologist
Norman Plummer, A.B., Ceramist
Ada Swineford, M.S., Geologist
John I. Moore, M.S., Petroleum Engr.†
Frances L. Schloesser, Assistant Chemist
W. P. Ames, A.B., Laboratory Assistant
Ethel Owen, Assistant

PUBLICATIONS AND RECORDS:
Donald E. Dowers, Draftsman†
Eileen Martin, B.M., Draftsman
Robyn Ashby, Draftsman
Betty J. Hagerman, Bookkeeper

COOPERATIVE PROJECTS WITH UNITED STATES GEOLOGICAL SURVEY

GROUND-WATER RESOURCES:
Stanley W. Lohman, M.S., Geologist in charge
John C. Frye, Ph.D., Geologist
Thad G. McLaughlin, Ph.D., Geologist
Bruce Latta, A.B., Geologist
Charles C. Williams, M.A., Geologist
V. C. Fishel, B.S., Physicist
James B. Cooper, A.B., Well Driller†
Oscar S. Fent, B.S., Well Driller
Charles K. Bayne, A.B., Instrumentman
Jean W. Asher, Stenographer
W. W. Wilson, Well Observer†

MINERAL FUELS RESOURCES:
Wallace Lee, E.M., Geologist in charge
Constance Leatherock, B.S., Geologist
Theodore Botinelly, B.S., Geologist

TOPOGRAPHIC SURVEYS:
C. L. Sadler, Division Engineer
Max J. Gleissner, Section Chief
J. P. Rydeen, Topographer

SPECIAL CONSULTANTS: Ray Q. Brewster, Ph.D., Chemistry; Claude W. Hibbard, Ph.D., Vertebrate Paleontology; Eugene A. Stephenson, Ph.D., Petroleum Engineering.

COOPERATING STATE AGENCIES: *State Board of Agriculture, Division of Water Resources*, George S. Knapp, Chief Engineer; Robert Smrha, Assistant Chief Engineer; *State Board of Health, Division of Sanitation*, Paul D. Haney, Chief Engineer and Director; Ogden S. Jones, Geologist.

† Absent on leave for military service.

CONTENTS

ILLUSTRATIONS

TABLES

FOREWORD

This report, Oil and Gas in Eastern Kansas, constitutes a summary of the results of past work and a preface to important future work on the occurrence and development of oil and gas deposits in eastern Kansas. The history of petroleum developments in this area covers a span of 85 years. It has passed from an era of relatively easy discovery of shallow pools to one of more difficult prospecting for deposits in older and more obscured rocks, and of varied techniques for extracting oil from reservoirs that were only partly exhausted during the earlier period of flush production. Significant quantities of oil will undoubtedly be produced from eastern Kansas rocks for many years to come.

The State Geological Survey has for many years been carrying on investigations of the geology of the oil and gas producing rocks of the state. Much of this work has been in eastern Kansas, and the resulting reports are shown in the list of Survey publications. During recent years annual reviews of oil and gas developments and production in western Kansas have been published by the Survey. This report constitutes a comparable review for eastern Kansas and includes also a summary of the geology of the oil and gas producing rocks. It is planned that subsequent reports of a similar nature will be issued periodically and thus furnish basic data to the industries and residents of the region.

JOHN C. FRYE.

OIL AND GAS IN EASTERN KANSAS

By John Mark Jewett and George E. Abernathy

ABSTRACT

Eastern Kansas, as the term is used in this report, includes 43 counties that comprise the east ranges of land division in the state. Oil and gas were discovered in eastern Kansas in 1860. The year 1904 was the first during which more than 1,000,000 barrels of oil were produced in the area; peak oil production, amounting to more than 45½ million barrels, was in 1918. During the last few years water flooding has brought about an increase of oil production in several counties. Now 27 counties in eastern Kansas produce oil and 26 counties produce gas. In 1943, 16,259,083 barrels of oil and 12,211,735 thousands of cubic feet of gas were produced in these counties.

The exposed consolidated rocks in eastern Kansas are Cretaceous, Permian, Pennsylvanian, and Mississippian in age. In general these rocks dip gently to the west. Subsurface geologic conditions are complex because of the presence of several structural elements, of which the Nemaha anticline is the most prominent. These conditions are shown diagrammatically in four cross sections.

In this report each county is treated separately. Surface and subsurface geology is described briefly and oil and gas developments are discussed. Tables showing monthly oil production in 1941 and the years that follow and yearly gas production during the period from 1939 to 1943 are included.

INTRODUCTION

Purpose and scope of the report.—This report contains results of studies on oil and gas occurrence and development in Kansas counties that lie east of the north-south line known as the sixth principal meridian, the line of separation between east and west ranges as used in land division in Kansas. The location of these counties is shown in figure 1.

For several years the State Geological Survey of Kansas has published reviews of oil and gas developments in the state. The first report in this series was prepared by L. W. Kesler and was published in 1928 as Mineral Resources Circular 1. The second was written by Anthony Folger and Roy H. Hall and was issued in 1933 as Mineral Resources Circular 2. Edward A. Koester (1934) is the author of the third of the series, Mineral Resources Circular 3. These three reports reviewed the oil and gas developments in all of Kansas. Since 1938, Walter A. Ver Wiebe has prepared annual data for Survey publications on oil and gas de-

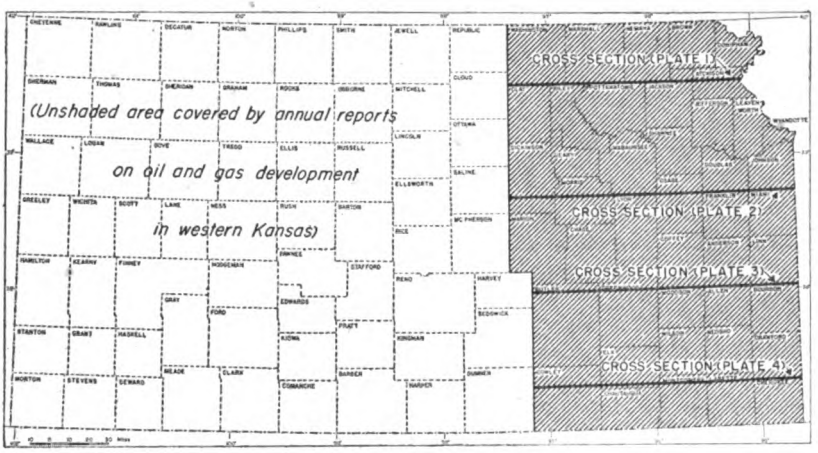

FIG. 1. Index map of Kansas showing location of "eastern Kansas."

velopments in western Kansas counties. Ver Wiebe's latest report (1944a) was published as Bulletin 54.

The Geological Survey is issuing also a series of reports on oil and gas in individual counties. Such reports have been published for Labette county (Abernathy, 1939), Linn county (Jewett, 1940a), and Montgomery county (Abernathy, 1940). These county oil and gas reports show principally the geographic and stratigraphic extent of drilling. Other reports of this series are in preparation.

In 1935 the State Geological Survey published Bulletin 20, Subsurface studies in northeastern Kansas (Ockerman, 1935), which contains results of studies of logs and samples from wells and information on oil and gas possibilities in Atchison, Brown, Doniphan, Douglas, Jackson, Jefferson, Johnson, Leavenworth, Shawnee, Wabaunsee, and Wyandotte counties. Bulletin 38, part 10, by Wallace Lee (1941), is a preliminary report on the McLouth oil and gas field, Jefferson and Leavenworth counties. A more extensive report on the same area is contained in Bulletin 53, McLouth gas and oil field, Jefferson and Leavenworth counties, by Wallace Lee and Thomas G. Payne (1944). Bulletin 51, Stratigraphy and structural development of the Forest City basin in Kansas, by Wallace Lee, was published in 1943. These and other publications that contain discussions of subsurface geology and oil and gas in individual eastern Kansas areas are listed at

the end of this report. Special attention is called to a recent publication of the United States Bureau of Mines, History of water flooding of oil sands in Kansas (Grandone, 1944).

This report is intended to bring up to date the review of oil and gas developments in eastern Kansas. The brief discussions of stratigraphy and structure should aid in acquainting the reader with general geologic conditions.

Oil and gas are important mineral resources in eastern Kansas. Methods of secondary recovery, chiefly water flooding, are increasing the yields in many fields. A few new oil and gas fields are being developed each year. In addition to oil and gas in eastern Kansas, there are the lead and zinc deposits of the Tri-State district, practically all of the state's minable coal beds, raw materials for cement manufacture, gypsum deposits, large supplies of ceramic raw materials, virtually unlimited supplies of limestone, sand, and gravel, and fairly large reserves of asphalt rock. The Geological Survey is making chemical analyses of limestones, shales, and other Kansas rocks. Chemical analyses of Kansas oil-field brines, including brines from several eastern Kansas fields, were recently published as State Geological Survey Bulletin 47, part 2 (Schoewe, 1943). Attention is called also to Bulletin 41, part 3, Kansas mineral resources for wartime industries (Jewett and Schoewe, 1942), and to the map showing the mineral resources of Kansas (Moore and Frye, 1942).

Acknowledgments.—Thanks are expressed to the large number of oil and gas operators and drillers who for many years have voluntarily cooperated with the State Geological Survey. As a result of this aid, logs of a large percentage of the wells that have been drilled in Kansas and drill cuttings and cores from many wells are in the Survey files. We have had access to the records of oil and gas runs in the files of the Conservation Division of the Kansas State Corporation Commission. The valuable cooperation of T. A. Morgan and J. P. Roberts of that organization is acknowledged. Special thanks are also expressed to C. W. Studt, who supplied information on gas production, and to the Sinclair Prairie Pipe-Line Company, who furnished figures on oil runs.

The discussion of eastern Kansas geology was compiled from published and unpublished data. Contributions to the knowledge of the stratigraphy and structure of eastern Kansas have been made by many geologists, chief among whom is Raymond C. Moore.

John C. Frye has read and criticized the report, Edith H. Lewis and Betty H. Hagerman prepared the manuscript for the printer, and Eileen Martin supervised the drafting of the illustrations. Most of the information pertaining to rocks older than Pennsylvanian is based on data furnished by Wallace Lee.

OIL AND GAS DEVELOPMENTS

In 1860, the year following the discovery of oil in northwestern Pennsylvania, oil was discovered near Paola in Miami county, Kansas. It is believed that the first well drilled for the purpose of obtaining oil in Kansas was a 4-inch hole drilled near Paola during June, 1860, to a depth of 100 feet. A second 100-foot well was put down on Wea creek about 8 miles to the south. The third well drilled in 1860 is reported to have discovered oil. It was known as the David Lykins well, in the SW¼ sec. 15, T. 17 S., R. 23 E., and was bored to a depth of 275 feet. According to Haworth (1908, p. 25), "it was supposed that it would yield one barrel of oil per day." The advent of the Civil War halted oil-drilling activities in Miami county and near-by areas. However, several wells that yielded small amounts of both oil and gas were put down near Mound City in Linn county soon after the first drilling near Paola. During the 1860's gas and probably some oil were found in Wyandotte county within the present city limits of Kansas City, and it is recorded that prospecting was done in Bourbon, Shawnee, and Cherokee counties.

In 1873, a diamond-drill hole 737 feet deep was put down at Iola in Allen county. Gas from this well was used to light a sanatorium in which salt water from the same well was used. In 1884, Paola was supplied with gas piped from a newly opened field about 7 miles east of town, and an area nearly surrounding the town was being drilled. The heavy dark oil that was produced was sold as lubricating oil at a price ranging from $3.00 to $5.00 a barrel. In 1886 or soon afterward a small refinery was erected at Paola, and it is reported that in 1889 the Paola oil field yielded 500 barrels of oil. At about the same time gas produced in the vicinity of Fort Scott was utilized in that city. Gas was discovered in the vicinity of Independence, Montgomery county, as early as 1881, and in 1884 both oil and gas were found in a coal prospect hole at Independence. Development did not follow

immediately. Wells drilled in Kansas City during this period produced gas for 20 years.

In the last decade of the last century and the first decade of the present century the oil and gas industry developed rapidly in eastern Kansas. An oil well near Neodesha in Wilson county was the first well "shot" in Kansas. The event took place on July 4, 1894, on the same day that natural gas piped into Neodesha from a near-by field was first ignited. Several oil wells were completed in the Neodesha field during that year, and the first oil conservation law in Kansas was enacted at about that time. The Iola gas field was opened in 1893 or early in 1894.

Gas development advanced rapidly in Montgomery county in 1892 and 1893. Gas was piped into Coffeyville in the fall of 1892 and into Independence and Cherryvale the following year. In 1894 or 1895 gas was piped into the village of Peru in Chautauqua county from a few near-by wells. In 1897 a number of gas wells were drilled in the area west of Humboldt in Allen county, and in August of the same year gas was piped into Humboldt.

Several oil wells were drilled in the Neosho river valley east of Chanute in 1899, and the operator of the Chanute field began shipping oil to Omaha and Kansas City in 1900. Many oil wells were drilled in the Neosho river valley in the vicinity of Chanute and Humboldt during the next three years. The Chanute district produced 165,000 barrels of oil in 1902, and it is reported that much more could have been marketed if there had been sufficient pipe lines. By 1903 Chanute had become an important oil and gas center and oil and gas fields extended in various directions for several miles. Gas was piped into Erie in Neosho county in 1903. In that year a local company reported that they had drilled 35 wells, of which 14 were gas wells, 7 were oil wells, and 14 were dry holes. Oil was discovered near Bolton in Montgomery county in 1903 and within two years this field, containing some wells that flowed at the rate of 1,000 barrels of oil a day, became the most important oil district in the state (Haworth, 1908, p. 37). There were about 200 wells in the field in 1905, but the larger producers had declined to about 40 barrels of oil per day. At the end of 1903 there were 151 producing oil wells in the Peru field in Chautauqua county. Kansas oil production in 1904 exceeded 4 million barrels.

By 1910, 50 years after the discovery of oil in the Mid-Continent region at Paola, wells had been drilled in the majority of eastern Kansas counties and many shallow oil and gas fields had been developed. The oil and gas territory extended from Miami county on the north to the Oklahoma line in Montgomery and Chautauqua counties. Gas had been discovered farther west in eastern Kansas at Longton, Elk Falls, Moline, Dexter, Winfield, Arkansas City, Augusta, and Elmdale in the first few years after 1900. There were oil refineries in Coffeyville, Neodesha, Chanute, and several other places, and many miles of pipe lines for both oil and gas had been laid. Many towns and cities were using natural gas, and the abundance of cheap gas had led to the establishment of numerous industries in southeastern Kansas. Gas was being used in cement plants, brick and tile plants, zinc and lead smelters, glass factories, and other industries.

During the first half century of Kansas oil and gas development, production was largely from rocks of Pennsylvanian age. Permian rocks, however, yielded significant quantities of gas in fields near Elmdale in Chase county; Dexter, Winfield, and Arkansas City in Cowley county; and Augusta in Butler county. The occurrence of oil seeps in Miami and northern Linn counties attracted early prospecting for oil in the vicinity of Paola. After discoveries near these seeps, test holes were put down in nearly every county; and in the early part of the 20th century the eastern Kansas oil and gas territory, except the Nemaha anticline area, was more or less completely outlined. The first important application of structural geology to oil and gas finding in Kansas was probably that of Erasmus Haworth, J. W. Beede, and John Bennett, who worked in the early part of the present century. The relationships of oil and gas occurrence to lenticular sand bodies and to anticlinal structures were explained by Haworth (1908, pp. 161-179). After the finding of large amounts of oil and gas in anticlines and domes in the Nemaha anticline area in Butler county in 1914 and 1915, surface structure mapping led to the drilling of many wells.

The discovery of oil and gas in the El Dorado and Augusta fields in 1914 marked the beginning of large-scale oil and gas production in Kansas. Henceforth production of oil was measured in tens of millions of barrels, and gas production in tens of billions of cubic feet. The discovery of oil and gas in condemned pre-

Pennsylvanian rocks and the acquisition of evidence demanding drastic revision of the earlier ideas of subsurface structure in eastern Kansas make the opening of the El Dorado field an important event. Its effect on Kansas oil production is shown by the increase in oil production during the period from 1915 to 1918. In 1915 oil output in Kansas was 2,823,487 barrels; in 1916 it was 8,783,077 barrels; in 1917 it was 36,536,125 barrels; and in 1918 it reached 45,451,017 barrels.

The discovery well in the El Dorado field is the Wichita Natural Gas Company No. 1 Stapleton, in the NE¼ SE¼ sec. 29, T. 25 S., R. 5 E. Commercial production estimated at 50 to 200 barrels per day was found in sandstone between 660 and 678 feet. The discovery well was later deepened and the "Stapleton pay zone" was found at 2,465 feet. About 600 wells were producing in the El Dorado field at the end of 1916; most of them produced from the 660-foot sand. That year the daily output of the field was estimated at more than 12,000 barrels of oil (Fath, 1921, p. 21). During 1917 the productive limits of the field were fairly well outlined and in September the daily production exceeded 100,000 barrels of oil. During 1917 and 1918, 309 "Stapleton" gushers having initial daily capacities of more than 500 barrels were brought in; 205 of these had initial daily capacities of more than 1,000 barrels, and 5 had initial daily capacities of more than 15,000 barrels. The Gypsy Oil Company No. 5 Shumway well, in the SW¼ NW¼ sec. 11, T. 26 S., R. 4 E., flowed at the rate of 19,000 barrels per day; the Empire Gas and Fuel Company No. 3 Shriver well, in the NW¼ sec. 14, T. 26 S., R. 4 E., was reported to have flowed at the rate of 23,000 barrels of oil per day (Fath, 1921, p. 23). In the El Dorado field large quantities of gas were found in five "sands" in Shawnee and Douglas rocks on the higher parts of the domes.

Soon after the El Dorado oil and gas fields were opened, important "Bartlesville sand" shoestring pools were found in areas not far east of the Nemaha trend. The Smock-Sluss, Weaver, and Fox-Bush pools of Butler county and the Sallyards pool of Greenwood county were discovered in 1917 (Bass, 1936, p. 60). Many oil and gas pools were found in eastern Kansas in the 1920's. Mississippian, Viola, "Wilcox" (St. Peter), and Arbuckle production became established, and the importance of subsurface geologic studies became evident.

Acidizing of limestone reservoir rocks was practiced and greatly increased production in areas of limestone production in eastern Kansas, especially in the late 1920's and early 1930's. Repressuring by air and application of vacuum were widely employed as means of increasing oil recovery.

Water flooding of oil sands is now being widely practiced in eastern Kansas. This means of supplying energy to move oil into wells is reported to have been first practiced in organized projects in Kansas in 1935 (Grandone, 1944, p. 1), but small water-flooding projects were operated in Miami, Chautauqua, Montgomery, and perhaps other counties in eastern Kansas long before that time. Water-flooding projects were started in Greenwood, Chautauqua, and Linn counties in 1935; by November, 1942, 52 water-flooding projects had been initiated and the list of counties extended to include Allen, Anderson, Bourbon, Crawford, Elk, Franklin, Miami, Montgomery, Neosho, and Wilson. These projects covered 2,612 acres from which a total of 4,209,634 barrels of oil was recovered as the result of injecting 40,654,726 barrels of water (Grandone, 1944, p. 2). Only three of the 52 projects begun between 1935 and 1942 had been abandoned. Several new projects have been established since 1942. Numerous Pennsylvanian sandstones ranging in depth from about 250 feet or less, as in Crawford and Miami counties, to about 2,000 feet in Greenwood county have been flooded; most of the oil recovered by this method is from depths of less than 1,000 feet.

The common method of water flooding in eastern Kansas conforms to the 5-spot pattern, in which a square pattern is formed having an oil-producing well at each corner and a water-input well in the center. Hence, developments consist of alternate rows of oil-producing wells and water-input wells. The distance between like wells is usually 330 feet, or one input well to each 2.5 acres (Grandone, 1944, p. 21). Sources of water for these projects include both surface and ground water. According to Grandone (1944, p. 24) in 1942 water from Arbuckle or Mississippian limestone was used in 23 projects in Kansas; water from streams was used in 9 projects; water from shallow fresh-water wells was used in 6 projects; water from sandstones (Pennsylvanian) was used in 5 projects; surface ponds supplied the water in 4 projects; municipal water supplies were used in 3 projects; and brine produced with oil from oil wells was injected in 2 proj-

ects. It is evident that water flooding is a very important means of secondary recovery of oil in eastern Kansas. It is expectable that more such projects will be established in these shallow fields as primary methods of oil recovery leave large amounts of oil in the reservoirs.

Within the last year, a shaft was driven to a shallow sandstone in southeastern Linn county for the purpose of drilling horizontal holes radiating from the shaft into oil-bearing sandstone. The project is not yet completed.

Statistics concerning the total number of barrels of oil and the total number of thousands of cubic feet of gas that have been produced in eastern Kansas are not available. Until 1923 when oil was discovered in Russell county in western Kansas, the entire output of oil in Kansas came from eastern ranges (Kesler, 1928, p. 9). In 1889 oil production in eastern Kansas (Paola field) amounted to about 500 barrels. In 1896 oil production was 113,571 barrels; it declined steadily for four years and in 1890 the production was 69,700 barrels. A high of 4,250,779 barrels was reached in 1904. This amount was not exceeded until 1916, when the annual production was 8,738,077 barrels (Moore and Haynes, 1917, p. 198). Peak oil production in eastern Kansas was in 1918, when 45,451,017 barrels of oil was produced. Since that time production has generally declined. Table 1 shows the amount of oil produced in various eastern Kansas counties in 1941, 1942, and 1943. Table 2 shows the amount of gas produced in eastern Kansas counties in 1939, 1940, 1941, 1942, and 1943.

GEOLOGY OF EASTERN KANSAS

Stratigraphy

For the purpose of this report the rocks of eastern Kansas can be conveniently placed in seven units. Although these units contain in several instances rocks assigned to more than one system, they are characterized by uniformity of structural attitude and similarity of lithology. Four of these units crop out at the surface. They are Quaternary-Tertiary, Cretaceous, Permian-Pennsylvanian, and Mississippian. The other three units, which in Kansas are known only through information obtained by deep drilling, are Devonian-Silurian, Ordovician-Cambrian, and pre-Cambrian.

TABLE 1.—*Oil production in eastern Kansas counties, in barrels*

County	1941	1942	1943
Allen	312,900	284,088	379,240
Anderson	336,304	501,768	486,603
Bourbon	3,897	6,912	45,354
Butler	5,304,450	4,864,103	4,540,224
Chase	——— [1]	——— [1]	——— [1]
Chautauqua	952,916	959,751	926,320
Coffey	20,956 [2]	19,968 [2]	17,912 [2]
Cowley	2,816,706	2,865,982	2,738,228
Crawford	36,309	26,942	26,207
Dickinson	——— [3]	——— [3]	3,047 [4]
Douglas	7,020	5,760	3,054
Elk	367,889	213,592	226,607
Franklin	85,319	159,400	142,745
Greenwood	3,263,647	3,362,191	3,324,714
Jefferson	19,672	78,824	162,371 [5]
Johnson	———	1,127	1,321
Labette	14,820	13,071	12,896
Leavenworth	13,020	22,964	——— [6]
Linn	26,195	24,529	38,845
Lyon	108,287 [7]	106,278 [7]	133,287 [7]
Marion	840,640 [8]	979,397 [8]	815,358 [8]
Miami	199,185	235,402	218,898
Montgomery	311,523	377,376	367,332
Morris	——— [9]	——— [9]	——— [9]
Neosho	722,859	703,408	674,037
Wilson	106,247	86,157	55,714
Woodson	287,081	263,830	253,263
Miscellaneous	669,196	835,635	665,506
Totals	16,827,038	16,998,455	16,259,083

[1] Included with Greenwood and Lyon counties
[2] Production from Van Noy pool only; production from other pools is included with Greenwood and Woodson counties
[3] Combined with Marion county
[4] Production from Lost Springs pool is included with Marion county
[5] Includes some production from Leavenworth county
[6] Included with Jefferson county
[7] Includes some production from Greenwood and Chase counties
[8] Includes some production from Morris and Dickinson counties
[9] Included with Marion county

TABLE 2.—*Gas production in eastern Kansas counties, in thousands of cubic feet*

County	1939	1940	1941	1942	1943
Allen	649,377	702,378	644,235	664,624	718,726
Anderson	62,616	39,254	16,609	9,666	6,696
Bourbon	170,500	179,494	193,599	143,146	124,631
Butler	99,700	90,650	82,414	74,200	75,000
Chase	84,761	89,223	93,920	180,000	180,000
Chautauqua	770,352	670,037	756,697	844,579	805,726
Coffey	8,056	13,691	17,864	7,650	18,186
Cowley	298,857	406,409	274,878	318,849	400,802
Crawford	30,000	107,499	154,817	140,634	70,000
Douglas	7,522	9,380	29,499	26,120	35,997
Elk	756,675	962,558	961,647	654,686	627,246
Franklin	396,365	390,832	412,800	318,139	273,075
Greenwood	500	1,000	7,000	8,000	8,000
Jefferson	———	———	1,631,445	4,878,124	2,788,470
Johnson	157,742	236,114	136,923	272,624	193,075
Labette	438,386	346,960	425,971	332,416	405,750
Leavenworth	39,000	30,403	34,052	29,946	37,750
Linn	123,849	119,577	102,065	96,988	99,609
Marion	79,335	84,956	69,699	79,343	94,984
Miami	1,027,123	919,607	949,272	812,749	645,110
Montgomery	1,548,394	1,538,373	1,496,140	1,803,633	3,422,417
Morris	177,157	231,510	226,767	193,718	149,485
Neosho	492,304	826,550	411,793	439,721	507,000
Wilson	734,880	687,886	517,605	463,954	417,748
Woodson	62,484	52,542	87,984	105,118	106,252
Wyandotte	———[1]	———[1]	———[1]	———[1]	———[1]
Totals	8,215,935	8,736,883	9,735,695	12,898,627	12,211,735

[1] Included with Leavenworth county

SURFACE ROCKS

The geologic map of Kansas (Moore and Landes, 1937) shows the areal distribution of outcropping rocks in Kansas. Classification and brief description of these rocks are given by Moore, Frye, and Jewett (1944).

Quaternary and Tertiary deposits.—Glacial drift, lake deposits, wind-blown clay and silt, and alluvial material, mostly unconsolidated, occur as the mantle rock in much of eastern Kansas. Glacial drift, comprising materials ranging in size from clay particles to huge boulders, is confined to the northeastern part of the state, but outwash material was deposited at an undetermined distance

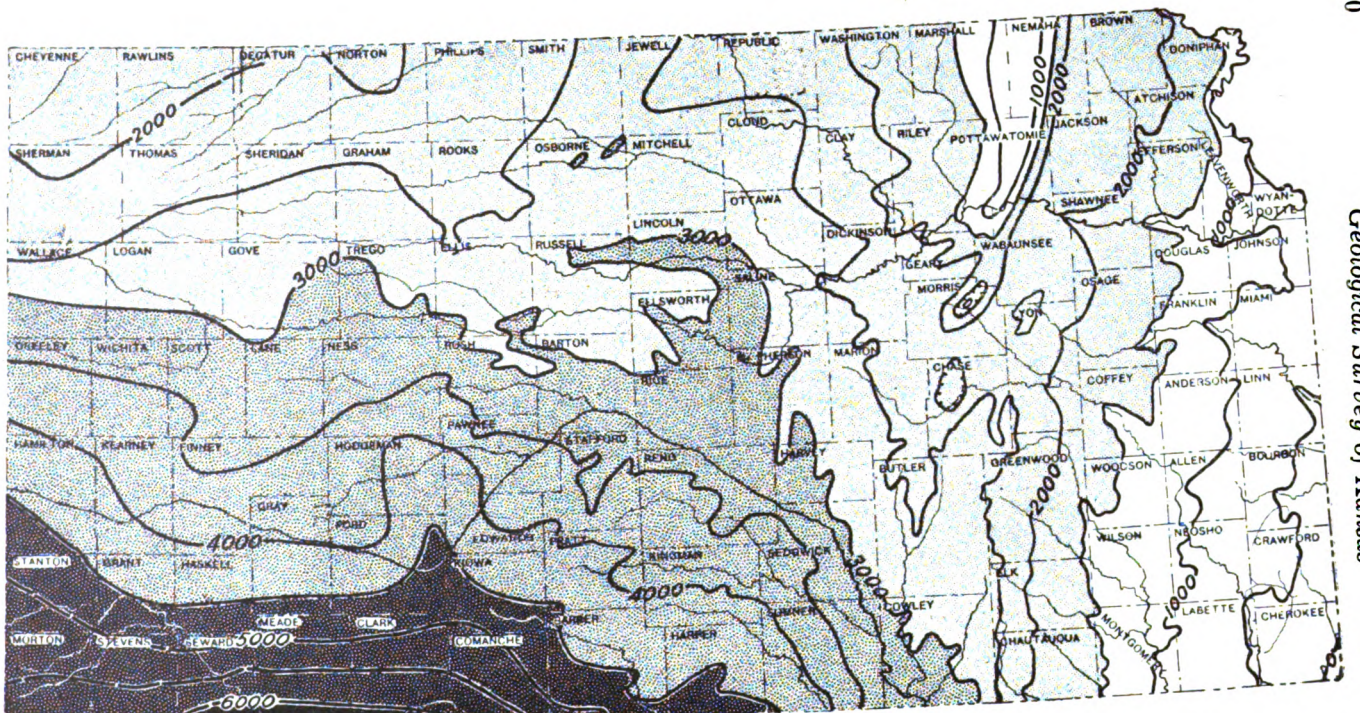

FIG. 2. Map showing the approximate configuration of the pre-Cambrian rock surface in Kansas. Contour lines are drawn on sea-level datum. (Moore and Jewett, 1942.)

south of the generally recognized "drift border." Ice sheets invaded Kansas in an area bounded on the west by a line a few miles west of Big Blue river, and on the south by a line several miles south of Kansas river. The glacial deposits consist of clay, sand, silt, gravel, and boulders of quartzite of various colors, granite, and other igneous rock. Glacial deposits do not form a continuous cover for there are numerous outcrops of Permian and Pennsylvanian rocks in the glaciated area.

Alluvium of Recent and Pleistocene age is found in the main stream valleys. These stream-laid deposits have a maximum thickness of 85 feet or more and consist of clay, silt, sand, and gravel. Sand and gravel predominate in the larger stream valleys. Flint gravels of probable Tertiary age occur as thin upland deposits at many localities. This material was deposited by eastward-flowing streams over wide valley floors before elevation that brought about the present erosion cycle. Similar flint deposits of a somewhat younger age constitute alluvial terraces along some of the streams, especially in southeastern Kansas. The thickness of the upland flint deposits is generally less than 20 feet, but greater thicknesses are encountered locally.

Cretaceous rocks.—Cretaceous rocks of Gulfian and Comanchean age, chiefly clays and quartz sandstones, are present at the surface in Washington, Marion, Clay, Dickinson, Riley, and Marshall counties. The thickness ranges from a featheredge to approximately 300 feet. Cretaceous rocks overlie beveled Permian beds that dip more steeply to the west than do the Cretaceous deposits.

Igneous rocks.—In Riley county there are three outcrops of pluglike masses of basic igneous rock of probable Cretaceous age. These locations are shown on the geologic map of Kansas and on the map of Riley and Geary counties (Jewett, 1941, pl. 1.). A granite dike of post-medial Pennsylvanian age crops out in Woodson county.

Permian and Pennsylvanian rocks.—Although regarded as belonging in different geologic systems, the Pennsylvanian and Permian rocks in eastern Kansas are here treated as a unit. The rock layers are essentially parallel and the Permian rocks are separated from the underlying Pennsylvanian beds by an unconformity that is conspicuous in only a few places. About 1,000 feet of Permian rocks classed as the lower part of the Sumner group (Leonardian series) and the Chase, Council Grove, and Admire groups (Wolf-

campian series) (fig. 6) are the surface consolidated rocks east of the Cretaceous outcrop in the western part of eastern Kansas. These rocks are largely marine shales and limestones. Detailed descriptions of these strata were given by Fath (1921); Bass (1929 and 1936); Jewett (1941); and Moore, Frye, and Jewett (1944).

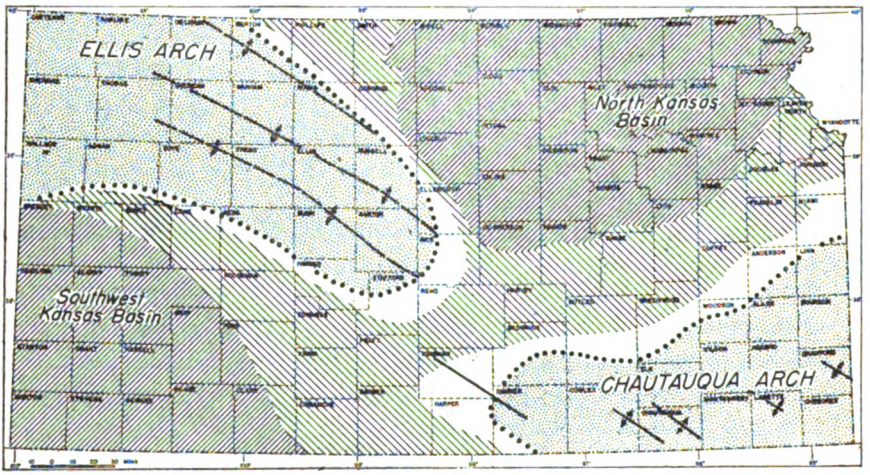

FIG. 3. Sketch map showing main structural elements in Kansas during Mississippian time. (Moore and Jewett, 1942.)

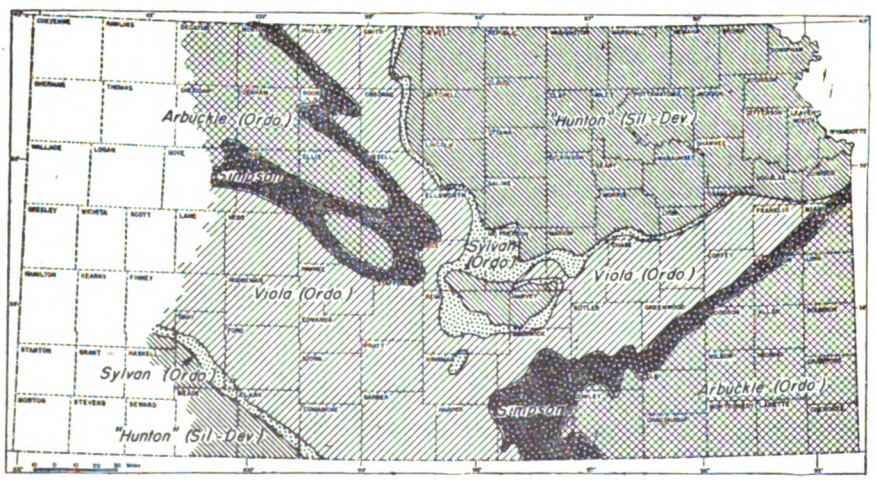

FIG. 4. Map of Kansas showing inferred post-Devonian pre-Mississippian areal paleogeology. (Moore and Jewett, 1942.)

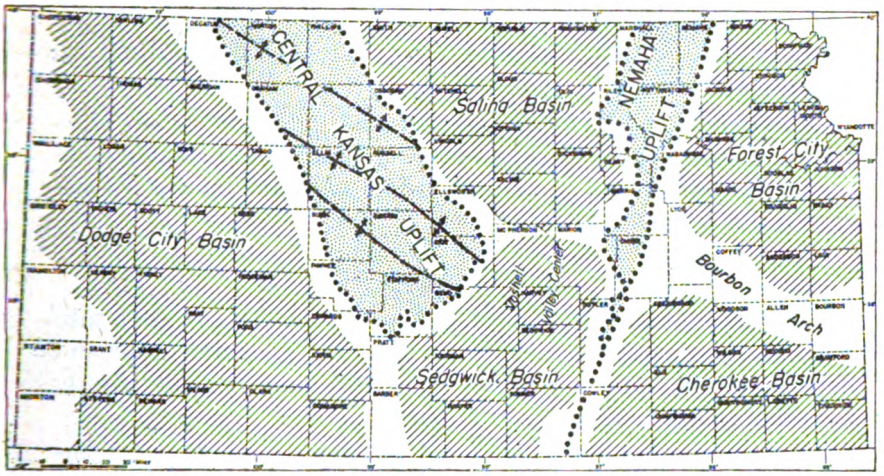

FIG. 5. Sketch map showing early Pennsylvanian structural provinces in Kansas. (Moore and Jewett, 1942.)

An area of Pennsylvanian outcrops occupies the approximate eastern one-fourth of Kansas and is continuous with an area of exposures of the same beds in Oklahoma, Missouri, Nebraska, and Iowa. The beds dip gently outward from the Ozark uplift in Missouri, and in eastern Kansas the direction of dip of the Pennsylvanian beds is generally westward. These rocks are composed largely of shale, sandstone, limestone, and coal beds. The total thickness of Pennsylvanian rocks is about 2,000 feet.

Pennsylvanian rocks in Kansas are classified as belonging in the Virgilian series, comprising the Wabaunsee, Shawnee, and Douglas groups; the Missourian series, comprising the Pedee, Lansing, Kansas City, Bronson, and Bourbon groups; and the Desmoinesian series, which includes the Marmaton group and the Cherokee shale (figs. 7, 8, 9). The series boundaries are marked by important regional unconformities, but the beds of the various series are essentially parallel. Detailed descriptions of Pennsylvanian rocks are given by Moore (1936) and by Moore, Frye, and Jewett (1944).

In Kansas, Permian and Pennsylvanian limestones, shales, and coal beds are generally persistent. These strata include many key beds suitable for structural mapping. A regional unconformity separates Pennsylvanian and underlying rocks. Throughout most of eastern Kansas Pennsylvanian strata lie upon various Missis-

sippian formations; however, along the Nemaha uplift the beveled edges of older rocks, including pre-Cambrian, are overlain by Pennsylvanian deposits (pls. 1-4).

Mississippian rocks.—Mississippian limestones of Osagian, Meramecian, and possibly Chesterian age crop out in the southeastern corner of Kansas (fig. 9). The total thickness of exposed Mississippian limestones is about 50 feet.

BURIED ROCKS

Rocks of Quaternary and Tertiary age constitute only a thin discontinuous mantle in eastern Kansas. The glacial deposits and deposits of alluvium in the river valleys obscure the more firmly consolidated rocks at many localities.

Cretaceous rocks.—Cretaceous rocks have a maximum thickness of about 600 feet in the eastern Kansas area. No oil or gas has been found in these rocks in eastern Kansas.

Permian and Pennsylvanian rocks.—The uppermost consolidated rocks encountered in drilling in much of eastern Kansas are either Permian or Pennsylvanian in age. The thickest section of Permian and Pennsylvanian rocks in eastern Kansas is in southwestern Cowley county where they are more than 3,000 feet thick. Permian rocks do not occur east of a line extending roughly from the north-central part of Brown county southward to the southeast corner of Cowley county. The geologic map of Kansas is a guide to the identification of the uppermost rocks in various places.

Permian rocks in eastern Kansas are classified as belonging to the Leonardian and Wolfcampian series. Rocks of these two series are considered to be conformable and the boundary between them is regarded as being at the top of the Herington limestone member of the Nolans formation. The Leonardian series includes the Nippewalla and Sumner groups, but the Nippewalla group and the upper part of the Sumner group are not present anywhere in the counties described in this report. The Sumner group includes the Ninnescah shale (absent in eastern Kansas) and the Wellington formation. The Wellington formation lies below the more commonly red Permian sediments and above the Herington limestone. It is chiefly gray shale, but contains some red and green shale, thick salt deposits in central and western Kansas, impure limestone, anhydrite, and gypsum beds. The thickness of the Wellington is about 750 feet.

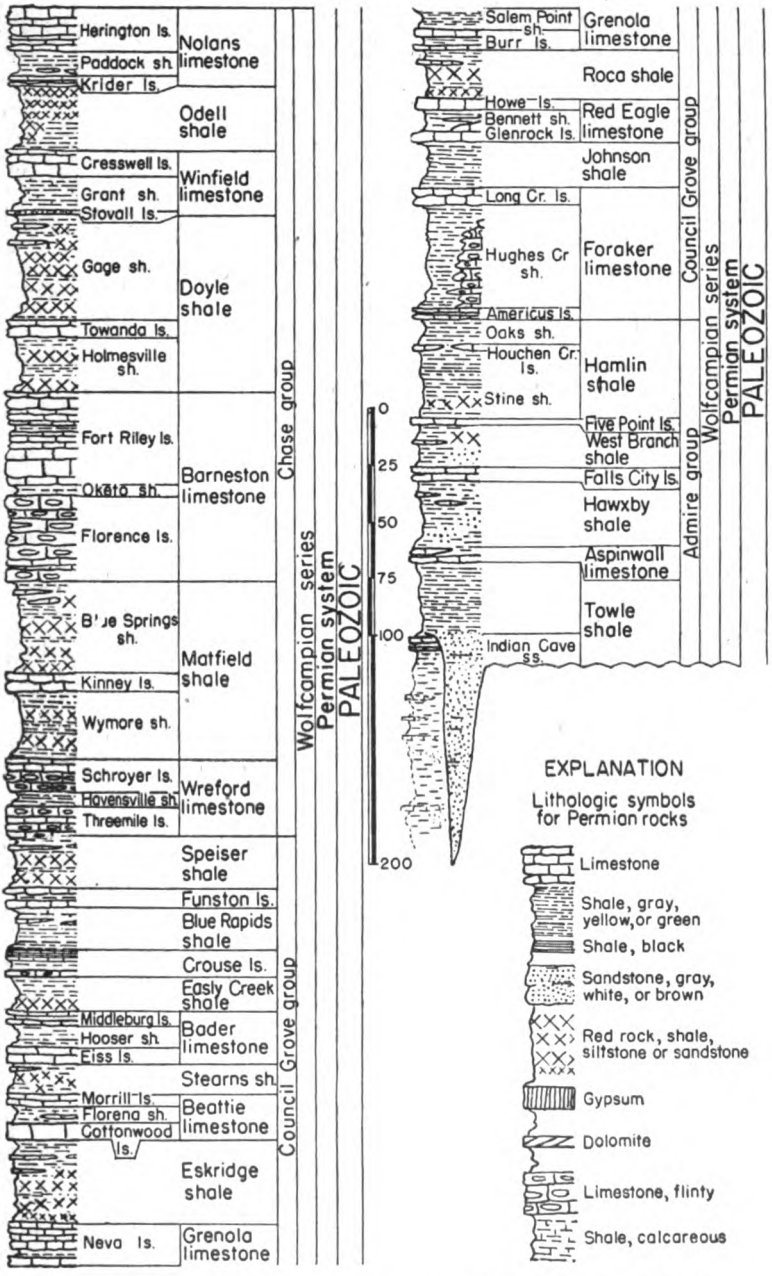

Fig. 6. Generalized section of outcropping lower Permian rocks in Kansas. (Moore, Frye, and Jewett, 1944.)

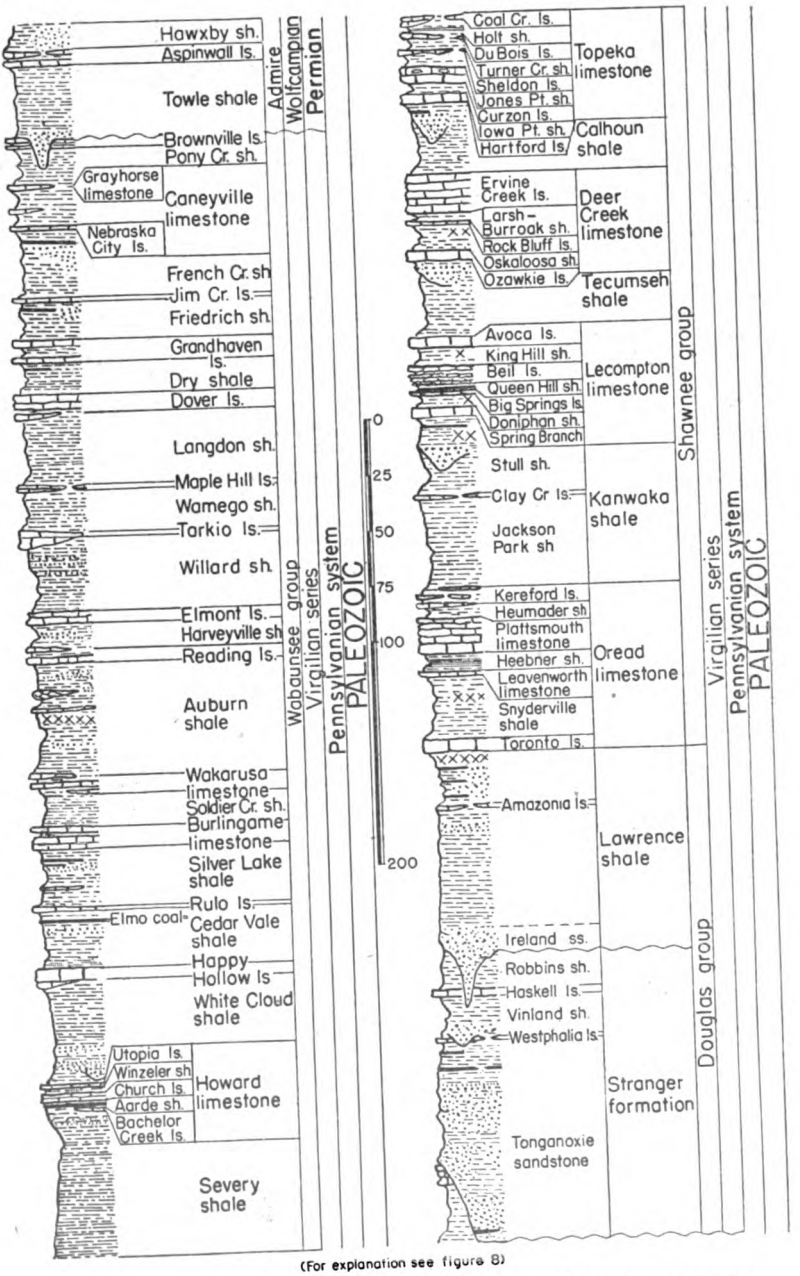

FIG. 7. Generalized section of outcropping Virgilian rocks in Kansas. (Moore, Frye, and Jewett, 1944.)

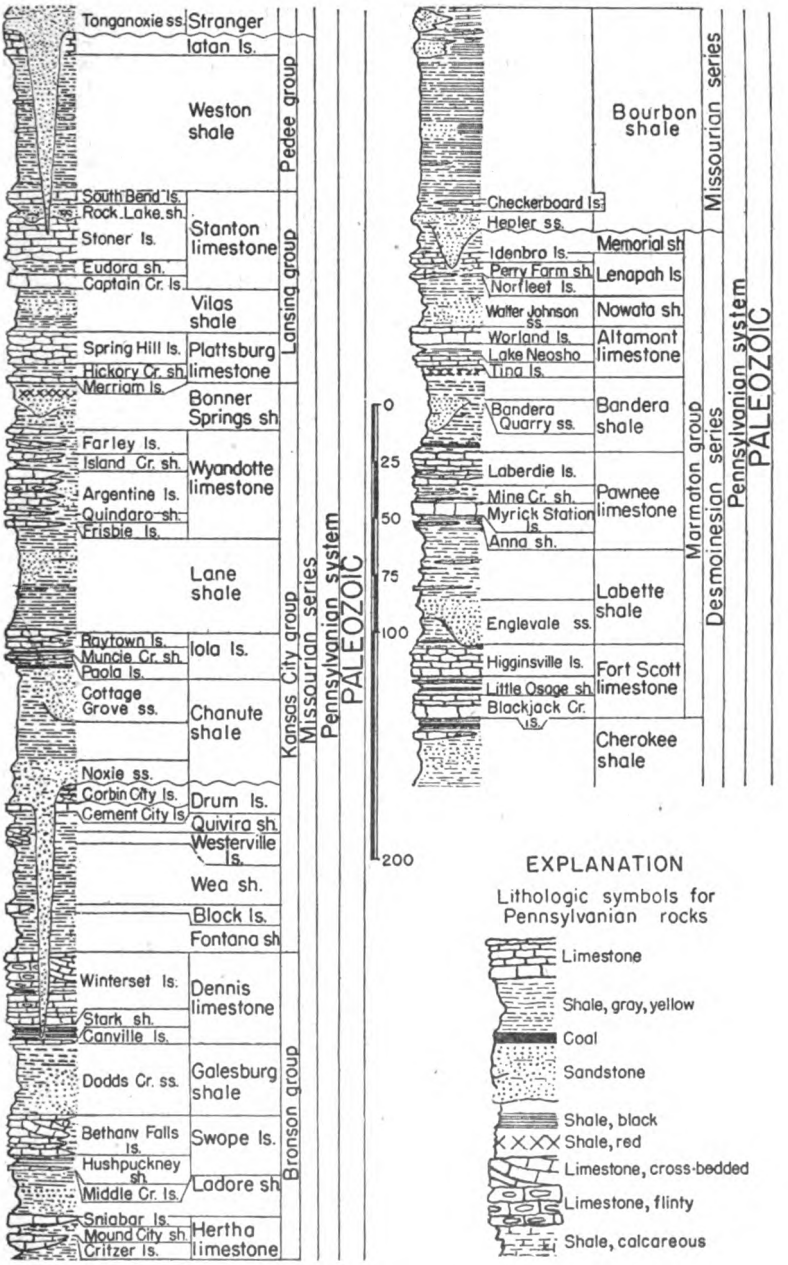

FIG. 8. Generalized section of outcropping Missourian and late Desmoinesian rocks in Kansas. (Moore, Frye, and Jewett, 1944.)

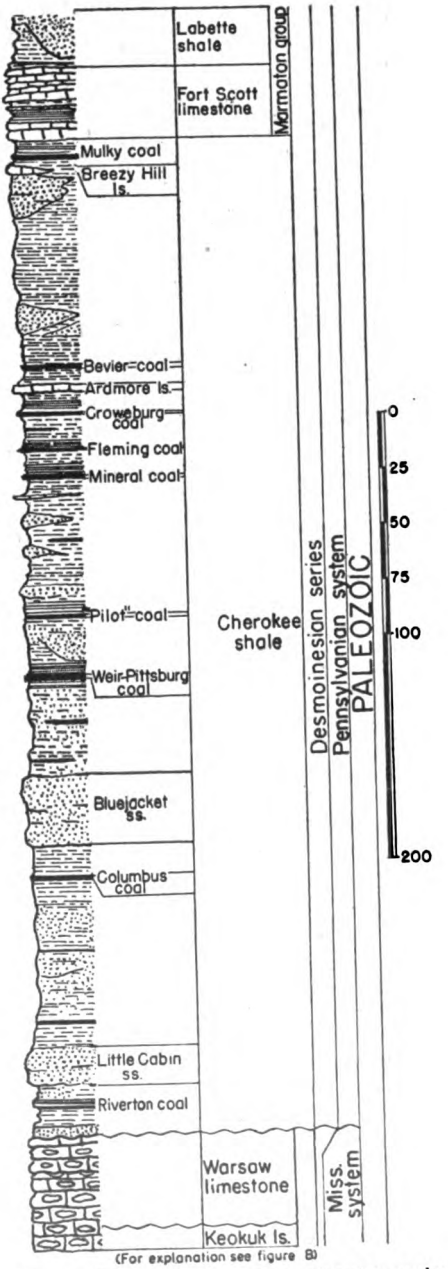

FIG. 9. Generalized section of outcropping Cherokee rocks in Kansas. (Moore, Frye, and Jewett, 1944.)

Permian rocks of Wolfcampian age (formerly called Big Blue) are remarkably persistent in thickness and lithology both in the area of their outcrop in eastern Kansas and in the subsurface. The series is about 750 feet thick and contains light-gray limestones, several of which are flinty, highly colored shales and siltstones, and a little sandstone in the lower part. These rocks yield gas in Cowley, Morris, and Chase counties, and oil in Butler county. The Chase, Council Grove, and Admire groups (fig. 6; pls. 1-4) comprise the Wolfcampian series.

The Chase group includes the Nolans limestone, the Odell shale, the Winfield limestone, the Doyle shale, the Barneston limestone, the Matfield shale, and the Wreford limestone. Flint is abundant in the Stovall member of the Winfield limestone, in the Florence member of the Barneston limestone, and in the Wreford limestone. The shale formations are highly colored; reds, chocolate colors, and greens are prominent. The general thickness of the Chase group is approximately 370 feet.

The Council Grove group includes the Speiser shale, the Funston limestone, the Blue Rapids shale, the Crouse limestone, the Easly Creek shale, the Bader limestone, the Stearns shale, the Beattie limestone, the Eskridge shale, the Grenola limestone, the Roca shale, the Red Eagle limestone, the Johnson shale, and the Foraker limestone. Individual limestone formations and members are thinner than those in the Chase group. Flint is less plentiful, although there is much flint in the Red Eagle formation in the southern part of the state. The shale formations are somewhat more somber in color, but reds and greens are conspicuous. Fusulines are abundant in both limestone and gray calcareous shale. It should be noted, however, that fusulines range upward into the Barneston limestone of the Chase group. The Council Grove rocks have a fairly uniform thickness of about 320 feet.

The important oil and gas "sands" of eastern Kansas are included within the Pennsylvanian rocks. Four east-west cross sections (pls. 1-4) show subsurface relations and thicknesses of the Pennsylvanian groups and other rock units. The group and series boundaries as recognized in outcropping Pennsylvanian rocks can be more or less exactly identified from drillers' logs and by studies of well cuttings.

The uppermost series of the Pennsylvanian is the Virgilian, which includes the Wabaunsee, Shawnee, and Douglas groups.

The top of the Wabaunsee group, which is also the top of the Pennsylvanian system, is not readily identified in some drillers' logs. However, the clastic basal Permian Admire contrasts somewhat with the more limy Wabaunsee rocks. Locally the Indian Cave sandstone in the basal part of the Permian marks the boundary, and locally a transitional zone at the Permian-Pennsylvanian contact consists of red shales. The average thickness of the Wabaunsee group in eastern Kansas is about 500 feet. Shale is the most common rock, but sandstone, which occurs in the thicker shale formations, and limestone are also important. The Tarkio limestone, characterized by large fusulines, is a fairly easily recognized marker bed about 175 feet below the top of the Wabaunsee. Other easily recognized rocks are the Burlingame limestone, at about the middle of the Wabaunsee, and the Howard limestone, about 75 feet above the base.

The Shawnee group is easily identified in well logs because it contains relatively thick limestone formations in the upper and lower parts and it is overlain and underlain by more clastic rocks. The average thickness of the group is about 350 feet. Throughout most of eastern Kansas the Shawnee group is a fairly compact unit consisting of four limestones and three separating shales. The limestone formations, including their shale members, range from about 30 to more than 50 feet in thickness. Lenticular and locally thick sandstone bodies are common in the upper parts of the shale formations. This group is thicker and contains less limestone in southern Kansas than in northern Kansas. The Topeka limestone occurs at the top and the Oread limestone at the base of the Shawnee group.

The Douglas group, consisting principally of shale, sandstone, and minor amounts of limestone and coal, underlies the Shawnee group. The thickness of the group, from the base of the Oread limestone to the regional disconformity that separates Virgilian and Missourian rocks, ranges from about 75 to 350 feet in the subsurface in eastern Kansas. A disconformity of wide extent occurs within the group and separates the Lawrence formation from the underlying Stranger formation. The basal part of the Lawrence formation is distinguished by the Ireland sandstone which consists of lenticular sand bodies. A similar series of lenticular sandstone bodies, the Tonganoxie sandstone, occurs in the lower part of the Stranger formation. Locally the upper part of the Lawrence shale

is silty and sandy and in many places the name Tonganoxie is applied to two sandstone beds separated by several feet of shale. Conglomerates occur locally in the basal parts of the sandstone deposits.

The Haskell limestone occupies a position near the top of the Stranger formation. Because of the erosional disconformity at the base of the Virgilian rocks, Douglas deposits are in contact with Missourian formations ranging downward from the Pedee group to the upper part of the Lansing group.

The Missourian series occurs below the Virgilian and includes the Pedee, Lansing, Kansas City, and Bronson groups and the Bourbon shale. The Pedee group is about 200 feet thick and consists chiefly of clastic sediments that lie above the Stanton limestone and below the disconformity at the base of the Stranger formation. The Iatan limestone, about 10 feet thick, is the uppermost formation of the group. The Weston shale, the basal formation of the group, consists chiefly of gray clay shale. It is probable that locally a few feet of shale occurs above the Iatan limestone and below the post-Missourian disconformity. Pedee rocks are difficult or impossible to detect in many drillers' logs.

The Lansing group is 75 to 275 feet thick in eastern Kansas and consists largely of limestone. It includes the Stanton limestone, the Vilas shale, and the Plattsburg limestone. In southeastern Kansas this group is thicker than farther north and contains more shale and sandstone. A few feet of black platy shale in the Eudora shale member of the Stanton limestone is a marker bed. In some areas it is difficult to differentiate the Plattsburg limestone from the Wyandotte limestone, in the upper part of the Kansas City group. South of T. 30 S., both the Lansing and Kansas City groups are largely clastic and consist of clayey and sandy shales and thin limestone beds.

The Kansas City group, like the overlying Lansing and the underlying Bronson groups throughout most of eastern Kansas, is largely limestone, and the Kansas City rocks are differentiated with difficulty. The Kansas City group increases in thickness southward, and south of T. 30 S. it consists almost entirely of shale, sandy shale, and sandstone. The group ranges in thickness from about 75 to 385 feet.

The Bronson group also is characterized by rather thick limestone beds, but the limestones are more persistent southward than are those of the Lansing and Kansas City groups. Flinty and oölitic

limestones are characteristic. Two thin black shale beds, one in the Swope formation and one in the Dennis formation, are subsurface marker beds. The group is about 85 feet thick in northeastern Kansas (pl. 1); it thickens southward, where the shale formations are thicker and more sandy, to about 200 feet (pl. 4). The base of the Bronson group (base of the Hertha limestone) is an excellent subsurface horizon marker. It is convenient to group together the Lansing, Kansas City, and Bronson groups in much of eastern Kansas; the combined thickness ranges from about 250 to 700 feet.

The relatively thick Bourbon assemblage of shale, sandstone, and very thin limestone beds lies below the Bronson rocks and above the pre-Missourian and post-Desmoinesian disconformity. In eastern Kansas the thickness ranges from about 100 to 225 feet. "Big shale" is the drillers' common term for the Bourbon shale, and the term "Pleasanton shale" is sometimes used for the same rocks. In northeastern Kansas lenticular sandstone bodies in the upper part, called Knobtown sandstone, locally yield oil. The more persistent Hepler sandstone in the basal part of the group yields oil in Miami county. In some places, as in eastern Miami county, the disconformity at the base of the Bourbon rocks brings the Hepler sandstone in contact with rocks as low as the Bandera shale.

The Desmoinesian series occurs below the Missourian and includes the oldest Pennsylvanian rocks of eastern Kansas. The Marmaton group, consisting of shale and limestone formations, is the uppermost group of the Desmoinesian. Along the outcrop of Marmaton rocks, which extends from Linn county southwestward to Labette and Montgomery counties, the limestone formations are well developed and are differentiated into limestone and shale members (Jewett, 1941a). Because of the occurrence of important oil and gas reservoir rocks in this group and in the underlying Cherokee shale, identification of Marmaton formations in the subsurface is important. The group includes the Memorial shale, the Lenapah limestone, the Nowata shale, the Altamont limestone, the Bandera shale, the Pawnee limestone, the Labette shale, and the Fort Scott limestone.

The Lenapah limestone is about 30 feet thick in the southern part of eastern Kansas; elsewhere it is thin or locally absent because of local post-Desmoinesian erosion. The Nowata shale contains sandstone lenses, including the "Wayside sand," an impor-

tant oil reservoir in southeastern Kansas and northeastern Oklahoma. The Altamont limestone, commonly less than 20 feet thick, occurs about 30 feet below the Lenapah limestone. The Bandera shale, consisting of gray and yellow clay shale and sandstone, occurs below the Altamont and includes the "Weiser sand." This formation ranges in thickness from 20 feet or less to about 100 feet. The Pawnee limestone is a persistently conspicuous pinkish limestone that ranges in thickness from about 20 to 60 feet in the subsurface in eastern Kansas. Two or more limestone members can be differentiated in many drillers' logs. The Labette shale ranges in thickness from about 25 to 100 feet except in most of Cowley county and locally in Chautauqua county where only a few feet of this shale lies between the Pawnee and Fort Scott limestones. The Labette consists of gray and black clay shale and gray silty and sandy shale, sandstone, thin beds of limestone, and thin coal beds. "Peru sand" is the common term for sand bodies in the Labette shale in the subsurface. The Fort Scott limestone is the lowermost Marmaton formation and immediately overlies the Cherokee shale. In most wells in eastern Kansas two limestones and a separating shale member can be identified; in some parts of southern Kansas four or more limestones are present. The thickness of the Fort Scott limestone ranges from about 25 to 100 feet. Many wells in eastern Kansas produce gas from black shale associated with the Fort Scott limestones. Production from this zone is often referred to as "Oswego" production.

The Cherokee shale, which includes important oil and gas reservoirs in eastern Kansas, comprises beds below the Fort Scott limestone (lowermost Marmaton) and above pre-Pennsylvanian rocks. The Cherokee shale is not of Early Pennsylvanian age, but it is the oldest Pennsylvanian rock in eastern Kansas. It lies on Mississippian limestone formations in most parts of eastern Kansas, but it overlies pre-Mississippian rocks in the Nemaha anticlinal area. The thickness of Cherokee rocks ranges from a few feet along the Nemaha uplift to about 800 feet in the Forest City basin. The common thickness in eastern Kansas is about 350 or 400 feet.

The Cherokee consists of dark and light-colored clayey and silty shales, some important sandstones, and a minor amount of limestone and coal. The upper few feet is commonly black platy shale and this zone is an important "shale gas" reservoir in several

eastern Kansas counties. Sandstone beds, called "Squirrel sand," commonly occur in the upper part of the Cherokee shale. These sandstones are gas and oil reservoirs in several eastern Kansas counties, especially Franklin, Linn, and Miami. The "Squirrel sand" where present is generally about 30 feet below the Fort Scott limestone. The thickness is as much as 80 feet (Lee, 1943, p. 83). The Ardmore limestone, commonly about 4 feet thick, is a convenient marker bed in the upper middle part of the Cherokee shale. It is generally 80 to 100 feet below the top of the Cherokee.

"Burbank sand" is a term applied locally to sandstone in the middle part of the Cherokee, and the name "Bartlesville sand" is applied commonly to sand bodies in the middle and lower parts of the Cherokee. Sandstone that lies on or a few feet above the Mississippian limestone is called "Burgess sand." In some areas it is customary and convenient to refer to an "Upper and Lower Bartlesville sand." The Bartlesville sandstone as originally defined is a producing rock in the Bartlesville, Okla., area. In that area it is separated from Mississippian limestone by a small thickness of shale (Bass, 1936, p. 27). The "Burbank sand" occurs 50 to 100 feet above the Bartlesville in northeastern Oklahoma. Productive shoestring sandstones in Greenwood, Butler, Cowley, and other counties in Kansas, commonly called "Bartlesville sand," would be more nearly correctly called "Burbank sand." Nevertheless the term "Bartlesville" when used locally is generally well understood. It is commonly applied to lower Cherokee sandy zones as far north as Franklin and Douglas counties. Lee (1941) has given the name McLouth to a sandstone at about the same stratigraphic position in Jefferson and Leavenworth counties.

Mississippian rocks.—Various Mississippian limestone formations ranging in age from Osagian or Kinderhookian through Meramecian are present throughout most of eastern Kansas (Lee, 1939; 1940; 1943, pp. 66-79). These rocks were removed by late Mississippian or early Pennsylvanian erosion from a large area along the northern part of the Nemaha anticline northward from the northern part of Chase county and from higher parts of the anticline as far south as Augusta in Butler county (Lee, 1939, pl. 1). The thickness of the Mississippian limestone formations in eastern Kansas ranges from a featheredge to more than 450 feet. Various kinds of limestone and dolomite are present and chert

is characteristic of some of the formations. The distribution of various Mississippian formations in Kansas is shown by Lee (1940, pl. 8).

In most parts of eastern Kansas the Mississippian limestones are underlain by the Chattanooga shale of early Mississippian or late Devonian age. The Chattanooga shale and some younger beds (Northview shale and Compton limestone) were deposited above an extensive peneplain which had been developed on previously deformed rocks. The maximum thickness of the Chattanooga shale is about 260 feet, but the thickness commonly is not more than 50 feet. The Chattanooga shale is dark gray or black in southeastern Kansas, but it is lighter and greenish gray in the northern part. Sandstone is included in the basal part in some areas. Generally the Chattanooga contains plant spores and locally it is silty. In southeastern Kansas the Northview shale, which has a maximum thickness of about 28 feet, and the Compton limestone, which has a maximum thickness of about 60 feet (Lee, 1940, p. 31), occur conformably above the Chattanooga shale. The Northview and Compton are correlative with the Chouteau limestone of Missouri.

Devonian and Silurian rocks.—The terms "Siluro-Devonian" (Ockerman, 1935, p. 30, pl. 1) and "Hunton" limestone are commonly used to designate formations in eastern Kansas that occupy a position below the Chattanooga shale and above the Ordovician rocks. These are convenient names, but Lee (1943, pp. 43-59, fig. 3) has shown that there is an angular unconformity between Silurian and Devonian rocks in eastern Kansas and that several formations that crop out in Missouri and Oklahoma can be identified in the subsurface in Kansas. According to Lee (1943, p. 52), undifferentiated limestones and dolomites of late Devonian age and the Cooper limestone, of middle Devonian age, occur in eastern Kansas, and the Silurian rocks of the area consist of the Brassfield and Edgewood limestones which are correlative with the Chimneyhill limestone of Oklahoma (Lee, 1943, p. 45).

Devonian and Silurian rocks occur in eastern Kansas east and west of the northern part of the Nemaha anticline, and a small area in the southeastern part of Marion county is underlain by these rocks (McClellan, 1930; Ockerman, 1935, fig. 2). With the exception of the Nemaha anticlinal area, Devonian and Silurian rocks are present north and west of a line extending in a general

east-west direction in or near T. 15 S. According to Lee (1943, pp. 45, 57), the greatest known thickness of Devonian rocks in eastern Kansas is about 250 feet and that of Silurian rocks is about 150 feet. The rocks are chiefly limestone and dolomite.

Ordovician and Cambrian rocks.—Maquoketa shale, Kimmswick limestone, Decorah shale, Plattin limestone, St. Peter sandstone, undifferentiated Cotter and Jefferson City dolomites, Roubidoux formation, undifferentiated Gasconade and Van Buren dolomites, and Gunter sandstone of Ordovician age have been identified in eastern Kansas. The Eminence and Bonneterre dolomites and the Lamotte sandstone of Cambrian age have been identified. The rocks between the St. Peter sandstone and the Lamotte sandstone are commonly called Arbuckle or may be referred to as "Siliceous lime." Lee (1943, pp. 19, 20), however, has pointed out that the Bonneterre dolomite does not properly belong in the Arbuckle assemblage. It is recognized that the Arbuckle rocks, with or without the inclusion of the Bonneterre dolomite, constitute a convenient grouping of formations of late Cambrian and early Ordovician age. Late Devonian or early Mississippian rocks rest directly on Arbuckle rocks in the Chautauqua arch area. Oil has been discovered in Arbuckle rocks in eastern Kansas in Elk, Wilson, Chautauqua, Montgomery, Labette, Cowley, and Marion counties.

Lee (1943) has made known many data concerning the stratigraphy and structure of older Paleozoic rocks in the Forest City basin. Keroher (Jewett, 1941, pp. 107, 110) interpreted drillers' logs of several wells in Riley and Geary counties, but he did not make separations within the Arbuckle rocks. Keroher also studied cuttings of pre-Mississippian rocks from a well in Linn county in the northern part of the Chautauqua arch area (Jewett, 1940a, pp. 12-14) and subdivided these rocks. Abernathy (1943) studied samples from the Jayhawk Ordnance Works deep water well in northeastern Cherokee county, and identified the Cotter dolomite, the Jefferson City dolomite, the Roubidoux formation, and the Gasconade dolomite. This well, which is near the crest of the Chautauqua arch, reached 20 feet into the Gasconade dolomite. Early Mississippian (Kinderhookian) beds lie on Cotter dolomite in this area.

The Maquoketa shale occurs east and west of the Nemaha anticline in northeastern Kansas (McClellan, 1930; Ockerman, 1935, fig.

2; Lee, 1943, fig. 12, pp. 40-42). It was originally deposited throughout northeastern Kansas and probably across the Chautauqua arch (Lee, 1943, p. 42). Pre-Devonian erosion removed it and some older and younger rocks from large areas in southeastern Kansas and Missouri. Near the end of Mississippian time, the Maquoketa was eroded generally from the northern part of the Nemaha anticline. According to Lee (1943, p. 41), the formation is separable roughly into an upper and a lower part. Generally the upper zone is silty impure dolomite, and the lower zone is dolomitic silty dark shale. In general, the Maquoketa shale is gray and greenish gray, and ranges from a featheredge to about 80 feet in thickness.

The Kimmswick limestone has been eroded from the northern part of the Nemaha anticline and from the Chautauqua arch. The formation is largely dolomite in northeastern Kansas but it changes to limestone toward the south in Johnson, Douglas, and adjacent counties (Lee, 1943, p. 36). Chert is characteristic of the middle part of the formation. The thickness ranges from a featheredge to about 180 feet. Lee has identified the Decorah shale and the Plattin[1] limestone in cuttings from several northeastern Kansas wells. The Decorah shale is characterized by sandy dolomite interstratified with dark and gray-green shale (Lee, 1943, p. 32). The Decorah shale is believed to be more generally present than is the Plattin limestone. The thickness of the formations east of the Nemaha anticline ranges from a few feet to about 85 feet. About 300 feet of Viola limestone occurs in Clay and other counties in the northwestern part of eastern Kansas. The Kimmswick limestone, the Decorah shale, and the Plattin limestone are often correlated with the Viola limestone of Oklahoma. However, Lee believes that only the Decorah shale and the Kimmswick limestone correspond in age to the Viola limestone.

The St. Peter sandstone occurs generally between the Viola and Arbuckle rocks, but it is separated from younger and older rocks by important disconformities. In northeastern Kansas it oversteps all older Ordovician and Cambrian rocks and in the northwestern part of eastern Kansas it lies on pre-Cambrian granite (Lee, 1943, pp. 29, 30, fig. 5, pl. 1). Lee has found that in

[1] After this report was in press Constance Leatherock, in Kansas Geol. Survey Bull. 60, pt. 1, discussed rocks of Simpson age in north-central Kansas. According to Leatherock, the Platteville limestone (Plattin in this paper) and the St. Peter sandstone are included in rocks of Simpson age.

most northeastern Kansas wells the Decorah shale lies upon the St. Peter sandstone, but in the deeper part of the North Kansas basin limestone tentatively identified as Plattin overlies the St. Peter sandstone.

The St. Peter sandstone and younger pre-Chattanooga rocks were eroded from the Chautauqua arch before deposition of the Chattanooga shale. Immediately before the beginning of Chattanooga deposition the St. Peter sandstone was exposed in a narrow belt extending from a point near the northeast corner of Johnson county southwestward to Sumner county. This line is used commonly to mark the boundary of the Chautauqua arch (fig. 3). Arbuckle rocks were exposed south and east of the St. Peter exposure; younger Ordovician, Silurian, and Devonian formations were exposed west and north of the St. Peter outcrop. South and east of this line the Chattanooga shale, or locally Mississippian limestones, now lie upon Arbuckle rocks (pls. 2 and 3). The St. Peter sandstone and other rocks were removed from the northern part of the Nemaha anticline before Pennsylvanian deposition (pl. 1). The St. Peter formation is chiefly white sandstone composed of well-rounded grains but it includes a minor amount of green shale. The thickness of the St. Peter in eastern Kansas ranges from a featheredge to more than 400 feet; the common thickness is between 50 and 85 feet.

In eastern Kansas the St. Peter sandstone oversteps older Ordovician and Cambrian rocks from the east (Lee, 1943, fig. 5). That is, the Cotter-Jefferson City dolomites and older rocks were beveled before burial under the St. Peter sandstone (pl. 2). Undifferentiated Cotter and Jefferson City dolomites are absent in the Forrester and others No. 1 Hummer well in Shawnee county, but they are 106 feet thick in the Duffens and others No. 1 Stanley well in Douglas county. Keroher (Jewett, 1940a, fig. 2B) identified 168 feet of tan and gray oölitic cherty dolomite as undifferentiated Cotter-Jefferson City in the Holeman and Edwards No. 9 Pollman well in Linn county. Abernathy (1943, fig. 2) identified 105 feet of Cotter dolomite, including a few feet of Swan Creek sandstone in the basal part, and 300 feet of Jefferson City dolomite in the Jayhawk Ordnance Works water well in Cherokee county. An inconspicuous unconformity is believed to occur between the Cotter and Jefferson City formations in eastern Kansas.

The Roubidoux formation is present throughout a wide area in eastern Kansas (Keroher, in Jewett, 1940a, pl. 2B; Abernathy, 1943, p. 85, fig. 2B; Lee, 1943, pp. 25, 26, fig. 5). It comprises sandy gray dolomite and sandstone. Recorded thicknesses are 175 feet in Shawnee county, 167 feet in Douglas county, 145 feet in Linn county, and 155 feet in Cherokee county.

Undifferentiated Gasconade-Van Buren formations are believed to occur throughout eastern Kansas except in the northern part of the Nemaha anticline area. Lee (1943, fig. 5) reported 90 feet in the Hummer well in Shawnee county and 206 feet in the Stanley well in Douglas county. Both figures include a few feet of Gunter sandstone in the basal part. Keroher (Jewett, 1940a, pl. 2A) reported that these formations, including a few feet of Gunter sandstone, are 135 feet thick in the Pollman well in Linn county. The Jayhawk Ordnance Works well in Cherokee county was drilled 20 feet into the upper part of the Gasconade dolomite (Abernathy, 1943, fig. 2B). The undifferentiated Gasconade-Van Buren formations are chiefly cherty dolomite.

The Eminence dolomite underlies the Gunter sandstone in most parts of eastern Kansas, but it is not present in the northwestern part of the Forest City basin (Lee, 1943, p. 23, fig. 5). Recorded thicknesses are 90 feet in Shawnee county, 175 feet in Douglas county, and 150 feet in Linn county. The formation consists chiefly of light crystalline dolomite. Lee has pointed out that the Potosi dolomite may be present in easternmost Kansas as a thin wedge between the Eminence and Bonneterre dolomites. The Bonneterre dolomite is commonly present in eastern Kansas unconformably below the Eminence dolomite and unconformably above the Lamotte sandstone. The thickness ranges from a featheredge to 100 feet or more. In many areas in eastern Kansas several feet of sandstone lies next above the pre-Cambrian floor. This sandstone is probably equivalent to the Lamotte sandstone of Missouri and it commonly is called Lamotte. The Reagan sandstone, which is exposed in the Arbuckle mountains in southern Oklahoma, occupies a stratigraphic position similar to that of the Lamotte sandstone. The Lamotte in eastern Kansas is coarse-grained and arkosic sandstone ranging in thickness from a featheredge to 40 feet or more.

Pre-Cambrian rocks.—Many wells in eastern Kansas have been drilled completely through the Paleozoic rocks into the

more crystalline basement rocks. Some early wells were continued into granite or metamorphic rocks because it was not recognized that these rocks are pre-Cambrian in age and are generally believed not to contain oil or gas. Pre-Cambrian rocks in Kansas are everywhere buried by sediments; hence they are known only from well cuttings or cores. They consist chiefly of granite, gneiss, and schist; quartzite, other metamorphic rocks, and igneous rocks of various kinds are also included.

According to Landes (1927), most of the "granite wells" east of the Nemaha anticline encountered granite or gneiss, but schist is not uncommon. Gneiss is a metamorphic rock in which the various minerals occur in more or less distinct bands. Some gneisses cannot be distinguished readily from granite in well cuttings. Schist is rather easily mistaken for shale. Wells that have been drilled through the sedimentary rocks in the area of the Nemaha anticline have chiefly revealed granite or gneiss in contact with the overlying Paleozoic rocks. It is reasonable to believe that in eastern Kansas beyond the flanks of the Nemaha anticline great thicknesses of metamorphic rocks lie between rocks of Paleozoic age and deeply buried granite or other igneous rocks. In fact, a well in Marshall county penetrated nearly 2,000 feet of schist and other pre-Cambrian rock, and a well in Greenwood county was drilled into 650 feet of schist that was logged as shale (Landes, 1927, p. 822).

The upper surface of the eastern Kansas pre-Cambrian rocks is an ancient irregular surface which was subjected to erosion for a long time before it was buried under younger rocks. The approximate configuration of the pre-Cambrian rock surface in Kansas is shown in figure 2. Sedimentary rocks ranging in age from Pennsylvanian to Cambrian directly overlie pre-Cambrian rocks in Kansas (pls. 1-4). Pre-Cambrian rocks in Kansas are nearest the surface in Nemaha county on the crest of the Nemaha anticline where the cover of Pennsylvanian rocks is about 600 feet thick. The crest of the crystalline rock ridge in the core of the Nemaha anticline slopes southward. It is about 2,700 feet below the land surface near El Dorado, in Butler county, and it is deeper southwest of El Dorado. The pre-Cambrian floor is generally more than 2,000 feet lower just east of the Nemaha anticline than it is on the crest of the granite core. Thence the surface of contact between crystalline and sedimentary rocks rises to the east.

It is commonly believed that the pre-Cambrian floor marks the lower limit of oil and gas occurrence. However, both oil and gas have been found in pre-Cambrian rocks in Rice and Russell counties, Kansas. The oil and gas there occur in stratigraphic traps in metamorphic rocks lying immediately below sediments of Pennsylvanian age.

Major Structural Features in Eastern Kansas

A map designed to show the major structures in eastern Kansas is somewhat misleading inasmuch as in some places uplifts now occur in former basins, or basins now occupy areas of former uplifts. As examples, the southeastern counties of Kansas are in the Cherokee basin and also on the Chautauqua arch, and the Nemaha uplift crosses the area of the North Kansas basin. The Cherokee basin is the northern portion of a shallow basinlike area that existed in a part of Pennsylvanian time, and the Chautauqua arch is the Kansas part of an earlier elevated area. In general, basins are areas in which sections of rock of some particular age span are thicker than rocks of the same age in surrounding areas, and uplifts are areas in which certain rocks, although present in neighboring areas, are absent (pls. 1-4).

PRE-CHATTANOOGA STRUCTURES

The unconformity lying next below the Chattanooga shale (uppermost Devonian or lowermost Mississippian) is an important and convenient datum horizon in subsurface studies in eastern Kansas. Pre-Mississippian structures can be separated readily from those of later origin. Devonian and Silurian rocks occur next below the pre-Chattanooga unconformity in a large area in northeastern Kansas. Elsewhere different formations of Ordovician age lie next below the Chattanooga shale or, in places where the Chattanooga is absent, next below Mississippian limestone. Several southeastern Kansas counties lack Devonian, Silurian, and Upper and Middle Ordovician rocks, and there the strata next below the pre-Mississippian unconformity are classified as belonging to the "Arbuckle group," of early Ordovician or late Cambrian age. The major pre-Mississippian structural features in eastern Kansas are the Chautauqua arch and the North Kansas basin (fig. 3).

Chautauqua arch.—In southeastern Kansas there is a broad area in which Arbuckle rocks, flanked on the northwest by bands of successively younger Ordovician formations, lie next below the

pre-Chattanooga unconformity (fig. 4, pls. 3 and 4). This situation is due to early uplift and erosion of the westward extension of the Ozark uplift. The ancestral Ozark dome was undergoing differential elevation in Ordovician and Cambrian time and probably earlier. Before burial under the Chattanooga shale, the area was partly peneplaned; hence the Chattanooga sediments overstep various formations along the flanks of the dome.

In Kansas the Chautauqua arch occupies the area south and east of a line extending from about the southeast corner of Miami county to a point near the northwest corner of Sumner county (fig. 3). Such a line approximately coincides with the line of pre-Mississippian outcrop of the contact between the Arbuckle rocks and the overlying St. Peter formation. The St. Peter sandstone, along with other pre-Chattanooga rocks, dips outward from the Chautauqua arch.

North Kansas basin.—The North Kansas basin is a large area north of the Chautauqua arch which was covered by Silurian and Devonian seas and which was the site of extensive sedimentation during Mississippian time (fig. 4, pls. 1 and 2). In eastern Kansas the area north and west of a diagonal line extending from a point near the southeast corner of Miami county southwestward to a point near the northwest corner of Sumner county is included in the North Kansas basin. Devonian and Silurian strata, rocks of late and medial Ordovician age, and the St. Peter sandstone, all of which are absent in the Chautauqua arch area, lie between the Chattanooga shale and the Arbuckle rocks in the North Kansas basin. Lee (1943, pp. 101-114) has thoroughly discussed the deformation that occurred in this area before Chattanooga time.

MISSISSIPPIAN AND LATER STRUCTURES

Lee (1943, p. 115) has shown that movements of minor importance took place along the axis of the present Nemaha anticline during Mississippian time. However, deformations that occurred during early Pennsylvanian time produced the present main subsurface structural elements in eastern Kansas (fig. 5). These structures include the Nemaha anticline and small parallel folds such as the Voshell anticline, the Cherokee and Forest City basins, and the low Bourbon arch between the two basins. Farther west and extending into western Kansas are the Salina and Sedgwick basins.

Nemaha anticline.—The Nemaha anticline, whose buried crystalline core is often referred to as the Nemaha mountains or granite ridge, trends south-southwest across Kansas from Nemaha county to Sumner county. Mississippian and older rocks are tilted and eroded on the flanks of this uplift. Pennsylvanian sediments on the anticline overstep and overlap rocks ranging in age from pre-Cambrian to Mississippian. Pennsylvanian strata lie upon pre-Cambrian rocks in a belt extending in a northeastward-trending direction from a point in T. 11 S., R. 10 E., and in isolated areas farther south. The extreme northern part of the ridge of pre-Cambrian granite in the Nemaha anticline was not covered by Pennsylvanian sediments until Virgilian time. Older Pennsylvanian beds overlap and overstep pre-Cambrian and Paleozoic rocks along the southern part of the axis of the ridge.

Forest City basin, Bourbon arch, and Cherokee basin.—Thinning of Cherokee sediments in a narrow area extending northwestward from Bourbon county to Lyon county indicates that briefly eastern Kansas was separated into two depositional basins, the Forest City basin in the north and the Cherokee basin in the south. The low separating structure expressed in pre-Pennsylvanian rocks is known as the Bourbon arch (Lee, 1943, fig. 2). The Forest City basin extends into northwestern Missouri, southeastern Nebraska, and southwestern Iowa. Pennsylvanian sedimentation seemingly began earlier in the Forest City basin than in the Cherokee basin. The Cherokee basin, however, is the northern or Kansas part of a sedimentation area that extended across eastern Oklahoma, and Pennsylvanian rocks older than any known in the Forest City basin occur in northeastern Oklahoma.

Salina basin.—The Salina basin (fig. 5) lies between the Nemaha anticline and the Central Kansas uplift. The greatest thickness of Mississippian rocks there is in the western part adjacent to the Central Kansas uplift. Pennsylvanian sediments were laid down in the Salina basin after Mississippian strata had been peneplaned. Washington, Clay, and Dickinson counties in eastern Kansas are in the Salina basin. Detailed studies of stratigraphic and structural conditions in the Salina basin are now being made by the State Geological Survey of Kansas in cooperation with the Federal Survey.

Sedgwick basin.—A basinal area southeast of the Central Kansas uplift and west of the Nemaha anticline is called the Sedgwick

basin (Moore and Jewett, 1942, p. 7). It is differentiated from other structural provinces partly because it is more or less separated geographically from northward and westward continuations of other basinal areas and partly because of the general nature of geologic structure and oil and gas occurrence in the region. Large amounts of oil and gas are produced in the Sedgwick basin area, mainly from anticlinal folds on trends generally parallel to those of the Nemaha anticline. Marion county and western Butler county in eastern Kansas are in the Sedgwick basin.

Prairie Plains monocline.—In eastern Kansas and part of neighboring states, outcropping Permian and Pennsylvanian rocks dip gently in a general westward direction. This regional dip, which generally is about 20 feet per mile, is modified locally, especially in the area of the Nemaha anticline. Because of this regional dip, the area is called the Prairie Plains monocline. Outcropping Pennsylvanian rocks dip gently outward from the Ozark dome, and Permian beds, whose strike is more nearly directly north-south, dip westward into a Mesozoic basin. Hence the so-called monocline is a large, more or less indefinitely limited tectonic element. It is chiefly post-Permian in age. Overstep of Cretaceous rocks on beveled Permian beds in eastern Kansas and on beveled Pennsylvanian rocks in southeastern Nebraska and southwestern Iowa indicates pre-Cretaceous age for the Prairie Plains structure.

Minor Structural Features

The regional westward dip of Pennsylvanian and Permian rocks in eastern Kansas is modified by small more or less local anticlines, synclines, domes, and basins. There are many places in which dips to the east, north, or south amount to several feet per mile. Structural maps compiled from altitudes measured on limestones or other key beds and covering an area of a few square miles almost invariably show these structures. Many of them are known to contain oil or gas or both. However, a great amount of oil production in eastern Kansas is from lenticular sand bodies that in most cases are called shoestring sands. In other words, this oil accumulation in Pennsylvanian rocks in eastern Kansas was localized by changes in porosity of the strata. A combination of porosity changes and anticlinal structures is responsible for the oil and gas accumulations. Locally oil and gas have accumulated in curved portions of shoestring sands that lie in a relatively high

position due to regional dip of the beds (Rich, 1926, p. 579). Rich found that accumulation in the Bush City shoestring and the Colony-Welda gas pool in Anderson county was probably due to this relationship. Rich wrote:

> In the case of the Colony-Welda gas pool, the sand, which southwest of Colony carries water, extends diagonally up the regional dip out of the water; turns north along the strike for several miles, filled with gas all the way; and finally turns northwestward down the regional dip and again runs into water.

ALLEN COUNTY

Gas was discovered in Allen county near Iola in 1873. Oil was discovered about 10 years later in the vicinity of Humboldt. The geology and oil and gas resources of Allen county were described by Moore and Elledge (1920).

Surface Rocks

The surface rocks of Allen county consist of alternating beds of limestone and shale and some beds of sandstone. The rocks exposed in the county belong to the Lansing, Kansas City, Bronson, and Bourbon groups of Pennsylvanian age (Moore and Landes, 1937). The Lansing rocks (fig. 8) are about 90 feet thick in the county. The Stanton limestone is exposed in the northwestern part of the county and the Plattsburg limestone caps the uplands in a broad belt east of the Stanton outcrops. All the rocks of the Kansas City group are exposed in the eastern part of Allen county. Their average thickness is about 210 feet. The entire Bronson group is exposed in the southeastern part of the county. The upper part of the Bourbon shale is exposed in the northern part of T. 26 S., R. 31 E.

Subsurface Rocks

Subsurface geologic conditions along the northern boundary of Allen county are shown diagrammatically on plate 3.

Pennsylvanian rocks.—The Bourbon rocks in Allen county are about 100 feet thick and consist mostly of shale. The Marmaton rocks are about 165 feet thick; they consist of alternating beds of limestone and shale, some sandstone, and a few thin beds of coal. The Cherokee shale in Allen county is about 340 feet thick. It consists of light and dark shale, sandy shale, sandstone, and a few thin beds of limestone and coal. Lenticular sandstones in the Cherokee shale yield oil and gas.

Mississippian rocks.—The Mississippian rocks in Allen county consist of limestone (some cherty or dolomitic) and shale. The Warsaw, Burlington, Sedalia, and Chouteau limestones and the Chattanooga shale (probably of Mississippian age) (Lee, 1940, pl. 3) are present in the county. The total thickness of Mississippian limestones in the county averages about 300 feet (Lee, 1939, pl. 1). The Chattanooga shale is less than 50 feet thick.

Ordovician and Cambrian rocks.—The Arbuckle limestone of Ordovician and Cambrian age lies immediately below the Chattanooga shale in Allen county. Its thickness in a well drilled at Iola is about 750 feet.

Pre-Cambrian rocks.—The record of a well drilled at Iola indicates that pre-Cambrian metamorphic rock was reached at 2,160 feet. The well was drilled to a total depth of 3,440 feet. Seemingly granite was not found in this well.

Oil and Gas Developments

Most of the western half of Allen county is included in the **Iola, Iola Northeast**, and **Humboldt-Chanute** oil and gas producing areas. Production in these areas is from the "Bartlesville sand" in the Cherokee shale, which is encountered at depths ranging from 650 to 800 feet. The "Bartlesville sand" ranges in thickness from 10 to 100 feet, and has an average thickness of about 25 feet. It lies about 200 feet below the Fort Scott limestone. The northwestern part of the county is an important gas-producing area and the southwestern part is an important oil-producing area. Some of the gas wells had initial open flows of about 15,000,000 cubic feet per day. The oil is a low-gravity crude; the gravity ranges from 18 to 38° Bé. Some of the wells had initial productions of about 100 barrels per day.

Information pertaining to water flooding in this county has been obtained chiefly from United States Bureau of Mines Report of Investigations 3761 (Grandone, 1944, pp. 25-52).

There are four water-flooding projects in the **Humboldt-Chanute** area. The Matson, Towne, and Melvin water-flooding project was started in April, 1938, in sec. 18, T. 26 S., R. 18 E. The first important increase in oil production occurred six months after flooding began. Between the time of starting the project and November 1, 1942, 193,375 barrels of oil were recovered; 995,895 barrels of water had been injected. When water flooding was started

18 barrels of oil per day were being produced from nine wells. The Carl Weiner project, in sec. 23, T. 26 S., R. 18 E., was started in October, 1941. An increase in yield was noted two months after the beginning of water injection. To November 1, 1942, 13,182 barrels of oil were recovered as the result of injecting 86,993 barrels of water. The Williams Producing Company project, in sec. 17, T. 26 S., R. 18 E., was started in October, 1941. Here the depth to the top of the "Bartlesville sand" is 810 feet. During the first 13 months of operation 15,998 barrels of oil were produced as the result of injecting 65,803 barrels of water. The T. B. Wilson No. 2 water-flooding project, in secs. 16 and 22, T. 26 S., R. 18 E., was started in August, 1938. The first increase in production was noted three months after injection was initiated. To November 1, 1942, 135,354 barrels of oil were recovered and 1,089,712 barrels of water had been injected.

The **Moran** oil and gas producing area extends west of Moran to La Harpe, east to the county line, and about 10 miles north and south. Oil and gas are produced in this area from the "Bartlesville sand," which is about 25 feet thick and lies at a depth of about 680 feet. In the Moran area the "Bartlesville" is about 235 feet below the Fort Scott limestone. Oil and gas were discovered in this area in 1903. Water flooding to increase oil production was begun in this area in 1937 (Landes, 1937, p. 5).

The **Elsmore** pool is a shoestring sand pool about 2 miles east of Elsmore. It is about one-half mile wide and more than 5 miles long. The "Bartlesville sand" is about 55 feet thick in this pool. It lies at a depth of about 550 feet and is about 160 feet below the Fort Scott limestone. The Fees and Hoyt water-flooding project, in sec. 3, T. 26 S., R. 21 E., was started in September, 1941. The top of the "Bartlesville sand" into which water is being injected is about 600 feet deep. When flooding was started all wells on the property were yielding a total of only about 1½ barrels of oil per day. In 14 months, 10,958 barrels of oil were recovered as the result of injecting 170,688 barrels of water.

There are four water-flooding projects in the **Elsmore West** field. The Conklin and Cooper water-flooding project, in sec. 18, T. 26 S., R. 21 E. and secs. 13 and 24, T. 26 S., R. 20 E., is the first that was started in the county. The property was first drilled in 1918. At the time water flooding was started, only 12 barrels of oil per day were obtained from all wells. Production is from the

"Bartlesville sand." By November 1, 1942, 78,408 barrels of oil had been produced as a result of water flooding. The Chas. J. Cooper water-flooding project, in sec. 18, T. 26 S., R. 21 E., was started in July, 1942. Production is from the "Bartlesville sand." The Fetty and Wagner project, in sec. 24, T. 26 S., R. 20 E., was started in January, 1939. When the project was started, 10 wells on the property yielded about 4 barrels of oil per day. To November 1, 1942, 16,845 barrels of oil were produced as a result of injecting 87,660 barrels of water. At that time the oil-production rate was increasing. The Keas Drilling Company water-flooding project, in sec. 18, T. 26 S., R. 21 E., was started in June, 1942. Production had been suspended for some time when water flooding began. To November 1, 1942, the cumulative oil production resulting from injecting 3,698 barrels of water was 576 barrels.

The McIntire and Travis water-flooding project was started in August, 1937, in secs. 3 and 10, T. 24 S., R. 21 E., in the **Davis-Bronson** field (known locally as the Alba pool). At the time water flooding was started, cumulative oil recovery by primary methods amounted to 2,500 barrels per acre, and the total production from the property was about 10 barrels per day. In 63 months 3,836,896 barrels of water were injected and 555,822 barrels of oil were recovered. This amounted to 5,053 barrels per acre. The Tindle Oil Company water-flooding project, which includes sec. 22, T. 23 S., R. 21 E. in this area in Allen county, is described under Bourbon county.

The Shell Oil Company water-flooding project was started in October, 1937, in sec. 33, T. 24 S., R. 21 E. in the **Bronson-Zenia** field. The tract was originally developed in 1903. Vacuum was applied in 1924 and continued for about 2 years. Air was injected into the formation from 1926 to 1936. When water-flooding started the daily production was about 5 barrels of oil per day from the entire property. An increase in production was noted one month after flooding was begun. During 19 months of operation 92,850 barrels of oil were recovered and 1,453,260 barrels of water were injected.

The oil and gas fields in Allen county as designated by the Oil Field Nomenclature Committee of the Kansas Geological Society are given in table 3. Oil and gas production statistics are given in tables 4 and 5.

TABLE 3.—*Oil and gas fields in Allen county, Kansas*

(As designated by the Oil Field Nomenclature Committee of the Kansas Geological Society, November 15, 1944)

Name	Location
Bayard (Abandoned)	T 24 S, R 20 E, secs. 1, 12, 13
	T 24 S, R 21 E, secs. 5 to 8, 18
Bronson-Zenia[1]	T 24 S, R 21 E, secs. 15, 21, 22, 27, 28, 32 to 34
	T 25 S, R 21 E, secs. 3, 4, 7 to 10, 15 to 18, 20 to 22, 28, 29
Colony West[2]	T 23 S, R 18 E, secs. 21, 22, 27 to 29
Davis-Bronson[1 2]	T 23 S, R 21 E, secs. 22, 34
	T 24 S, R 21 E, secs. 3, 10, 15, 16
Elsmore Shoestring[1]	T 25 S, R 21 E, secs. 27, 34
	T 26 S, R 21 E, secs. 3, 9, 10, 15, 16, 21
Elsmore West	T 26 S, R 20 E, secs. 12 to 14, 21 to 24, 26, 27
	T 26 S, R 21 E, secs. 5 to 8, 18
Humboldt-Chanute[3]	T 25 S, R 17 E, secs. 11, 13, 14, 23 to 26, 35, 36
	T 25 S, R 18 E, secs. 18 to 21, 28 to 33
	T 26 S, R 17 E, secs. 1, 2, 11 to 14, 23 to 26, 35, 36
	T 26 S, R 18 E, secs. 1 to 36
	T 26 S, R 19 E, secs. 1 to 36
	T 26 S, R 20 E, secs. 18, 19, 28 to 34
Iola	T 23 S, R 19 E, secs. 32 to 34
	T 24 S, R 17 E, secs. 24 to 26, 35, 36
	T 24 S, R 18 E, secs. 1 to 6, 8 to 17, 19 to 36
	T 24 S, R 19 E, secs. 3 to 10, 14 to 36
	T 24 S, R 20 E, sec. 31
	T 25 S, R 17 E, secs. 1, 2
	T 25 S, R 18 E, secs. 1 to 15
	T 25 S, R 19 E, secs. 1 to 11, 14 to 18
Iola Northeast	T 24 S, R 19 E, secs. 1, 12
	T 24 S, R 20 E, sec. 7
Jonestown	T 24 S, R 20 E, secs. 9, 15, 16, 21
Moran	T 24 S, R 20 E, secs. 33 to 35
	T 25 S, R 19 E, secs. 1, 11 to 14, 22 to 24, 26 to 35
	T 25 S, R 20 E, secs. 2 to 8, 10 to 12, 17 to 20
Neosho Falls[4]	T 23 S, R 17 E, secs. 26, 35, 36
	T 24 S, R 17 E, sec. 2
Savonburg[1]	T 26 S, R 21 E, secs. 22, 27, 28, 33
Savonburg West	T 26 S, R 20 E, secs. 25, 35, 36
	T 26 S, R 21 E, secs. 30, 31
Seibert	T 26 S, R 20 E, secs. 2 to 5, 8 to 11, 15, 16
Seibert North	T 25 S, R 20 E, secs. 21 to 23, 26 to 29, 32 to 34

[1] Also in Bourbon county (see table 12)
[2] Also in Anderson county (see table 6)
[3] Also in Neosho, Wilson, and Woodson counties; includes fields formerly known as Diamond, Earlton, and Nyman (see tables 75, 86, 89)
[4] Also in Woodson county (see table 89)

TABLE 4.—*Reported monthly production of oil in Allen county, Kansas, in barrels*

Month	1941	1942	1943
January	25,739	19,630	28,522
February	22,030	17,450	31,056
March	27,859	19,783	34,848
April	25,681	19,536	34,486
May	26,966	21,985	34,858
June	26,924	20,690	33,169
July	26,238	22,244	37,358
August	27,523	34,326	22,851
September	28,266	32,752	21,930
October	24,742	33,354	34,971
November	25,346	28,495	33,903
December	25,586	13,843	31,288
Totals	312,900	284,088	379,240

TABLE 5.—*Natural gas production in Allen county, Kansas*

Year	Thousands of cubic feet
1939	649,377
1940	702,378
1941	644,235
1942	664,624
1943	718,726

ANDERSON COUNTY

Gas was found in Anderson county near Garnett in 1904, and oil was found in the same district a few years later. Peak production was reached several years ago, but water flooding is now bringing the county back into a position of importance. All production is from Pennsylvanian rocks.

The geology and oil and gas resources of Anderson county were described by Charles (1927). Carefully made observations were recorded by Charles, and his conclusions should be considered by anyone interested in developing untested areas or in increasing production by secondary recovery methods.

SURFACE ROCKS

With the exception of unconsolidated surficial beds of sand and gravel which range in age from Recent to Tertiary (?), the outcropping rocks of Anderson county belong to the Shawnee, Douglas, Pedee, Lansing, Kansas City, and Bronson groups of the Pennsyl-

vanian system (Moore and Landes, 1937). The oldest rocks crop out in the southeastern part of the county and the youngest Pennsylvanian rocks are exposed in the northwestern part. The youngest exposed Pennsylvanian rock is the Plattsmouth limestone member of the Oread formation and the oldest exposed rock is the Bethany Falls limestone member of the Swope formation.

The Oread limestone, which caps hills in the northwestern part of the county, is the only formation of the Shawnee group (fig. 7) present in Anderson county. All recognized units of the Douglas group, with the possible exception of the Robbins shale, are believed to be exposed in the county. The Williamsburg coal and the Ireland sandstone are rather persistent units of the Lawrence shale. There is some sandstone included in the Vinland shale. The thickness of the Douglas group in the county is about 300 feet. The Westphalia limestone occurs about 60 feet from the base, and the Haskell limestone 60 or 75 feet higher. It is difficult to separate the Stranger formation from the underlying Weston shale at some exposures and on soil-covered slopes, and it is nearly impossible to separate them in the subsurface by means of drillers' logs.

The Pedee is the uppermost group in the Missourian series (fig. 8). It is limited at the top by a regional disconformity which separates it from the overlying Virgilian series. The Iatan limestone is not known to occur in Anderson county. Probably it and the upper part of the Weston shale were removed by erosion before deposition of the overlying rocks of Virgilian age. Based on surface and subsurface observations, the Weston shale in Anderson county ranges in thickness from a featheredge to about 30 feet.

The total thickness of the Lansing group (fig. 8) in Anderson county is about 110 feet. The units vary in thickness. The thickness of the Stanton limestone is generally about 50 feet. At outcrops the Vilas shale ranges from less than 2 to about 30 feet. The Plattsburg limestone in the shallow subsurface is about 50 feet thick, but where exposed its thickness is generally somewhat less. Thin shales are included in the Stanton and Plattsburg formations. The most prominent escarpments in the county are capped by the Stanton and Plattsburg limestones. Cliffs of Plattsburg limestone are especially noticeable. The lines of outcrop extend in a general north-south direction across the east-central part of the county. The Stanton limestone, covered only by thin residual soil or by

deposits of gravel, underlies the surface in a wide area west of its outcrop.

Rocks of the Kansas City group (fig. 8) are exposed in the eastern part of Anderson county. The Wyandotte limestone seems to be represented only by calcareous sandy shale and very thin limestone beds. The Westerville limestone is believed to be absent in the county. Hence the rocks of the Kansas City group, whose total thickness is about 250 feet, crop out in an area characterized by the prominent Iola limestone escarpment and the thick Wea-Fontana and Lane-Bonner Springs shale sections.

The Bronson group of limestones and shales (fig. 8) is approximately 100 feet thick in Anderson county. No single exposures showing the whole group are known in the county. The upper part of the Winterset limestone (upper member of Dennis formation) is generally eroded from the top of the Bronson escarpment, and rocks below the Bethany Falls limestone (upper member of the Swope formation) are not exposed. Rocks of the Bronson group in Anderson county are characterized by flinty and oölitic limestones in the Winterset and Bethany Falls limestones and by black platy shale in the Stark shale member of the Dennis formation. These rocks crop out only in the southeastern part of the county.

Subsurface Rocks

Hundreds of wells, most of which did not reach Mississippian rocks, have been drilled in Anderson county. Several wells have penetrated Mississippian or deeper strata, however. The following discussion of rocks older than Mississippian is based largely on data obtained from the record of the Lambert and others No. 1 Wiggins well, in the SE¼ NE¼ sec. 12, T. 23 S., R. 17 E., which was drilled to a total depth of 2,303 feet. Subsurface geologic conditions along the southern boundary of Anderson county are shown in plate 3.

Pennsylvanian rocks.—The Bourbon shale has an average thickness of about 175 feet in Anderson county. Lenticular sandstones occur in its upper part. Marmaton rocks are about 175 feet thick in the county. They include shale, limestone, and sandstone. All formations and most members known from surface exposures of the Marmaton can be recognized in most drillers' logs. Care must be taken in using the base and top of the Marmaton rocks as subsurface markers. Locally the Fort Scott limestone is under-

lain by a lenticular limestone in the upper part of the Cherokee shale, and locally the upper limestone formation of this group, the Lenapah, is absent. Sandstone in the Bandera shale formation, commonly called "Wayside sand," has yielded some oil in the county.

The average thickness of the Cherokee rocks in Anderson county is about 400 feet. The Cherokee is composed principally of dark shale containing sandstone lenses and thin limestone and coal beds. A thin limestone called Ardmore is a persistent marker in the upper part of the Cherokee rocks. Lenticular sandstones near the top of the Cherokee shale are called "Squirrel sand" by drillers. The "Bartlesville sand" or "Colony sand" lies in the upper middle part of the Cherokee, and thicker lenticular sandstones occur in the basal part. The Cherokee shale lies on the eroded Mississippian limestone surface and is conformably overlain by the Fort Scott limestone.

Mississippian rocks.—Mississippian limestones lie next below the Cherokee shale. Their total thickness is about 300 feet. Drillers commonly report shaly zones in the lower part and sandstone in the middle part. The latter is the "first break" of drillers. Cherty limestone is characteristic of the "Mississippi lime" in eastern Kansas. Lee (1939, 1940) has studied carefully the subsurface Mississippian rocks in Kansas and has shown several disconformities within them. Lee (in Jewett, 1940a, fig. 2B) has shown that rocks of Meramecian, Osagian, and Kinderhookian ages are present in Linn county, and it is probable that sample studies would show the presence of the same subdivisions in Anderson county.

Shale assigned to the Chattanooga formation, about 40 feet thick and seemingly conformable with the overlying Mississippian limestone, is believed to underlie all of Anderson county.

Ordovician rocks.—The Chattanooga shale lies upon Ordovician rocks in a large triangular area in southeastern Kansas and extends into Missouri and Oklahoma (McClellan, 1930; Ockerman, 1935, fig. 2; Lee, 1940, fig. 1); therefore, rocks representing a long interval of Silurian and Devonian time are absent there. McClellan (1930) has shown that the Simpson (St. Peter) sandstone dipping under younger Ordovician rocks to the northwest is present in the northwestern corner of Anderson county. This indicates that the overlying Chattanooga shale oversteps various Ordovician

strata. This condition resulted from erosion on the Chautauqua arch before the Chattanooga shale was deposited. The Chattanooga shale lies on slightly upturned and intensely eroded Ordovician strata that in Anderson county dip to the northwest away from the ancient Chautauqua arch. Because of this condition there is a possibility of stratigraphic oil traps in Ordovician rocks.

Cambro-Ordovician rocks.—The Arbuckle rocks include about 700 feet of strata, mostly dolomite but containing some shale in the lower part and perhaps some sandstone. Keroher (in Jewett, 1940a, pp. 12-14, pl. 2A) was able to differentiate Cambrian and Ordovician strata and to subdivide rocks of each system in the Holeman and Edwards No. 9 Pollman well, in the SE¼ sec. 35, T. 19 S., R. 24 E., Linn county. It is probable that a study of well cuttings from Anderson county would reveal a sequence of Arbuckle rocks similar to that in Linn county. Available data indicate a rather uniform total thickness for the Arbuckle rocks in the two counties.

Cambrian rocks.—About 30 feet of sandstone in Anderson county lying on granite is correlated with the Lamotte sandstone of Missouri.

Oil and Gas Developments

The first well in Anderson county of which we have record was drilled in about 1885 in the SW¼ sec. 6, T. 20 S., R. 20 E. A good show of oil was reported, but because gas was being sought the well was not completed as an oil well. Another early well was drilled in the SE¼ sec. 19, T. 20 S., R. 20 E. A small flow of gas was encountered, but the well was abandoned at about 500 feet. During the next several years only a few scattered wells were drilled. Gas was discovered a mile southeast of Garnett in 1904. An important field which supplied gas to the city of Garnett was soon developed. As drilling continued to the northeast, both oil and gas were discovered in a narrow discontinuous belt between Garnett and Greeley. Gas was discovered near Colony in the summer of 1921. Rapid development followed and in less than 2 years an unbroken strip of oil and gas-producing territory 12 miles long was opened between Colony and Mount Ida (Charles, 1927, p. 14). Oil was discovered about 1 mile southeast of Garnett in September, 1921. This opened the Garnett shoestring which extends westward into sec. 2, T. 21 S., R. 19 E. and south and west to sec. 14, T. 21 S., R. 19 E.

Although several deep tests have been drilled in Anderson county, all oil and gas production has been from Pennsylvanian rocks. Production is from sandstone in the Bandera shale and from sandstones in the Cherokee rocks. The shoestring type of sandstone body is the common form.

The oil and gas fields in Anderson county as designated by the Oil Field Nomenclature Committee of the Kansas Geological Society are listed in table 6.

Information about water-flooding projects in this county has been obtained chiefly from United States Bureau of Mines Report of Investigations 3761 (Grandone, 1944, pp. 52-61).

The **Bush City Shoestring** oil pool extends from sec. 27, T. 20 S., R. 21 E. to sec 14, T. 21 S., R. 19 E. This is a narrow pool 13 miles long and averaging about one-quarter of a mile in width. It seemingly is a continuation of the Goodrich shoestring in Linn county. Production is from an elongated sand body that lies 20 to 40 feet below the top of the Cherokee shale. This sand body is at approximately the same horizon as is the sand body underlying the Pottawatomie valley from southwest of Garnett to Greeley. Charles (1927, p. 44) believed these sand bodies to be channel fillings. Water flooding was introduced in this pool in June, 1939, by the Reed Oil Company project in secs. 13 and 18, T. 21 S., R. 20 E. Although air injection and vacuum had been previously used to stimulate production, only 13 barrels of oil per day were being produced from the lease when flooding operations started. During 41 months of water flooding, 145,740 barrels of oil were produced. This was a recovery of 1,619 barrels of oil per acre and an injection of 9.3 barrels of water per barrel of oil produced. In 1942 there were 32 water input wells and 37 oil wells. The Connelly and Loriaux water-flooding project, in sec. 8, T. 21 S., R. 21 E., had 7 injection wells and 11 oil wells on November 1, 1942. On June 30, 1941, when water flooding was started, daily production from all wells on the property is reported to have been only 10 barrels. The first increase in oil production was noted in December, 1941, and the cumulative production from July, 1941, to November 1, 1942, was 32,504 barrels. This is a recovery of 1,757 barrels of oil per acre for an injection of 12.8 barrels of water per barrel of oil produced.

The **Colony** oil pool is in secs. 15, 16, 21, 22, 26 to 29, 32, and 33, T. 22 S., R. 19 E. Production is from the "Squirrel sand" near the

TABLE 6.—*Oil and gas fields in Anderson county, Kansas*

(As designated by the Oil Field Nomenclature Committee of the Kansas Geological Society, November 15, 1944)

Name	Location
Blue Mound[1]	T 22 S, R 21 E, secs. 27, 34
	T 23 S, R 21 E, sec. 3
Bush City Shoestring	T 20 S, R 21 E, secs. 27, 28, 32 to 34
	T 21 S, R 19 E, secs. 12 to 14
	T 21 S, R 20 E, secs. 7 to 9, 13 to 18
	T 21 S, R 21 E, secs. 4, 5, 7, 8, 17, 18
Cedar Creek (Abandoned)	T 22 S, R 18 E, secs. 15, 22
Centerville[1]	T 21 S, R 21 E, secs. 3, 4, 10, 15, 22, 27, 34
Colony-Welda	T 21 S, R 19 E, secs. 17, 20 to 22, 25 to 29, 34, 35
	T 22 S, R 19 E, secs. 2 to 4, 9, 10, 15, 16, 21 to 23, 26 to 29, 32 to 34
	T 23 S, R 18 E, sec. 12
	T 23 S, R 19 E, secs. 4 to 9
Colony West[2]	T 23 S, R 18 E, secs. 15, 16
Davis-Bronson[3]	T 23 S, R 21 E, sec. 15
Garnett Shoestring	T 20 S, R 19 E, secs. 26, 33 to 36
	T 20 S, R 20 E, secs. 2, 10, 11, 14, 15, 21 to 23, 27 to 29, 31 to 33
	T 21 S, R 19 E, secs. 1 to 5
	T 21 S, R 20 E, secs. 5, 6
Garnett West	T 20 S, R 19 E, secs. 24, 25
Goodrich-Parker[1]	T 20 S, R 21 E, sec. 34
	T 21 S, R 21 E, sec. 3
Graves	T 20 S, R 21 E, secs. 8, 9, 16, 17, 20, 21, 29, 32
	T 21 S, R 21 E, sec. 5
Greeley[4]	T 19 S, R 21 E, secs. 20, 29, 31, 32
	T 20 S, R 20 E, sec. 1
	T 20 S, R 21 E, sec. 6
Kincaid	T 22 S, R 21 E, secs. 29, 32
	T 23 S, R 20 E, sec. 13
	T 23 S, R 21 E, secs. 4, 5, 7 to 10, 15 to 18
Northcott	T 23 S, R 17 E, secs. 12, 13
	T 23 S, R 18 E, secs. 7, 18
Scipio (Abandoned)	T 19 S, R 20 E, sec. 31
Selma	T 21 S, R 21 E, secs. 21, 22, 28, 33, 34
	T 22 S, R 21 E, secs. 3, 4, 9, 10, 15, 16, 20 to 22

[1] Also in Linn county (see table 59)
[2] Also in Allen county (see table 3)
[3] Also in Allen and Bourbon counties (see tables 3 and 12)
[4] Also in Franklin county (see table 38)

top of the Cherokee shale. The sandstone in most of the wells ranges from 16 to 18 feet in thickness.

The **Garnett Shoestring** oil pool is in secs, 2, 10, 11, 14, 15, 21 to 23, 27 to 29, and 31 to 33, T. 20 S., R. 20 E.; secs. 26 and 33 to 36, T. 20 S., R. 19 E.; secs. 5 and 6, T. 21 S., R. 20 E.; and secs. 1 to 5, T. 21 S., R. 19 E. The producing sand is a part of the same shoestring which produced in the Greeley pool. The primary development in this pool took place between 1921 and 1923. Water-flooding operations were started in the pool in December, 1936, by the Brundred Oil Corporation, and 260 acres had been put under water drive by January 1, 1943. At that time there were 135 injection wells and 144 oil wells. The cumulative oil production from December, 1936, to January 1, 1943, was 658,997 barrels. Enough pressure is applied to cause the wells to flow. Between 1929 and 1936 parts of the pool had been repressured by air.

The **Greeley** oil pool, now abandoned, is in secs. 29 and 31, T. 19 S., R. 21 E. This is in the northeast extension of the "Pottawatomie Valley field" of Charles' report (1927, p. 49). Oil was produced from sandstone near the top of the Cherokee shale. This sandstone is a shoestring that extends the entire length of the "Pottawatomie Valley field" and beyond. It is locally known as "the 800-foot sand" or the "Squirrel sand."

The **Welda** oil and gas-producing area is in the S½ secs. 34 and 35, T. 21 S., R. 19 E. and in secs. 2, 3, 9, 10, 15, and 16, T. 22 S., R. 19 E. Oil is produced from the "Squirrel sand." A small amount of gas has been produced from sandstone in the Bandera formation, and gas is produced from the "Colony sand."

The **Colony** gas pool is at the southern end of the Colony-Mount Ida trend. The pool is centered in the town of Colony. It extends southwestward from sec. 33, T. 22 S., R. 19 E. to sec. 12, T. 23 S., R. 18 E. This pool was drilled out rapidly and great quantities of gas were wasted. Closely spaced drilling on town-lot locations resulted in many wells being exhausted after a few weeks. The first wells were drilled in 1921. The pool is now nearly abandoned. Production is from the "Colony sand."

The **Polkinghorn** oil and gas-producing area is in secs. 21, 22, 26, 27, 28, 34, and 35, T. 21 S., R. 19 E. Gas has been produced in this area from three zones: a sandstone in the Bandera formation, a sandstone near the top of the Cherokee shale, and the "Bartlesville" or "Colony sand." Most of the gas has been produced from

the "Colony sand," which has a maximum thickness of more than 100 feet. The largest gas well is reported to have had an initial flow of 32 million cubic feet. The maximum open flow of the field is estimated to have been 250 million cubic feet. The original rock pressure was 280 pounds per square inch (Charles, 1927, p. 61). Oil was produced in small disconnected areas from the "Squirrel sand." Initial daily productions of the wells ranged from 25 to 125 barrels.

The **Schermerhorn-Selma-Kincaid Shoestring** oil and gas area is in the SW¼ sec. 3, E½ sec. 4, secs. 10, 15, 22, and 27, T. 21 S., R. 21 E.; secs. 9, 10, 20, 21, 29, and 32, T. 22 S., R. 21 E.; and secs. 4, 5, and 9, T. 23 S., R. 21 E. Oil is produced at the north and south ends of the shoestring; the central part bears gas. Production is from the "Bartlesville sand." In June, 1942, the Woodson Pipeline and Producing Company started a water-flooding project in secs. 9 and 10, T. 22 S., R. 21 E. The first important increase in rate of oil production took place three months after water injection began. At the time water flooding was started, the entire property produced about 20 barrels of oil per day. In five months, 80,372 barrels of water were injected and 2,759 barrels of oil were recovered. Seven water input wells and 15 oil wells were being operated. Air and gas injection also have proved to be successful in this area.

Oil and gas have been produced in Anderson county in a few scattered areas other than those described above. Some gas has been produced 3 miles west and 1 mile south of Garnett from the "Colony sand." Several years ago a small oil pool was discovered in sec. 16, T. 23 S., R. 18 E. Oil was produced there from the "Squirrel sand." A small pool in sec. 28, T. 21 S., R. 21 E. produced gas from the "Colony sand." A small amount of gas has been produced from a thick sand at the base of the Cherokee shale near Northcott in the southwestern part of the county.

Reported monthly production of oil in Anderson county in 1941, 1942, and 1943 is given in table 7. Yearly gas production figures are given in table 8.

ATCHISON COUNTY

Oil and gas in commercial quantities have not been found in Atchison county. Testing, especially of deeper formations, has not been sufficient to disprove the area as potential oil and gas territory. Atchison county is in the Forest City basin and on the

TABLE 7.—*Reported monthly production of oil in Anderson county, Kansas, in barrels*

Month	1941	1942	1943
January	12,317	33,630	41,207
February	12,981	35,603	38,950
March	17,313	43,677	41,592
April	18,846	41,413	43,342
May	15,950	40,508	41,659
June	31,514	40,947	42,089
July	38,077	44,397	43,855
August	37,391	43,595	42,791
September	31,444	43,526	38,082
October	37,335	46,794	37,289
November	37,461	43,034	37,048
December	45,675	44,644	38,699
Totals	336,304	501,768	486,603

TABLE 8.—*Natural gas production in Anderson county, Kansas*

Year	Thousands of cubic feet
1939	62,616
1940	39,254
1941	16,609
1942	9,666
1943	6,696

eastern margin of the North Kansas basin. The outcropping bedrocks are of Pennsylvanian age, and glacial drift occurs in thick deposits.

SURFACE ROCKS

Outcropping Pennsylvanian rocks in Atchison county include those from near the top of the Pennsylvanian system (Pony Creek shale) to the upper part of the Douglas group (fig. 7).

SUBSURFACE ROCKS

Subsurface geologic conditions in Atchison county are shown in plate 1. Depths to some key stratigraphic horizons are listed in table 9.

Pennsylvanian rocks.—Pennsylvanian rocks are about 2,500 feet thick in the northwestern part of Atchison county where nearly the whole section is present.

Mississippian rocks.—According to Lee (1939, pl. 1), the total thickness of Mississippian limestone formations in Atchison county ranges from less than 200 feet in the northwestern part to slightly

more than 400 feet in the southeastern part. The Ste. Genevieve limestone is the uppermost Mississippian formation that has been identified in the county. It lies next below Pennsylvanian rocks in the eastern and northeastern parts of the county (Lee and Payne, 1944, fig. 17). West of the area of the Ste. Genevieve limestone, Pennsylvanian sediments overstep the St. Louis and Spergen limestones and in the western part of the county they lie on the Warsaw limestone. The Warsaw, Burlington-Keokuk, and Gilmore City limestones are believed to be present throughout the county.

TABLE 9.—*Depths to some key horizons in the Wakefield et al. No. 1 National Life well, sec. 17, T. 6 S., R. 20 E., Atchison county, Kansas*

Horizon	Depth, in feet
Base of Oread limestone	350
Top of Stanton limestone	555
Base of Hertha limestone	875
Base of Fort Scott limestone	1,085
Top of Mississippian (Ste. Genevieve) limestone	1,665
Top of Chattanooga shale	2,060
Top of Devonian limestone	2,150
Top of Maquoketa shale	2,425
Top of Viola limestone	2,502
Top of Decorah shale	2,657
Top of St. Peter sandstone	2,675
Top of Arbuckle limestone	2,750

The thickness of the Chattanooga shale in Atchison county ranges from slightly more than 50 feet in the southeastern part to nearly 200 feet in the northwestern part (Lee, 1943, fig. 14).

Pre-Chattanooga rocks.—According to Lee (1943, fig. 12), the thickness of rocks between the base of the Chattanooga shale and the top of the Maquoketa shale ranges from about 200 feet in the southeastern corner of Atchison county to 400 feet in the northwestern corner. In the Wakefield et al. No. 1 National Life well, in sec. 17, T. 6 S., R. 20 E., 275 feet of Devonian limestone was found between the Chattanooga shale and the Maquoketa shale (Lee, 1943, fig. 7). The thickness of rocks between the top of the St. Peter sandstone and the pre-Cambrian floor ranges from about 400 feet in the northwestern part of the county to about 700 feet in the northeastern part (Lee, 1943, fig. 9).

Oil and Gas Exploration

Data on eight wells in Atchison county of which the Geological Survey has records are given in table 10.

Table 10.—*Data on wells in Atchison county, Kansas*

Name of well	Location	Remarks	Total depth, in feet
Scroggins No. 1 Duff	Cen. SE¼ NE¼ sec. 5, T. 5 S., R. 17 E.	No log	1,800?
Carter Oil Co. No. 3 Stratigraphic test	Cen. NE¼ NW¼ SW¼ sec. 10, T. 6 S., R. 19 E.	Top of Arbuckle at 2,894 feet	2,941
Bailor Mfg. Company No. 1 Argol Plant	NE¼ SE¼ NW ¼ sec. 1, T. 6 S., R. 20 E.	Stopped in Bourbon shale	643
Bailor Mfg. Company No. 2 Argol Plant	SE¼ NE¼ NW¼ sec. 1, T. 6 S., R. 20 E.	Stopped in Cherokee shale	1,405
Atchison No. 1 Martin	NE¼ SW¼ SW¼ SE¼ sec 33, T. 6 S., R. 20 E.	Stopped in upper Cherokee shale	1,280
Wakefield et al. No. 1 National Life	Cen. NW¼ NE¼ sec. 17, T. 6 S., R. 20 E.	Depths to some horizons given in table 9	2,789
Citizens of Atchison No. 1 Atchison	SW cor. NE¼ sec. 18, T 6 S., R. 21 E.	Diamond drill hole; top Mississippian rocks at 1,300 feet	1,352
Indian Mound Oil Company No. 1 Oak Mills	NE cor. NE¼ sec. 13, T. 7 S., R. 21 E.	Pre-Cambrian at 2,900 feet (?)	3,085?

BOURBON COUNTY

As early as 1906 there were eight oil wells and six gas wells in Bourbon county. The Walnut-Hepler pool in the southwestern part of the county was discovered in 1917. Gas was discovered near Mapleton in 1918. Oil was found near Bronson in 1919. Pro-

duction of oil and gas in Bourbon county is almost entirely from sandstones in the Cherokee shale.

Surface Rocks

The surface rocks of Bourbon county consist of alternating beds of shale, limestone, and sandstone. All outcropping consolidated rocks are of Pennsylvanian age.

The youngest outcropping Pennsylvanian formation is the Chanute shale in the Kansas City group (fig. 8) which crops out in the northwestern part of the county. Bronson rocks crop out in a narrow band along the Bourbon-Allen county line and on the uplands between Marmaton and Little Osage rivers in the northwestern part of Bourbon county. They consist of alternating beds of limestone and shale and some thin beds of sandstone. The three limestone formations of the Bronson group crop out along a steep winding escarpment. The Dennis limestone is present below an extensive dip slope west of the escarpment. The Bronson group has a total thickness of about 110 feet in the county. The Bourbon shale consists of beds of shale and sandstone and a few thin beds of limestone; the total thickness is about 150 feet in Bourbon county. It is separated by a disconformity from the underlying Marmaton rocks. The Marmaton rocks consist of alternating beds of limestone and shale and some beds of sandstone and thin coal. The thickness of the Marmaton rocks in Bourbon county is about 180 feet.

The Cherokee shale (fig. 9) is the oldest outcropping rock in Bourbon county. It is exposed in the eastern part of the county in the valleys of Little Osage and Marmaton rivers and in the southeastern part of the county. The Cherokee consists of beds of shale and sandstone, a few thin beds of limestone, and several beds of coal. Some of the shale is sandy, and part of the sandstone contains shale. The total thickness of the Cherokee shale in Bourbon county is about 350 feet. Only the upper part is exposed.

Subsurface Rocks

Subsurface geologic conditions along the northern boundary of Bourbon county are shown in plate 3. Depths to some formations in the Oklahoma Natural Gas Company No. 1 Stevenson well, in sec. 16, T. 26 S., R. 24 E., are given in table 11.

Pennsylvanian rocks.—Pennsylvanian rocks in Bourbon county have an average thickness of about 500 feet. The Cherokee

shale, of which only the upper part crops out, is about 350 feet thick. The "Squirrel sand," about 20 feet thick, lies a few feet below the top of the Cherokee shale. The "Bartlesville sand" is about 180 feet below the top of the Cherokee and ranges from a few feet to 40 feet in thickness. The "Burgess sand" occurs in the basal part of the Cherokee and is about 10 feet thick.

Mississippian rocks.—The total thickness of Mississippian rocks in Bourbon county ranges from about 300 to 350 feet (Lee, 1939, pl. 1). Mississippian formations present in the county include the Warsaw, Keokuk, Burlington, Reeds Spring, and St. Joe limestones, the Northview shale, and the Compton limestone. The Chattanooga shale is less than 50 feet thick (Lee, 1940, pl. 3). It overlies beveled Ordovician rocks and is seemingly conformable with the overlying Compton limestone.

Ordovician rocks.—Studies of a deep well drilled in sec. 16, T. 26 S., R. 24 E. show the thickness of the Ordovician rocks to be 660 feet. The units identified are the Cotter-Jefferson City dolomite, the Roubidoux formation, the Gasconade and Van Buren dolomites, and the Gunter sandstone.

TABLE 11.—*Depths to some formations in the Oklahoma Natural Gas Company No. 1 Stevenson well in the SW¼ SW¼ sec. 16, T. 26 S., R. 24 E., Bourbon county, Kansas*

Formation	Depth, in feet
Top of Labette shale	35
Top of Cherokee shale	130
Top of Warsaw limestone	490
Top of Burlington-Keokuk limestone	600
Top of St. Joe limestone	790
Top of Sedalia (?) limestone	803
Top of Northview shale	818
Top of Compton limestone	845
Top of Chattanooga shale	900
Top of Sylamore sandstone	913
Top of Cotter-Jefferson City dolomite	915
Top of Roubidoux formation	1,200
Top of Gasconade-Van Buren formation	1,280
Top of Gunter sandstone	1,451
Top of Proctor dolomite	1,476
Top of Eminence dolomite	1,533
Top of Bonneterre dolomite	1,658
Top of Lamotte sandstone	1,760
Top of pre-Cambrian rocks	1,810

Cambrian rocks.—The thickness of Cambrian rocks in Bourbon county is about 300 feet. The Eminence-Potosi dolomite, the Bonneterre dolomite, and the Lamotte sandstone have been identified. They are separated from Ordovician rocks by an unconformity and rest on pre-Cambrian rocks.

Oil and Gas Developments

The locations of oil and gas producing areas in Bourbon county are shown in figure 10. Table 12 lists the oil and gas fields in the county as designated by the Oil Field Nomenclature Committee of the Kansas Geological Society.

Oil and gas have been found chiefly in the western part of Bourbon county. Some of the pools in eastern Allen county extend into Bourbon county. Gas is produced in the **Garland** area in the south-

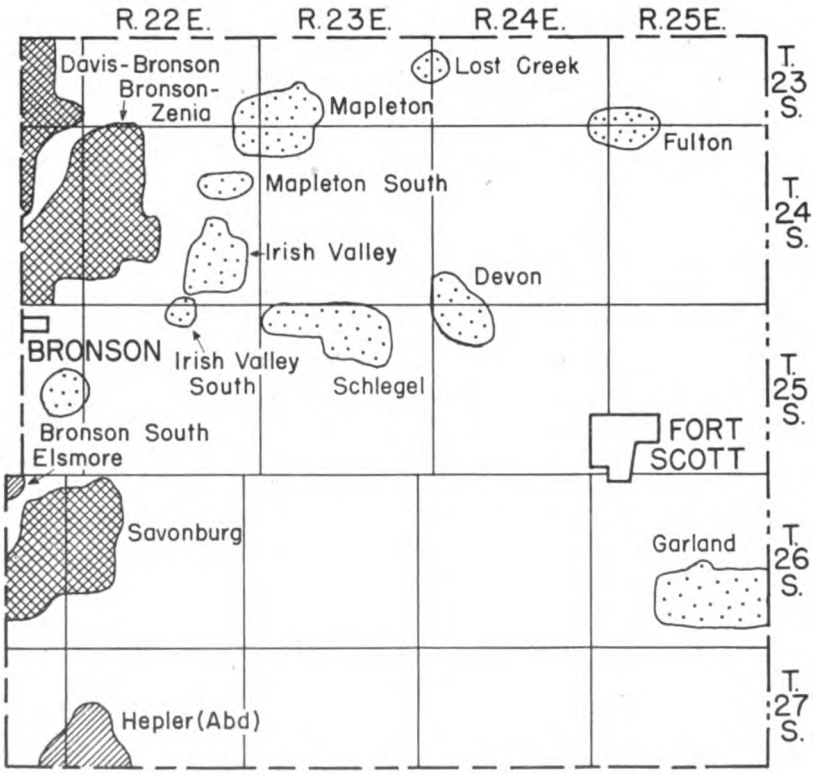

Fig 10. Map of Bourbon county showing oil and gas producing areas. (Gas, dots; oil, diagonal lines; oil and gas, crossed diagonal lines.)

TABLE 12.—*Oil and gas fields in Bourbon county, Kansas*
(As designated by the Oil Field Nomenclature Committee of the Kansas Geological Society, November 15, 1944)

Name	Location
Bronson Southeast	T 25 S, R 21 E, secs. 13, 14, 23, 24
Bronson-Zenia[1]	T 24 S, R 21 E, secs. 1, 11 to 14, 23 to 26, 35
	T 24 S, R 22 E, secs. 5 to 8, 17 to 21, 28 to 30
Davis-Bronson[2]	T 23 S, R 21 E, secs. 23, 26, 35, 36
Devon	T 24 S, R 24 E, sec. 31
	T 25 S, R 24 E, secs. 5 to 8
Elsmore Shoestring[1]	T 26 S, R 21 E, sec. 2
Fulton	T 23 S, R 24 E, sec. 36
	T 23 S, R 25 E, secs. 31, 32
	T 24 S, R 24 E, sec. 1
	T 24 S, R 25 E, secs. 5, 6
Garland	T 26 S, R 25 E, secs. 21 to 24, 27, 28, 35, 36
Hepler (Abandoned)[3]	T 27 S, R 21 E, sec. 24
	T 27 S, R 22 E, secs. 17 to 20
Irish Valley	T 24 S, R 22 E, secs. 23, 25 to 27, 34 to 36
Irish Valley South	T 24 S, R 22 E, sec. 34
	T 25 S, R 22 E, sec. 3
Lost Creek	T 23 S, R 23 E, secs. 24, 25
	T 23 S, R 24 E, secs. 19, 30
Mapleton	T 23 S, R 22 E, sec. 36
	T 23 S, R 23 E, secs. 29, 31 to 33
	T 24 S, R 22 E, sec. 1
	T 24 S, R 23 E, secs. 5, 6
Mapleton Southwest	T 24 S, R 22 E, secs. 11 to 14
Savonburg[1]	T 26 S, R 21 E, secs. 1, 11 to 14, 23, 24, 26
	T 26 S, R 22 E, secs. 5 to 8, 17 to 20
Schlegel	T 25 S, R 23 E, secs. 2 to 6, 9 to 11, 14, 15

[1] Also in Allen county (see table 3)
[2] Also in Allen and Anderson counties (see tables 3 and 6)
[3] Also in Crawford county (see table 30)

eastern part of the county. The **Fulton** gas pool, in sec. 36, T. 23 S., R. 24 E., secs. 31 and 32, T. 23 S., R. 25 E., sec. 1, T. 24 S., R. 24 E., and secs. 5 and 6, T. 24 S., R. 25 E., was discovered in 1943. Fifteen gas wells and one dry hole have been drilled in the Fulton area. Production is from the "Bartlesville sand" at a depth of about 450 feet; the average thickness of the sand is about 20 feet. The wells have an open flow of 150,000 to 750,000 cubic feet per day and a rock pressure of about 225 pounds.

A water-flooding project was started in secs. 22, 23, and 26, T. 23 S., R .21 E., in the **Davis-Bronson** field, in April, 1938. This project was operated by the Streeter Oil Company until June, 1942,

when it was acquired by the Tindle Oil Company (Grandone, 1944, pp. 43-46). Repressuring by air had been practiced for some time, but when water flooding was started the rate of oil production from the entire property had declined to about 35 barrels per day. Approximately 114,800 barrels of oil were produced from April, 1938, to November 1, 1942.

Earnest Oil Company started a water-flooding project in sec. 26, T. 24 S., R. 21 E., in the **Bronson-Zenia** field, in 1940 (Grandone, 1944, pp. 62, 63). Production is from the "Bartlesville sand" which has an average thickness of about 20 feet and lies at a depth of about 665 feet. Water was first injected in April, 1940. The first increase in oil production was in June, 1940. The cumulative oil recovery to November 1, 1942, was 27,456 barrels, a recovery of 2,746 barrels of oil per acre. The ratio of injected water to oil produced is 6.7: 1.

Reported monthly production of oil for 1941, 1942, and 1943 is given in table 13. Gas production statistics for the years 1939 to 1943 are given in table 14.

TABLE 13.—*Reported monthly production of oil in Bourbon county, Kansas, in barrels*

Month	1941	1942	1943[1]
January	190	64	3,752
February	224	86	3,494
March	320	452	3,903
April	322	796	3,688
May	235	989	3,559
June	258	——	4,084
July	——	827	3,750
August	602	860	3,658
September	645	452	3,750
October	645	860	4,348
November	391	774	3,523
December	65	752	3,845
Totals	3,897	6,912	45,354

[1] No production figures for the Alba pool were available before 1943.

TABLE 14.—*Natural gas production in Bourbon county, Kansas*

Year	Thousands of cubic feet
1939	170,500
1940	179,494
1941	193,599
1942	143,146
1943	124,631

BROWN COUNTY

Much information on the stratigraphy and structural geology of Brown and other northeastern Kansas counties has been made available by Lee (1943). Brown county is in the northwestern part of the Forest City basin and on the eastern margin of the North Kansas basin. The deepest part of the Forest City basin is in this county (Lee, 1943, fig. 1). Devonian rocks truncate northwestward-dipping Silurian rocks in this area.

Late in 1944 oil was discovered in the Gall No. 1 Livingood well in the NE¼ NW¼ SW¼ sec. 3, T. 1 S., R. 15 E.

Surface Rocks

The exposed consolidated rocks in Brown county are Permian and Pennsylvanian in age. Thick deposits of glacial drift cause difficulty in outcrop studies.

Permian rocks.—Permian rocks of the Council Grove and Admire groups (fig. 6) crop out in the western half of Brown county. There are few exposures because of the presence of glacial drift.

Pennsylvanian rocks.—Pennsylvanian rocks extending from the uppermost part of the system to the upper part of the Severy shale (fig. 7) are exposed in Brown county. These rocks crop out in the approximate eastern half of the county. Like the Permian rocks, the Pennsylvanian beds are exposed in relatively few places. From outcrop studies and data from shallow drilling, it is evident that both Permian and Pennsylvanian rocks in Brown county are similar to equivalent formations farther south where they are more completely exposed.

Subsurface Rocks

Depths at which some key stratigraphic horizons were reached in the Gall No. 1 Livingood well are given in table 15.

Pennsylvanian rocks.—In western Brown county, where the entire Pennsylvanian section is present under Permian beds, the Pennsylvanian strata have a total thickness of about 2,000 feet.

Mississippian rocks.—The total thickness of Mississippian limestone formations in Brown county ranges from about 50 feet in the northwestern corner to about 225 feet in the southeastern corner (Lee, 1939, pl. 1). According to Lee and Payne (1944, fig. 4), the St. Louis limestone is the uppermost Mississippian limestone formation. It lies next below Pennsylvanian deposits in southeastern Brown county. Successively the Spergen limestone and the War-

TABLE 15.—*Depths to some key horizons in the Gall No. 1 Livingood well in the NE¼ NW¼ SW¼ sec. 3, T. 1 S., R. 15 E., Brown county, Kansas*

Horizon	Depth, in feet
Top of Tarkio limestone	311
Top of Howard limestone	590
Top of Topeka limestone	650
Base of Oread limestone	919
Top of Lansing group	1,018
Base of Hertha limestone	1,335
Top of Mississippian rocks	2,215
Base of Mississippian limestones	2,314
Top of "Hunton" limestone	2,578

saw limestone are overstepped to the west, and in the western part of the county undivided Burlington and Keokuk limestones lie next below Pennsylvanian rocks.

The Chattanooga shale ranges in thickness from about 150 feet in the northeastern part of the county to slightly more than 250 feet in the western part (Lee, 1943, fig. 14). Lee identified 231 feet of Chattanooga shale in the Carter No. 4 stratigraphic test well, in sec. 24, T. 4 S., R. 16 E. (Lee, 1943, fig. 7). In the Gall No. 1 Livingood well, in sec. 3, T. 1 S., R. 15 E., rocks in the upper part of the 264 foot interval (table 15) between the base of Mississippian limestones and the top of the "Hunton" limestone may be post-Chattanooga in age.

Devonian and Silurian rocks.—Lee (1943, fig. 7) identified 163 feet of Devonian limestone and 263 feet of Silurian limestone in the Carter No. 4 stratigraphic test well. In the Wakefield et al. No. 1 National Life well, in sec. 17, T. 6 S., R. 20 E., Atchison county, no Silurian rocks were found and Devonian rocks lie on a reduced thickness of Maquoketa shale.

Ordovician rocks.—In the Carter No. 4 stratigraphic test well, Lee (1943, fig. 7) identified 135 feet of Maquoketa shale, 130 feet of Kimmswick limestone, and 95 feet of undivided Decorah-Plattin limestone. The St. Peter sandstone, 25 feet thick, lies on Arbuckle rocks. The maximum thickness of rocks between the top of the St. Peter sandstone and the pre-Cambrian floor in Brown county is about 400 feet (Lee, 1943, fig. 9).

OIL DEVELOPMENTS

The first test for oil and gas in Brown county of which we have record is a diamond drill hole that was put down at Horton in sec.

33, T. 4 S., R. 17 E., to a depth of 1,080 feet. This well did not reach Mississippian rocks. More recently several wells were drilled in the county.

Oil was discovered late in 1944 in the Gall No. 1 Livingood well in the NE¼ NW¼ SW¼ sec. 3, T. 1 S., R. 15 E. Production is from the upper part of the "Hunton" limestone at a depth of 2,578 feet. The initial production was approximately 100 barrels of oil per day.

BUTLER COUNTY

According to Fath (1921), shallow gas wells were drilled in the vicinity of Augusta as early as 1906. Oil was discovered near Augusta in June, 1914; the first commercial production was in 1915. Production from Butler county in 1918, the peak year, was 36,069,670 barrels. Of this amount, 28,807,680 barrels came from the El Dorado field. A comprehensive report on the El Dorado field was written by Fath (1921), and later Bass (1936) discussed the origin of the shoestring sands of Butler county.

Surface Rocks

The consolidated rocks exposed in Butler county belong to the Sumner, Chase, and Council Grove groups of the Permian system. The youngest rocks crop out along the western boundary of the county; the oldest rocks are exposed in the extreme eastern part.

Only the lower part of the Wellington shale is present in Butler county. It is underlain by the Herington limestone member of the Nolans formation. The maximum thickness of the rocks of the Sumner group in the county is about 65 feet. The Chase group (fig. 6) has a maximum thickness of about 340 feet in Butler county. The Fort Riley and Florence limestone members of the Barneston formation are the surface rocks throughout most of central and eastern Butler county. Their combined thickness ranges from about 80 to 90 feet. The upper part of the Council Grove group is exposed in extreme eastern Butler county. Strata slightly older than the Neva limestone member of the Grenola limestone are the oldest rocks exposed. The total thickness of rocks of the Council Grove group is about 310 feet.

Subsurface Rocks

Subsurface rocks in Butler county are modified by two major structural features, the Nemaha anticline and the older Chautauqua arch. The northwestern flank of the Chautauqua arch under-

lies the southern part of the county (fig. 3). In this area the Chattanooga shale rests upon rocks ranging in age from Devonian (Kimmswick limestone) to Ordovician (Cotter dolomite). Along the Nemaha anticline (fig. 5), which crosses the county from the north to the southwest, Pennsylvanian rocks rest upon the upturned edges of formations ranging in age from Mississippian to Ordovician. Subsurface geologic conditions in Butler county are shown diagrammatically on plate 3.

Permian rocks.—The Admire group has an average thickness of about 190 feet in Butler county. It consists of shale and thin limestones. The Permian rocks are slightly arched over the granite ridge.

Pennsylvanian rocks.—Pennsylvanian rocks in Butler county consist of about 2,100 feet of limestone, sandstone, and shale. The Wabaunsee group consists largely of shale and contains a few thin beds of coal, minor amounts of sandstone, and some thin beds of limestone. It is about 495 feet thick. The Shawnee group in Butler county consists of about 375 feet of interbedded limestones and shales. The Shawnee group contains four sandstones that produce gas (Fath, 1921, p. 43). The Douglas group is about 250 feet thick in Butler county. It is chiefly shale and contains a few thin limestone and sandstone beds. A disconformity separates the Douglas and Pedee groups, but it is difficult to differentiate them in drillers' logs.

The Lansing group is about 150 feet thick in Butler county. It is composed chiefly of limestone. The Kansas City group consists of shale, thick beds of limestone, and thin beds of sandstone. A sandstone called "Layton" which lies near the top of the group yields gas. The Kansas City group is about 150 feet thick. The Bronson group consists of limestone and shale. It is about 190 feet thick in the county. The Bourbon shale is about 125 feet thick. The Marmaton group, which consists of beds of limestone and shale, is about 165 feet thick.

The Cherokee shale in Butler county consists of light and dark shale, lenses of sandstone, a few thin beds of limestone, coal, and red shale. Shoestring sandstone lenses ("Bartlesville sand") in the lower part of the Cherokee yield oil. The average thickness of the Cherokee shale in this county is about 340 feet.

Mississippian rocks.—The Mississippian limestones are about 400 feet in total thickness in Butler county; they are mostly cherty.

Porous zones in Mississippian limestones yield oil. The common thickness of the Chattanooga shale in the county is about 100 feet; locally the Chattanooga is absent.

Ordovician and Cambrian rocks.—The Chattanooga shale or Mississippian limestone lies unconformably on Ordovician rocks. Silurian and Devonian rocks are absent. These structural relations are shown in plate 3. The Ordovician and Cambrian rocks, which are about 750 feet thick, are undifferentiated in Butler county.

Oil and Gas Developments

The locations of oil and gas producing areas in Butler county are shown in figure 11. A list of the oil and gas fields of the county, their locations, and other data are given in table 16.

The **El Dorado** oil and gas field was discovered in 1915, and became the greatest field ever developed in Kansas. It was the leading field in the United States in 1918; the production in that year was 28,807,680 barrels. On September 29, 1915, the Wichita Natural Gas Company started drilling on the Stapleton farm in the SE¼ sec. 29, T. 25 S., R. 5 E. Commercial production, estimated at 50 to 200 barrels per day, was found in a sandstone in the Admire group of Permian rocks at a depth of 660 feet. Late in 1915 deeper drilling found commercial production in the "Stapleton zone" at a depth of 2,465 feet. The discovery well was drilled 46 feet into the pay zone; the initial production of this well was 175 barrels per day. The field was extended to the east by drilling on the Wilson farm in the E½ sec. 27, T. 25 S., R. 5 E., 2½ miles east of the discovery well. In this well the "Stapleton zone" was encountered nearly 200 feet lower than the same zone in the discovery well.

Other developments rapidly extended this field. By the end of 1916 there were 600 producing wells having a total daily production of about 12,000 barrels. In the early part of 1917 several 500-barrel wells were drilled to the "Stapleton zone." In June, 1917, the first gusher was completed. Production of this well was estimated to be from 6,000 to 24,000 barrels per day. Many other gushers were soon drilled; production in all of these was from the "Stapleton zone."

The "Stapleton" is a porous zone of beveled Ordovician rocks which lie immediately below Pennsylvanian rocks. These Ordovician rocks include the Viola limestone, the St. Peter sandstone, and the Arbuckle dolomite. The accumulation of oil in them is the result of anticlinal concentration in a porous zone at the angular

TABLE 16.—*Oil and gas fields in Butler county, Kansas*

Pool	Location	Discovery Date	Production in barrels 1944	Production in barrels Cumulative[1]	No. of Wells	Producing horizon	Depth in feet
Allen	T 26 S, R 3 E, sec. 1		3,563		1		
Augusta	T 27 S, R 4 E, secs. 24 to 26, 35 T 28 S, R 4 E, secs. 2, 8 to 11, 15 to 17, 20 to 22, 29, 35	1916	217,405	34,611,005	138	Lansing	1,700
						Bronson	2,000
						Marmaton	2,200
						Ordovician	2,445
						Arbuckle	2,600
Augusta North	T 27 S, R 4 E, secs. 9, 10, 15, 16, 21, 27, 28, 33	1914	102,271	13,777,621	63	Lansing	1,650
						Bronson	1,950
						Ordovician	2,380
						Arbuckle	2,410
Bausinger	T 27 S, R 3 E, secs. 24, 25, 27		5,883		4	Ordovician	3,050
Beaumont South	T 28 S, R 8 E, secs. 16, 21, 28						
Benton	T 26 S, R 3 E, secs. 9, 10		4,338		2	Mississippian	2,765
Blankenship[2]	T 26 S, R 8 E, secs. 9, 16, 17, 19, 21, 29		66,948	350,948	85	"Bartlesville"	2,650
Brandt-Sensebaugh	T 28 S, R 7 E, secs. 2, 9, 10, 14 to 16, 22 to 24, 26	1936	172,641	1,127,468	54	Mississippian	
						"chat"	2,692
De Moss	T 28 S, R 7 E, secs. 5, 7, 8, 9		56,105		22	"Bartlesville"	2,700
						"Burgess"	2,732
Douglas	T 29 S, R 3 E, secs. 12 to 14 T 29 S, R 4 E, secs. 4, 6 to 9, 17 to 20		33,851		33	Lansing-Kansas City	1,790
Dunns Mill	T 29 S, R 4 E, sec. 32		12,709	41,010	1	Arbuckle	2,951
Eckel	T 27 S, R 7 E, secs. 6, 7		4,483	35,505	3		
Eckel West	T 27 S, R 6 E, sec. 12		0	0	1		

Elbing	T 23 S, R 3 E, sec. 13 T 23 S, R 4 E, secs. 4, 5, 8, 17 to 20, 29	1918	290,621	1,330,621	74	Viola	2,530
Elbing East	T 23 S, R 4 E, sec. 27		0	0	1		
El Dorado	T 25 S, R 4 E, secs. 25, 35, 36 T 25 S, R 5 E, secs. 2 to 9, 15 to 19, 21, 22, 27 to 34 T 26 S, R 4 E, secs. 1, 2, 3, 10 to 14, 24, 25 T 26 S, R 5 E, secs. 2 to 11, 16 to 21, 28 to 30	1917	2,680,652	187,535,265	1,588	Admire Lansing Bronson Viola Simpson Arbuckle	600 1,700 2,000 2,500 2,510 2,550
Ferrell	T 28 S, R 3 E, secs. 21, 28	1939	66,741	255,824	11	"Mississippi lime"	2,647
Fox-Bush	T 28 S, R 5 E, secs. 22 to 27, 35, 36 T 29 S, R 5 E, secs. 1, 2, 11 to 14, 23 to 26, 36 T 29 S, R 6 E, secs. 7, 18, 30, 31	1917	147,184	531,184	121	"Bartlesville"	2,730
Garden	T 26 S, R 6 E, secs. 29, 32 T 27 S, R 6 E, secs. 5, 6	1928	47,762		31	"Bartlesville"	2,760
Gelwick	T 27 S, R 4 E, sec. 6		7,292		2		
Hanna	T 29 S, R 8 E, sec. 33					Bourbon shale	2,100
Haverhill	T 27 S, R 5 E, secs. 15, 22, 23, 27, 34, 35 T 28 S, R 5 E, sec. 3	1927	138,629	3,753,879	71	"Bartlesville"	2,700
Keighley	T 27 S, R 7 E, secs. 14, 22, 23, 27, 28, 32 to 34 T 28 S, R 7 E, secs. 4, 5	1925	55,188		56	"Bartlesville" Simpson	2,650 3,148
Kramer-Stern	T 27 S, R 6 E, secs. 21, 27, 28, 33, 34 T 28 S, R 6 E, secs. 3, 4	1928	141,375		33	Ordovician rocks	3,030-3,088
Leon	T 27 S, R 6 E, secs. 17, 19, 20	1926	22,200	2,263,200	18	"Chat" Viola	2,660 3,050

TABLE 16.—*Oil and gas fields in Butler county, Kansas—Concluded*

Pool	Location	Discovery Date	Production in barrels 1944	Production in barrels Cumulative[1]	No. of Wells	Producing horizon	Depth in feet
McCaig	T 28 S, R 6 E, sec. 13	1937			1		2,700
McCullough	T 28 S, R 6 E, secs. 1, 2	1929	10,575	449,791	5	Ordovician	3,169
Pierce	T 25 S, R 4 E, sec. 28		2,439		2		
Potwin	T 24 S, R 3 E, secs. 25, 35, 36	1921	190,267	6,374,267	96	Bronson	2,550
	T 24 S, R 4 E, secs. 30 to 32					"Mississippi lime"	2,660
	T 25 S, R 3 E, secs. 1, 2, 3, 11 to 13						
	T 25 S, R 4 E, secs. 5, 6						
Potwin South	T 25 S, R 4 E, sec. 18		1,057		1		
Reynolds-Schaffer	T 27 S, R 6 E, secs. 4, 8 to 10, 17	1926	64,303		23	"Mississippi lime"	2,780
Seward	T 27 S, R 7 E, secs. 12 to 14		10,022	981,512	14	"Bartlesville"	2,650
Smock-Sluss	T 26 S, R 5 E, secs. 24 to 26, 35, 36	1918	54,153		43	"Bartlesville"	2,700
	T 26 S, R 6 E, secs. 19, 30					Ordovician	3,000
	T 27 S, R 5 E, secs. 2, 11						
Snowden-McSweeney	T 28 S, R 6 E, secs. 34, 35	1930	6,077		2	Mississippian	2,833
	T 29 S, R 6 E, secs. 2, 3						
Steinhoff	T 29 S, R 6 E, secs. 21, 22, 27, 28	1926	3,414		2	Mississippian	2,803
Vandenburg	T 27 S, R 6 E, sec. 35	1942			1	Bronson	2,122
Weaver	T 27 S, R 5 E, sec. 36	1929	2,159		5	"Bartlesville"	2,690
	T 28 S, R 5 E, secs. 1, 2						
Young	T 26 S, R 7 E, secs. 20 to 22, 27 to 29	1919	61,714		30	Kansas City	2,190
						Mississippian	2,650

[1] Cumulative production to December 31, 1944
[2] Also in Greenwood county (see table 42)

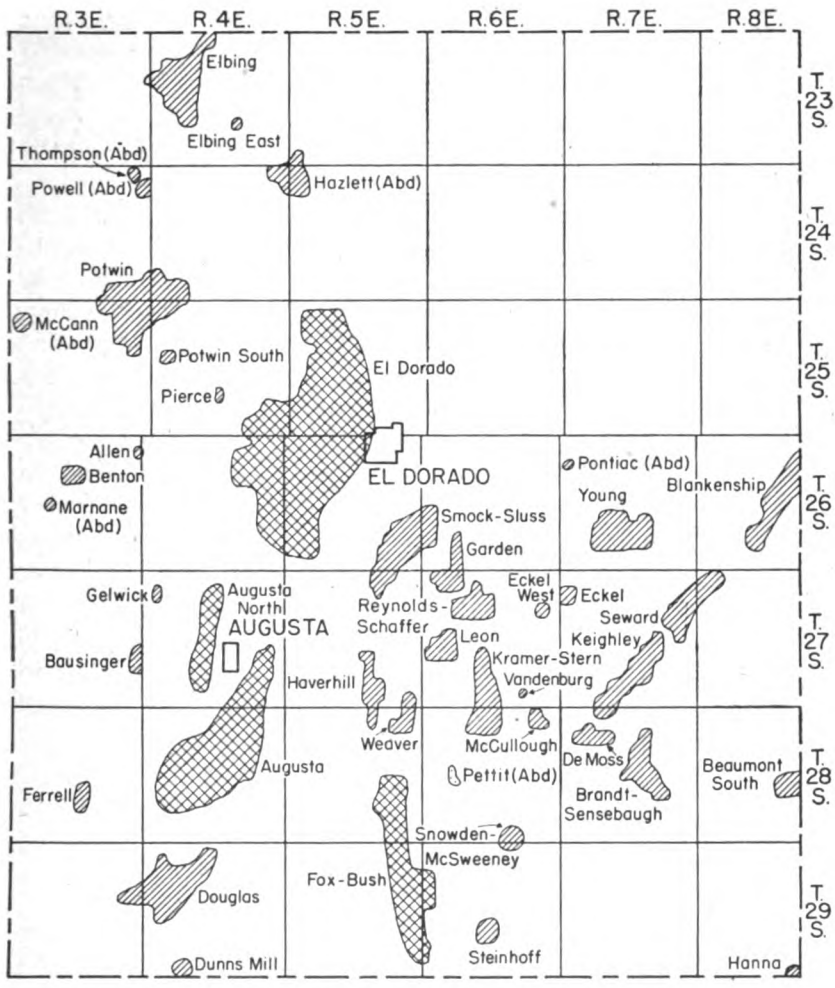

FIG. 11. Map of Butler county showing oil and gas producing areas. (Gas, dots; oil, diagonal lines; oil and gas, crossed diagonal lines.)

disconformity immediately below Pennsylvanian rocks. This anticline, which has a structural relief of about 1,400 feet, is typical of the granite ridge of which it is a part. Most of the folding is confined to pre-Pennsylvanian rocks. However, the field was discovered on the basis of surface structural mapping.

The El Dorado field now has 1,588 producing oil wells. Oil occurs in the Admire group at a depth of about 600 feet; in the lower

part of the Douglas group at about 1,550; at the top of the Lansing group at about 1,700 feet; in the upper part of the Kansas City group at about 2,000 feet; and in the "Stapleton zone" which ranges in depth from 2,350 to 2,750 feet. Gas is produced from rocks of the Admire, Shawnee, and Douglas groups which range in depth from 900 to 1,500 feet.

The **Augusta** oil and gas field, in the southwestern part of the county, is on an anticline that is only slightly smaller than the El Dorado dome. Production in this field is from Pennsylvanian and Ordovician rocks. In the **Potwin, Ferrell, Snowden-McSweeney, Steinhoff, Leon, Shaffer, Stern,** and **Young** pools (fig. 11) production is from the Mississippian limestone, on the flanks of the granite uplift. In the **Blankenship, De Moss, Fox-Bush, Garden, Keighley, Seward,** and **Smock-Sluss** pools, in the central and eastern parts of the county, production is from the "Bartlesville sand" at depths ranging from 2,650 to 2,800 feet. In some of the pools near the eastern boundary of the county production is from shoestring sand bodies which are extensions of the "Golden Lanes" of Greenwood county.

The production of oil in Butler county in 1918 was 36,069,670 barrels; in 1920, 18,423,716 barrels; in 1925, 9,659,608 barrels; in 1935, 6,000,000 barrels; and in 1941, 5,250,460 barrels. Reported monthly production of oil in Butler county is given in table 17. Gas production statistics for the years 1939 to 1943 are given in table 18.

TABLE 17.—*Reported monthly production of oil in Butler county, Kansas, in barrels*

Month	1941	1942	1943	1944
January	415,192	412,972	345,233	387,190
February	419,146	431,769	359,468	370,968
March	425,321	433,290	373,004	390,755
April	438,978	423,587	383,528	360,900
May	443,754	418,964	377,110	410,967
June	440,986	420,089	383,832	394,620
July	453,031	406,371	386,174	389,639
August	493,617	396,303	388,243	431,241
September	439,951	392,927	392,440	395,220
October	446,522	382,980	389,885	407,309
November	439,636	372,547	396,060	382,350
December	448,316	372,304	365,247	380,494
Totals	5,304,450	4,864,103	4,540,224	4,701,653

TABLE 18.—*Natural gas production in Butler county, Kansas*

Year	Thousands of cubic feet
1939	99,700
1940	90,650
1941	82,414
1942	74,200
1943	75,000

CHASE COUNTY

Oil has been found in the southeastern corner of Chase county. The Teeter field has been extended into Chase county from Greenwood county and the Atyeo field has been extended westward from northwestern Greenwood and southwestern Lyon counties. Production is from the "Bartlesville sand." Several gas pools have been found in the county. Gas production is from lower Permian and Pennsylvanian rocks.

SURFACE ROCKS

The consolidated surface rocks of Chase county are of Permian age. They include the lower part of the Sumner group, the Chase and Council Grove groups, and the upper part of the Admire group.

The youngest Permian rocks in Chase county comprise several feet of shale and thin limestone beds belonging to the lower part of the Wellington shale, the lowermost formation of the Sumner group. Rocks of the Chase group (fig. 6) in Chase county are about 350 feet thick. Strata of this group are well exposed in the county in Flint Hills slopes. Numerous limestones are useful key beds in structural mapping. This group is characterized by flinty massive limestones and by gray, red, green, and chocolate-colored shales. The Fort Riley limestone member of the Barneston limestone, occurring as massive beds forming a rim near the tops of many slopes, underlies a dip slope which is extensive in the southwestern quarter of the county. The general thickness of the Council Grove group (fig. 6) in Chase county is about 300 feet. Shale constitutes more than two-thirds of the total thickness. This group is characterized by highly colored shales in the Johnson and overlying shale formations and by thin limestones of various lithologies. Fusulines are common fossils in the limestones and in some of the shales.

The upper few feet of rocks of the Admire group are exposed along Cottonwood river in eastern Chase county and near the head of Verdigris river in the southeastern part of the county.

Subsurface Rocks

Pennsylvanian rocks.—Pennsylvanian rocks in Chase county are not greatly different from rocks of the same age in neighboring counties. The Wabaunsee and Shawnee groups are characterized by shale and relatively thin limestone beds. The thickness of the Wabaunsee section is about 475 feet and of the Shawnee about 500 feet. The Oread limestone, the basal formation of the Shawnee group, is about 75 feet thick. The Douglas group is almost entirely clastic material, but there is a persistent limestone approximately 100 feet below the top. This is probably the Haskell limestone. The thicknesses of Douglas rocks differ from place to place, which indicates that 50 or more feet of Missourian rocks was eroded locally before deposition of Douglas sediments. Sandstone, ranging from about 200 to 250 feet in thickness, commonly occurs in the basal part of the Douglas section. In places where the Douglas rocks are relatively thin, 30 feet or more of rocks identified as belonging to the Pedee group is present. The combined Lansing, Kansas City, and Bronson groups comprise approximately 400 feet of nearly solid limestone. The Bourbon shale is approximately 100 feet thick and the underlying Marmaton group is about 130 feet thick. Slightly more shale than limestone is present in the Marmaton section. About 350 feet of Cherokee shale is present in most of Chase county. The Cherokee is thin or absent in the Nemaha anticline area. Pennsylvanian beds lie upon pre-Cambrian rocks in the vicinity of Elmdale.

Mississippian rocks.—Mississippian limestone formations and the Chattanooga shale have been removed by post-Mississippian erosion from the Nemaha anticline area in the northwestern part of Chase county (Lee, 1939, pl. 1; 1940, pl. 3). The total thickness of Mississippian limestones in the county ranges from a featheredge to slightly more than 400 feet. The maximum thickness of the Chattanooga shale is about 150 feet.

Pre-Chattanooga rocks.—The "Hunton" limestone and the Maquoketa shale are seemingly absent from Chase county. The Viola limestone and other rocks as old as some part of the Arbuckle limestone have been eroded from most of the Nemaha anticline in the county (McClellan, 1930; Ockerman, 1935, fig. 2).

Oil and Gas Developments

Locations of oil and gas producing areas in Chase county are shown in figure 12. The **Teeter** oil pool extends north into Chase

county from Greenwood county. The **Atyeo** pool extends from Lyon county into Chase county. Oil production in these pools is from the "Bartlesville sand."

The **Lipps** gas pool is in the southeastern part of T. 18 S., R. 6 E., and the southwestern part of T. 18 S., R. 7 E. Production is from sandstone in the Lawrence shale. The **Davis** gas pool is in secs. 19 and 30, T. 18 S., R. 8 E. Production is from lower Permian rocks at depths of 350 to 400 feet. The **Elk** gas pool is in secs. 20, 21 and 27, T. 19 S., R. 6 E. Production is from lower Permian rocks at an

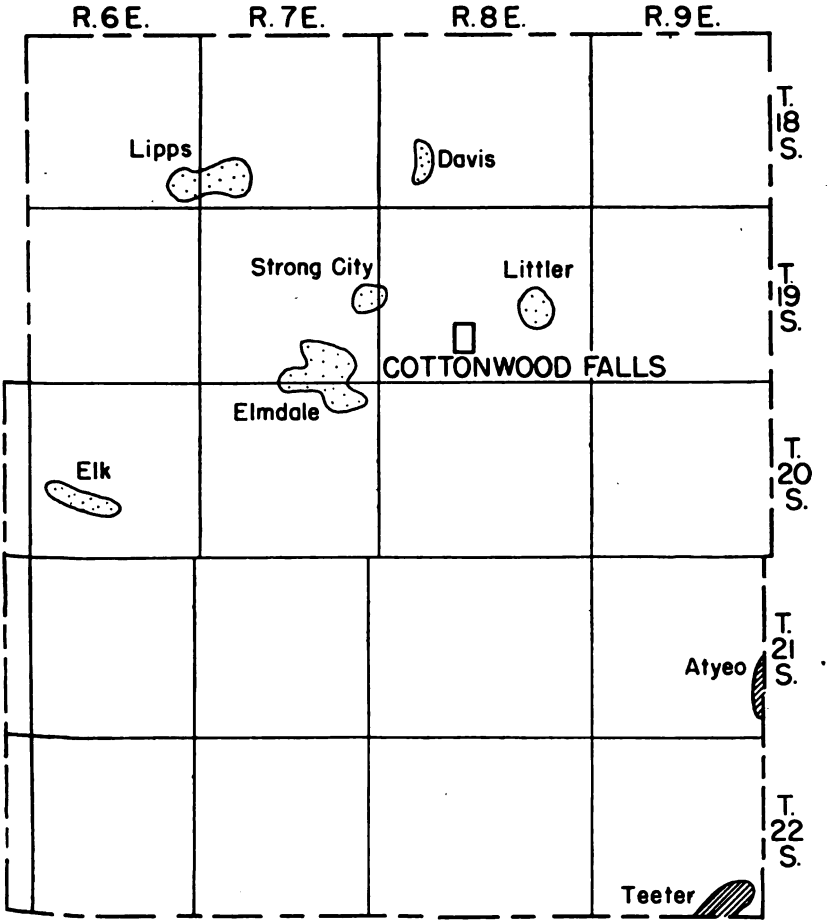

FIG. 12. Map of Chase county showing oil and gas producing areas. (Gas, dots; oil, diagonal lines.)

average depth of about 500 feet. The **Neva** gas pool is in secs. 13 and 25, T. 19 S., R. 7 E. The **Elmdale** gas pool is in secs. 26, 27, 28, 33, 34, 35, and 36, T. 19 S., R. 7 E., and in secs. 1 and 2, T. 20 S., R. 7 E. Production is from lower Permian rocks. The **Littler** gas pool is in sec. 15, T. 19 S., R. 8 E.

Gas production statistics in Chase county for the years 1939 to 1943 are given in table 19. Oil production from the Teeter field is included in table 43. Production from the Atyeo field is included in table 62.

TABLE 19.—*Natural gas production in Chase county, Kansas*

Year	Thousands of cubic feet
1939	84,761
1940	89,223
1941	93,920
1942	180,000
1943	180,000

CHAUTAUQUA COUNTY

Oil and gas have been produced in Chautauqua county since 1900 when oil was discovered in the Peru area. Large continuous areas in the vicinities of Sedan, Peru, and Chautauqua yield oil and gas.

SURFACE ROCKS

The consolidated surface rocks of Chautauqua county consist of alternating beds of limestone and shale, and some sandstone. The rocks exposed belong to the Council Grove and Admire groups of Permian age and the Wabaunsee, Shawnee, Douglas, Pedee, and Lansing groups of Pennsylvanian age. The youngest consolidated rocks, those of the Council Grove group, are in the northwestern part of the county in Ts. 30 and 31 S., R. 8 E.; the oldest outcropping rocks, those of the Lansing group, are at the surface in the southeastern part in T. 34 S., R. 13 E. (Moore and Landes, 1937).

Permian rocks.—The lower part of the Eskridge shale, Council Grove group (fig. 6), is the youngest consolidated rock in Chautauqua county. The total thickness of the Council Grove group in the county is about 150 feet. Rocks of the Admire group, which are chiefly clastic materials, have a total thickness of about 90 feet.

Pennsylvanian rocks.—The Wabaunsee group (fig. 7) comprises shale, sandstone, and thin beds of limestone. The total thick-

ness of these rocks in Chautauqua county is about 550 feet. The rocks of the Shawnee group consist of shale, sandstone, and limestone. The limestones are generally thicker than those of the Wabaunsee group. The average thickness of the Shawnee group is about 450 feet in Chautauqua county. The Douglas and Pedee groups, consisting chiefly of clastic materials, are about 300 feet thick. The Stanton limestone is the only formation of the Lansing group that crops out in the county. The upper part of the Stanton formation is exposed in the southeastern part of the county.

Subsurface Rocks

Pennsylvanian rocks.—The Lansing group is about 150 feet thick in Chautauqua county. The Kansas City group consists largely of limestone and contains some shale and sandstone. The sandstone in the upper part of this group is called "Layton sand." The total thickness of the Kansas City group in the county is about 350 feet. The Bronson group, which is about 90 feet thick, is composed almost entirely of limestone. The Bourbon shale in the county has an average thickness of about 50 feet.

The Marmaton group consists of about 320 feet of alternating beds of limestone and shale and some sandstone. Important producing sandstones in the Marmaton are the "Old Red" or "Wayside" in the Nowata shale, the "Weiser" in the Bandera shale, and the "Peru" in the Labette shale.

The Cherokee shale is composed chiefly of shale (partly sandy), sandstone, and a few thin beds of limestone and coal. Its thickness in Chautauqua county ranges from 250 to 450 feet. The "Bartlesville sand" occurs as lenticular bodies lying at a depth of about 180 feet below the top of the Cherokee shale. The "Burgess sand" is the basal part of the Cherokee and fills depressions on the surface of the Mississippian limestone.

Mississippian rocks.—The Mississippian limestone in Chautauqua county ranges in thickness from less than 150 to more than 350 feet (Lee, 1939, pl. 1). The Mississippian section is thinnest over the axis of the Longton anticline in the northeastern part of the county and thickest in the west-central part. The Warsaw, Reeds Spring, and St. Joe limestones, the Northview shale, and the Compton limestone are present in the eastern part of Chautauqua county. The Chattanooga shale is about 35 or 40 feet thick in eastern Chautauqua county. The Warsaw limestone and the Cowley formation, which lies directly on pre-Chattanooga rocks,

are present in the western part of the county. Large quantities of oil and gas are produced in Chautauqua county from a porous zone in the upper part of the Mississippian limestone.

Ordovician and Cambrian rocks.—Rocks of the Ordovician and Cambrian systems have not been completely subdivided in Chautauqua county. The total thickness of these rocks in the Sinclair Prairie No. 9 Brown well, in sec. 26, T. 34 S., R. 11 E., is 882 feet. Oil is produced from a porous zone in the upper part of the Cotter dolomite (upper part of the Arbuckle) of Ordovician age. This zone is locally called the "Siliceous lime" and sometimes is erroneously designated as "Wilcox."

Oil and Gas Developments

Oil and gas are produced in Chautauqua county from the "Wayside sand" in the Nowata shale (known locally as the "Old Red sand"); from the "Peru sand," in the lower part of the Marmaton group; from the Little Osage shale (locally called "Hancock") member of the Fort Scott limestone; from the "Bartlesville sand" in the middle part of the Cherokee shale; from the "Burgess sand" in the basal part of the Cherokee shale; from the upper part of the Mississippian limestone; and from the upper part of the Cotter dolomite of Ordovician age.

The oil and gas producing areas in Chautauqua county are shown in figure 13, and the oil and gas fields of the county as designated by the Oil Field Nomenclature Committee of the Kansas Geological Society are listed in table 20.

Oil and gas have been found in every township in Chautauqua county except in those along the western edge. The largest oil-producing areas are near Sedan, Chautauqua, and Elgin. Most of the oil wells in the county are small producers but are noted for their long life; some of the wells have produced for as long as 35 years.

The Peru, Sedan, Monett, and Chautauqua areas have been extended and now form one large area. This is called the **Peru-Sedan** area and covers most of the south-central part of the county. The **Hale-Inge** gas and oil area is in the northeastern part of the county; it extends northward into Elk county. The **Elk City** gas field of southeastern Elk county extends southward into Chautauqua county.

In 1935, oil was discovered in the Arbuckle dolomite at a depth of 2,300 feet in the **Oliver** pool in secs. 1 and 2, T. 32 S., R. 10 E.

Later oil was discovered in the Arbuckle dolomite in the vicinity of Monett and in the **McAllister** area. The dolomite was encountered at a depth of 1,790 feet in the Monett area. Gas and oil are also produced in these areas from the upper part of the "Mississippi lime." Oil and gas in the "Mississippi lime" and in the Arbuckle dolomite accumulated in anticlinal structures. Oil and gas accumlations in Pennsylvanian sandstones were controlled by changes in porosity and by minor structural elements.

A water-flooding project was operated by the Sinclair Prairie Oil Company in sec. 21, T. 33 S., R. 11 E., in the Peru-Sedan area (Grandone, 1944, pp. 63-65). An area of 40 acres was flooded by 12 injection wells. The water was first injected in March, 1937, and the first increase in oil production was noted in April, 1937. The project was discontinued on December 17, 1938. Oil was produced from the "Peru sand" which has an average thickness of about 25 feet and lies at a depth of about 1,225 feet. Twelve oil recovery wells produced a total of 665 barrels per acre.

The Forest Producing Corporation Paulus water-flooding project is in sec. 6, T. 35 S., R. 12 E., in the Sedan-Peru area (Grandone, 1944, pp. 65-67). An area of 50 acres is being flooded by five in-

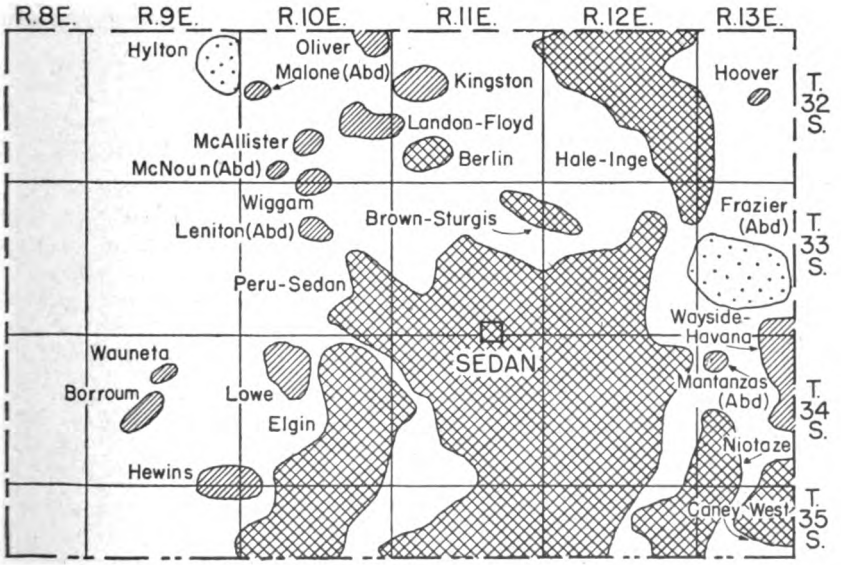

FIG. 13. Map of Chautauqua county showing oil and gas producing areas. (Gas, dots; oil, diagonal lines; oil and gas, crossed diagonal lines.)

jection wells. Oil is produced from the "Peru sand," which lies at a depth of about 1,100 feet and has a thickness of about 35 feet. Between August, 1938, and November 1, 1942, 10 oil recovery wells produced a total of 350 barrels of oil per acre.

Monthly production of oil in Chautauqua county is given in table 21. Gas production statistics for the years 1939 to 1943 are given in table 22.

TABLE 20.—*Oil and gas fields in Chautauqua county, Kansas*

(As designated by the Oil Field Nomenclature Committee of the Kansas Geological Society, November 15, 1944)

Name	Location
Borroum	T 34 S, R 9 E, secs. 16, 20, 21
Berlin	T 32 S, R 11 E, secs. 29 to 32
Brown-Sturgis	T 33 S, R 11 E, secs. 1, 2, 12
	T 33 S, R 12 E, secs. 7, 8
Caney West[1]	T 34 S, R 13 E, secs. 33, 34
	T 35 S, R 13 E, secs. 3 to 5, 8 to 10, 15, 16
Elgin	T 34 S, R 10 E, secs. 1 to 3, 10 to 15, 22 to 28, 32 to 36
	T 34 S, R 11 E, secs. 18, 19
	T 35 S, R 9 E, secs. 12, 13
	T 35 S, R 10 E, secs. 1 to 10, 15 to 18
Frazier (Abandoned)	T 33 S, R 12 E, secs. 13, 24
	T 33 S, R 13 E, secs. 15, 16, 18 to 22, 27 to 30, 32
Hale-Inge[2]	T 32 S, R 11 E, secs. 1, 12
	T 32 S, R 12 E, secs. 1 to 11, 13 to 18, 22 to 26, 35, 36
	T 32 S, R 13 E, secs. 18, 19, 30, 31
	T 33 S, R 12 E, secs. 1, 12
	T 33 S, R 13 E, secs. 6, 7
Hewins	T 34 S, R 9 E, secs. 35, 36
	T 34 S, R 10 E, sec. 31
	T 35 S, R 9 E, secs. 1, 2
	T 35 S, R 10 E, sec. 6
Hoover	T 32 S, R 13 E, sec. 16
Hylton	T 32 S, R 9 E, secs. 2, 3, 10 to 14
Kingston	T 32 S, R 11 E, secs. 7, 8, 17, 18
Landon-Floyd	T 32 S, R 10 E, secs. 14, 23, 24
	T 32 S, R 11 E, sec. 19
Leniton (Abandoned)	T 33 S, R 10 E, secs. 8, 9, 16, 17
Lowe	T 34 S, R 10 E, secs. 4, 5, 8, 9, 16, 17
Malone (Abandoned)	T 32 S, R 10 E, sec. 18
Mantanzas (Abandoned)	T 34 S, R 13 E, secs. 7, 8
McAllister	T 32 S, R 10 E, sec. 28
McNoun (Abandoned)	T 32 S, R 10 E, sec. 31
Niotaze	T 34 S, R 12 E, sec. 25, 36
	T 34 S, R 13 E, secs. 19, 20, 29 to 32

	T 35 S, R 12 E, secs. 1 to 3, 10 to 14
	T 35 S, R 13 E, secs. 5 to 7, 18
Oliver[2]	T 32 S, R 10 E, secs. 1, 2, 12
Peru–Sedan[3]	T 33 S, R 10 E, secs. 13, 14, 23 to 26, 34 to 36
	T 33 S, R 11 E, secs. 13 to 17, 20 to 36
	T 33 S, R 12 E, secs. 10, 11, 14, 15, 19 to 23, 26 to 34
	T 34 S, R 10 E, secs. 1, 2
	T 34 S, R 11 E, secs. 1 to 17, 20 to 28, 34 to 36
	T 34 S, R 12 E, secs. 1 to 12, 14 to 23, 26 to 35
	T 35 S, R 10 E, sec. 13
	T 35 S, R 11 E, secs. 1 to 4, 8 to 18
	T 35 S, R 12 E, secs. 3 to 10, 16 to 18
Wauneta	T 34 S, R 9 E, secs. 9, 10
Wayside-Havana[1]	T 33 S, R 13 E, secs. 33, 34
	T 34 S, R 13 E, secs. 3, 4, 9, 10, 15, 16, 21, 22
Wiggam	T 32 S, R 10 E, secs. 33, 34
	T 33 S, R 10 E, secs. 3, 4

[1] Also in Montgomery county (see table 70)
[2] Also in Elk county (see table 35)
[3] Includes fields formerly known as Sedan, Monett, Peru, and Chautauqua

TABLE 21.—*Reported monthly production of oil in Chautauqua county, Kansas, in barrels*

Month	1941		1942		1943	
	No. of wells	Production	No. of wells	Production	No. of wells	Production
January	2,309	78,761	1,647	74,912	1,630	75,988
February	2,169	68,640	1,638	72,730	1,685	73,611
March	2,257	78,936	1,641	81,280	1,686	79,905
April	2,224	74,866	1,652	79,847	1,687	77,480
May	2,272	79,365	1,670	79,447	1,629	75,955
June	2,258	75,194	1,686	83,437	1,683	78,552
July	2,359	89,308	1,664	81,923	1,679	77,656
August	2,351	78,409	1,650	80,715	1,685	80,012
September	2,316	83,283	1,697	81,950	1,670	75,719
October	2,283	82,628	1,656	80,869	1,682	74,817
November	2,296	76,903	1,669	79,145	1,640	80,138
December	2,339	86,623	1,690	83,496	1,604	76,487
Totals		952,916		959,751		926,320

TABLE 22.—*Natural gas production in Chautauqua county, Kansas*

Year	Thousands of cubic feet
1939	770,352
1940	670,037
1941	756,697
1942	844,579
1943	805,726

CHEROKEE COUNTY

Cherokee county is the only county in southeastern Kansas where commercial quantities of oil and gas have not been discovered. However, a few wells in this county have supplied small quantities of gas for many years. The producing zone is the "Burgess sand" in the basal part of the Cherokee shale, which ranges in depth from a few feet to about 300 feet. Oil shows have been reported from the "Bartlesville sand" and from pre-Pennsylvanian rocks (probably Mississippian).

Surface Rocks

Surface rocks in Cherokee county are Pennsylvanian and Mississippian in age. Cherokee is the only county in the state where Mississippian rocks are exposed.

Pennsylvanian rocks.—The Labette shale of the Marmaton group (fig. 8) is the surface rock in the extreme northwestern part of Cherokee county where it lies beneath northwestward-trending dip slopes. The Fort Scott limestone crops out in a narrow belt to the south and east.

The Cherokee shale (fig. 9) crops out in Cherokee county in a broad northeastward-trending belt 18 to 27 miles wide covering the entire county except the extreme northwestern and southeastern parts. The Cherokee consists of light to dark-gray and black shale, sandstone, numerous coal beds, and a few thin beds of limestone. Its maximum thickness is about 500 feet. It increases in thickness to the southwest. The increase occurs principally in beds below the Ardmore limestone, which lies about 100 feet below the base of the Fort Scott limestone. Sandstone occurs in several different zones but most of these sandstone beds are not persistent. Some of them are shoestring sands, which are elongated channel fillings or bars. The Cherokee shale is not readily divisible into formations unless cyclic units (cyclothems) are regarded as formations.

Mississippian rocks.—Rocks of Mississippian age (fig. 9) are exposed in a small area in the southeastern part of Cherokee county. They consist of light-gray cherty limestones, medium to coarse in texture. They probably include a few feet of Spergen limestone of Chesterian age. The Warsaw limestone of Meramecian age and the Keokuk limestone of Osagian age comprise most of the exposed section. The total thickness of outcropping Mississippian rocks in Cherokee county is about 50 feet.

Subsurface Rocks

Many lead and zinc test holes have penetrated Mississippian rocks in Cherokee county. Many wells in this and adjoining counties have penetrated the uppermost part of the Arbuckle rocks. Water wells in this area have encountered the Roubidoux sandstone or deeper beds, but only a few wells have reached pre-Cambrian rocks.

Subsurface geologic conditions along the northern boundary of Cherokee county are shown in plate 4. Depths to some stratigraphic horizons in a deep well in southeastern Cherokee county are given in table 23. Data are from Abernathy (1943, fig. 2).

Mississippian rocks.—The divisions of the Mississippian in Cherokee county are the Spergen, Warsaw, Keokuk-Burlington, Reeds Spring, and St. Joe limestones, the Northview shale, and the Compton limestone. The Spergen limestone is thin and is of local occurrence. The thickness of the Mississippian rocks in the county ranges from about 335 to 380 feet. Numerous sinkholes have been formed in the northeastern part of the county by subsidence of the roofs of solution caverns in a zone near the top of the Mississippian limestone. The Chattanooga shale is not known to be present.

Ordovician rocks.—In Cherokee county all Ordovician rocks younger than the Cotter dolomite were removed by erosion before deposition of Mississippian sediments. Ordovician formations in the county are the Cotter dolomite, including the Swan Creek sandstone member at its base; the Jefferson City dolomite; the Roubidoux formation; and the Gasconade and Van Buren dolomites (undifferentiated), including the Gunter sandstone member

Table 23.—*Depths to some stratigraphic horizons in the Jayhawk Ordnance Works water well, NW cor. SE¼ NE¼ sec. 4, T. 34 S., R. 25 E., Cherokee county, Kansas*

Horizon	Depth, in feet
Top of Burlington-Keokuk limestone	22
Top of Reeds Spring limestone	157
Top of St. Joe limestone	285
Top of Northview shale	307
Top of Compton limestone	312
Top of Cotter dolomite (Arbuckle)	314
Top of Jefferson City dolomite	419
Top of Roubidoux formation	719
Top of Gasconade dolomite	874
Total depth	897

at the base. The thickness of the Cotter dolomite in Cherokee county ranges from about 70 to 140 feet. Its thickness is not uniform because of the erosional disconformity below Mississippian rocks. The Cotter dolomite is locally absent about 4 miles north of Cherokee county in Crawford county. The Jefferson City dolomite ranges in thickness from 275 to 300 feet in Cherokee county. The Roubidoux formation consists of sandstone and dolomite. Some of the dolomite is sandy. The Roubidoux has an average thickness of about 170 feet. The formation includes two sandstone members which bear large quantities of water. The upper member, in the middle part of the formation, is about 15 feet thick; the lower member, in the basal part of the formation, is about 25 feet thick. The depth to the Roubidoux formation ranges from about 715 feet in the eastern part of the county to about 1,200 feet in the western part. The undifferentiated Gasconade and Van Buren dolomites range in thickness from about 100 to 265 feet. The Gunter sandstone ranges in thickness from about 5 to 20 feet. An unconformity separates the Gunter sandstone from underlying Cambrian rocks.

Cambrian rocks.—The Cambrian rocks in Cherokee county consist of the Eminence and Potosi dolomites (undifferentiated), Bonneterre dolomite, and Lamotte sandstone. The undifferentiated Eminence and Potosi dolomites have an average thickness of about 150 feet. The rocks between the top of the Cotter dolomite and the base of the Potosi dolomite are conveniently termed Arbuckle. The Bonneterre dolomite is about 175 feet thick in four wells. The Bonneterre is transitional into the underlying Lamotte sandstone. The Lamotte has an average thickness of about 65 feet in three wells. In some wells in Cherokee and adjoining counties a zone of detrital igneous material is found at the base of the Lamotte sandstone.

Pre-Cambrian rocks.—Pre-Cambrian rocks are about 1,900 feet below the surface in the western part of Cherokee county and about 1,800 feet below the surface in the eastern part. Pre-Cambrian rocks are encountered about 875 feet below sea level at Columbus, Kans., and their top is nearly level from Columbus to Carthage, Mo., about 30 miles to the east. A deep well 12 miles west of Columbus reached pre-Cambrian rocks at about 1,087 feet below sea level. This is 212 feet lower than the top of the pre-Cambrian rocks at Columbus.

CLAY COUNTY

A small amount of oil was produced several years ago in sec. 21, T. 9 S., R. 4 E. in Clay county. The oil was found in the upper part of the Mississippian limestone.

Surface Rocks

Cretaceous rocks.—Cretaceous sandstone, shale, and clay having a maximum thickness of approximately 250 feet are present in the western part of Clay county. These sediments overlap Permian rocks. Plummer and Romary (1942) have made preliminary studies of Cretaceous rocks in this part of Kansas.

Cretaceous rocks belonging to the Dakota and Kiowa formations have been identified in Clay county. Dakota sandstones and shales commonly lie on the Kiowa shale; locally they overstep the Kiowa and rest on Permian rocks. Massive sandstones are conspicuous in the Dakota formation, but the amounts of clay and sandstone are about equal. The maximum thickness of the Dakota in the county is approximately 200 feet. The Kiowa shale has a maximum observed thickness of about 50 feet. It consists almost entirely of dark rather fissile shale.

Permian rocks.—Permian sediments, including the lower part of the Sumner group (Leonardian) and the upper part of the Chase group (Wolfcampian), crop out in the southeastern half of Clay county. The oldest well-exposed bedrock is the Fort Riley limestone. Rocks of the Chase group (fig. 6) in Clay county are about 350 feet thick. Massive limestones, some of which are flinty, and bright-colored shales are characteristic. The Wellington formation consists chiefly of red and gray shales and thin impure limestones.

Subsurface Rocks

Clay county is in the central part of the North Kansas basin and on the eastern flank of the Salina basin. Subsurface geologic conditions along the northern boundary of the county are shown diagrammatically in plate 1.

Depths at which some key stratigraphic horizons were reached in the J. F. Boggess et al. No. 1 Younkin well, in the SW¼ SE¼ sec. 21, T. 9 S., R. 4 E., are given in table 24.

TABLE 24.—*Depths to some key horizons in the J. F. Boggess et al. No. 1 Younkin well, SW¼ SE¼ sec. 21, T 9 S., R 4 E., Clay county, Kansas*

Horizon	Depth, in feet
Base of Wreford limestone	125
Top of Shawnee group	1,050
Base of Oread limestone	1,335
Top of Lansing group	1,390
Base of Bronson group (Hertha limestone)	1,755
Top of Mississippian limestones	1,890
Top of Kinderhookian rocks	2,002
Top of Siluro-Devonian rocks	2,194
Top of Maquoketa shale	2,545
Top of Viola limestone	2,585
Top of St. Peter sandstone	2,745
Total depth	2,792

OIL AND GAS DEVELOPMENTS

A small amount of oil was produced from the Roth and Faurot No. 1 Bradbury well in sec. 21, T. 9 S., R. 4 E., which was completed in December, 1928. Several other test wells have been drilled in Clay county.

COFFEY COUNTY

Oil production in Coffey county is from lower Pennsylvanian and Mississippian rocks. Oil fields are confined to the southern and southwestern parts of the county. Oil was first discovered in the county near Le Roy in 1903, and important production started in 1916.

SURFACE ROCKS

Much of the upland surface of Coffey county is mantled with relatively coarse flint gravel of probable Tertiary age. Recent and Pleistocene alluvium partly fills the valleys of Neosho river and smaller streams. Surface bedrocks of Pennsylvanian age belong to the Virgilian and Missourian series. The oldest exposed Pennsylvanian rocks occur in the southeastern part of Coffey county. However, the wide trench of Neosho river in this area causes difficulty in stratigraphic studies. The youngest bedrock is the White Cloud shale and the oldest exposed rock in the Stanton limestone.

Rocks in the lower part of the Wabaunsee group (fig. 7) are present in the northwestern part of Coffey county. Several feet of White Cloud shale is exposed. This is underlain by the Howard limestone, which is about 15 feet thick. The Nodaway coal bed is

a short distance below the most prominent part of the Howard limestone. The thickness of the Severy shale, lowest formation of the Wabaunsee group, is about 65 feet.

Rocks of the Shawnee group (fig. 7) are well exposed in many places in Coffey county. These rocks are characterized by scarp-forming limestones, light and dark shales, and lenticular sandstones. The total thickness of the group is about 400 feet. The Oread limestone lies below an extensive dip slope which ranges in width from about 5 to 15 miles and extends from the northeastern to the southwestern parts of Coffey county. Other limestones in the group lie below narrower dip slopes. Various members of the limestone formations are easily recognized key beds.

Rocks of the Douglas group (fig. 7) are chiefly shales and sandstones; in Coffey county this group ranges in thickness from about 200 to 275 feet. The group comprises the Lawrence and Stranger formations, which are separated locally by a disconformity. The Lawrence shale includes a local limestone, the Amazonia?, about 25 feet below the top of the formation, and the Williamsburg coal bed, a few feet above the Amazonia? limestone. Local unconformities occur in the Lawrence shale. Subsurface studies indicate that much cutting and filling took place during the time of deposition of the upper part of the Lawrence rocks. Throughout Kansas and in neighboring states, the Douglas rocks are separated from underlying older rocks by a major erosional unconformity.

A few feet of Weston shale, lowermost formation of the Pedee group (fig. 8), crops out at the surface in the southeastern part of Coffey county. Locally in the subsurface a maximum thickness of about 20 feet of Iatan limestone and about 40 feet of Weston shale are present. The Weston shale includes several feet of sandstone in its middle and upper parts. Well records show that Douglas rocks rest on Stanton limestone and that Pedee rocks were removed by pre-Douglas erosion in much of the county.

Dip slopes of the upper limestone members of the Stanton formation of the Lansing group extend into southeastern Coffey county. Exposures of these rocks are rather poor. The Lansing rocks are about 90 feet thick in the subsurface. About 10 feet of shale separates the Stanton and Plattsburg limestones.

Subsurface Rocks

Coffey county lies on the northwestern flank of the Chautauqua arch. Ordovician rocks dipping to the northwest were beveled by

erosion and are buried under Mississippian sediments. The subsurface section includes Pennsylvanian, Mississippian, Ordovician, Cambrian, and pre-Paleozoic rocks. Geologic conditions along the southern boundary of Coffey county are shown in plate 3.

Pennsylvanian rocks.—The thickness of rocks of Pennsylvanian age from the base of the Oread limestone, which crops out in the southeastern part of Coffey county, to the base of the Cherokee shale is about 1,300 feet. Douglas rocks range from about 200 to 300 feet in thickness in the county. This difference in thickness is due to differential erosion of Lansing rocks before deposition of Douglas sediments. Lower Douglas rocks lie on formations which range downward from the Iatan limestone to the Stanton limestone. Rocks of the Lansing, Kansas City, and Bronson groups are similar in Coffey and adjacent counties. The combined thickness of these groups is about 430 feet. Because of the irregular surface upon which Bourbon rocks lie, the thickness of the Bourbon shale in the county ranges from about 100 to 150 feet. The Marmaton rocks range in thickness from about 150 to 200 feet. Locally, Bourbon rocks lie upon a surface near the top of the Altamont limestone. In other places, however, all of the Marmaton formations are present. Cherokee rocks are about 375 feet thick in Coffey county.

Mississippian rocks.—The Mississippian limestone formations in Coffey county range in total thickness from slightly less than 300 feet to a little more than 350 feet (Lee, 1939, pl. 1). The Chattanooga shale is about 50 feet thick. It is somewhat sandy in the midddle part.

Pre-Chattanooga rocks.—Rocks of Devonian age (unless the Chattanooga shale is in part Devonian) and of Silurian age are absent from Coffey county. The Viola limestone and the St. Peter sandstone (Ordovician) are absent from the southeastern part of the area. The maximum thickness of the Viola limestone is about 50 feet, and the St. Peter sandstone has about the same thickness. Arbuckle rocks underlie the St. Peter sandstone and rest directly on pre-Cambrian rocks. The average thickness of the Arbuckle is probably about 550 feet.

Oil and Gas Developments

The **Dunaway** and **North Virgil** pools extend from Greenwood county into southwestern Coffey county, and the **Winterscheid** pool extends into Coffey county from Woodson county. Oil is produced in these pools from the "Bartlesville sand."

In 1928 the Union Gas Corporation No. 1 Carter well, in sec. 8, T. 22 S., R 14 E., was completed. An initial flow of 1,178,650 cubic feet of gas was reported at 1,355 feet. The producing formation is a sandstone in the upper part of the Cherokee shale. The pool is known as the **Carter** gas pool.

The **Hatch** pool was discovered in 1930, when oil was found in a basal Pennsylvanian sandstone ("Burgess") at a depth of about 1,825 feet. The discovery well, the Prairie Oil and Gas Company No. 1 Hatch in the NW¼ SE¼ sec. 35, T. 21 S., R. 14 E., had an initial daily production of 80 barrels. In the same year a 15-barrel oil well was completed in the SW¼ NE¼ of the same section, and in 1935 a gas well having a reported initial flow of 300,000 cubic feet of gas per day was drilled at the Cen. S. line NE¼ SE¼ of the section.

The **Van Noy** pool is in sec. 1, T. 23 S., R. 14 E. and in secs. 6, 7, and 18, T. 23 S., R. 15 E. Oil was found in the upper part of the Mississippian limestone at depths of about 1,540 feet. Two wells were reported to have had an initial production of 100 barrels of oil per day. Smaller production was found in other wells. Although oil was discovered here earlier, most of the drilling was done in 1935 and 1936. It is reported that in the Van Noy field there is some production from the "Peru sand." There were 29 producing oil wells in this pool in December, 1944.

Reported monthly production of oil in Coffey county in 1941, 1942, 1943, and 1944 is given in table 25. Yearly gas production figures for 1939 to 1943 are given in table 26.

TABLE 25.—*Reported monthly production of oil in Coffey county, Kansas, in barrels*[1]

Month	1941	1942	1943	1944
January	1,125	1,567	1,359	1,736
February	1,521	1,836	1,697	840
March	1,551	1,774	1,589	1,302
April	2,038	1,429	1,213	1,290
May	2,038	1,622	1,701	1,426
June	1,703	1,822	1,550	1,170
July	1,916	2,170	1,414	837
August	1,947	1,650	1,982	1,861
September	1,855	1,618	1,557	1,680
October	1,855	1,696	1,766	1,302
November	1,886	1,816	1,302	1,020
December	1,521	968	782	837
Totals	20,956	19,968	17,912	15,301

[1] Production from Van Noy pool only; production from other pools is included in Greenwood and Woodson county tables.

TABLE 26.—*Natural gas production in Coffey county, Kansas*

Year	Thousands of cubic feet
1939	8,056
1940	13,691
1941	17,864
1942	7,650
1943	18,186

COWLEY COUNTY

Cowley county has been an important producer of oil and gas for many years. Gas was found near Winfield as early as 1902. Natural gas discovered near Dexter in 1905 attracted much interest because of its helium content; a plant for the extraction of the helium was built at Dexter in 1927. Although oil was discovered near Dexter in 1914, the first oil field in the county, the Peacock, was opened in 1916.

SURFACE ROCKS

The geology of Cowley county with special reference to the occurrence of oil and gas was described by Bass (1929). Flint gravels, Recent to Tertiary (?) in age and 20 feet or less in thickness, are present at the surface in many parts of Cowley county and are commercially important in several localities. The exposed bedrocks in Cowley county belong to the Sumner, Chase, Council Grove, and Admire groups of the Permian system and the Wabaunsee group of the Pennsylvanian system.

Permian rocks.—The youngest bedrock in Cowley county is the lower part of the Wellington shale which is present in most of the westernmost tier of townships. The rocks of the Chase group (fig. 6) average about 375 feet in thickness and they occupy about half the surface of the county. The Herington limestone member of the Nolans formation is about 30 feet thick. Its basal part consists of about 5 feet of fossiliferous limestone; the remainder is dolomitic and less fossiliferous. It is a useful key bed. The Barneston limestones are especially conspicuous. The Florence member lies below extensive dip slopes and the Fort Riley member crops out in wall-like cliffs near the top of Flint Hills slopes. The Council Grove group has an average thickness of about 150 feet in the county. Some of the Council Grove limestones are thicker in Cowley and Butler counties than in counties farther north. Flinty

limestone is characteristic of some of the beds. The Admire group in Cowley county has a total thickness of about 40 feet; it consists chiefly of shale.

Pennsylvanian rocks.—The Burlingame limestone of the Wabaunsee group (fig. 7), the oldest rock exposed in Cowley county, crops out in a very small area in the eastern part of T. 34 S., R. 8 E. Younger Pennsylvanian shales and limestones are exposed in a narrow band in the southeastern part of the county (Bass, 1929, pl. 1).

Subsurface Rocks

Subsurface geologic conditions in the northern part of Cowley county are shown in plate 4. The subsurface rocks of this county dip to the southwest at an average rate of about 22 feet per mile. Three parallel northeast-trending anticlines are the most pronounced structural features of the county. They are the Nemaha anticline in the extreme northwestern part of the county, the Winfield anticline in the west-central part, and the Dexter anticline in the southeastern part.

Pennsylvanian rocks.—The Wabaunsee group has an average thickness of about 400 feet in Cowley county. The Shawnee group has an average thickness of about 650 feet and consists of interbedded shale and limestone and some sandstone. The Douglas group consists of about 350 feet of shale, sandstone, limestone, and red beds. The Lansing group comprises about 400 feet of shale and minor amounts of sandstone and limestone. The sandstone yields oil and gas. The Kansas City group consists largely of shale and sandstone and some limestone. It averages about 200 feet in thickness. Sandstone beds in the upper part of this group are known as the "Layton sand." In the northern part of the county the Kansas City group is composed largely of gray limestone. Various beds in this group yield oil and gas.

The thickness of the combined Bronson, Bourbon, and Marmaton groups in Cowley county is about 300 feet. This part of the section is thickest in the southeastern part of the county. Shale, sandstone, and relatively thin beds of limestone are included. Oil and gas are produced from numerous zones between the Lansing and Cherokee rocks. The Cherokee shale ranges in thickness from slightly less than 300 feet in the eastern part of Cowley county to about 115 feet in the northwestern part (Bass, 1929). Local variations in thickness are common. The Cherokee shale is

thin above the granite ridge, in the Dexter anticline, and locally above other structural highs in pre-Pennsylvanian rocks. The Cherokee is composed of shale, sandstone, and a few thin beds of limestone. Coal is frequently found associated with sandstone. Sandstone beds in the Cherokee are important oil and gas bearing zones. Studies by Bass, Leatherock, Dillard, and Kennedy (1937) indicate that the "Burbank" and "Bartlesville" sandstones are zones composed of numerous lenses of sandstone which occur within narrow trends in the Cherokee shale. The "Burbank sand" lies 50 to 100 feet above the "Bartlesville sand." Shoestring sand bodies in the lower part of the Cherokee shale in Cowley county are called "Bartlesville sand" by geologists and drillers. The "chat," consisting of weathered fragments of chert, lies on Mississippian rocks.

Mississippian rocks.—Mississippian rocks in Cowley county range in total thickness from 225 to 450 feet; they consist chiefly of limestone. Thinning of Mississippian beds in structural highs and thickening of the beds in structural lows in the county have been pointed out by Bass (1929) and by Lee (1939). There is a close relation between thinning of Mississippian rocks and occurrence of oil and gas in anticlines. Oil occurs in Mississippian limestones in porous zones, most of which are in the upper 100 feet. Oil is produced from Mississippian rocks in the Dexter, Geuda Springs, and Murphy pools.

The Chattanooga shale underlies the Mississippian limestones. Locally the Chattanooga was removed by erosion before deposition of younger rocks. Its maximum thickness in Cowley county is about 200 feet.

Ordovician and Cambrian rocks.—Undifferentiated Ordovician and Cambrian rocks, known as the Arbuckle limestone, underlie the Chattanooga shale (or the Mississippian limestone where the Chattanooga is absent) in all of Cowley county except a small area in the northwestern and southwestern corners where rocks of the Simpson formation underlie the Chattanooga. Many wells have penetrated several hundred feet of strata below the Mississippian rocks. The Arbuckle rocks consist of alternating beds of thick limestone and shale. Well records indicate that the maximum thickness of these Ordovician and Cambrian rocks in Cowley county is about 670 feet. Oil and gas are produced from a porous zone near the top of the Arbuckle rocks.

Oil and Gas Developments

Oil and gas wells are widely distributed in Cowley county, but most of the producing pools are in the western half of the county. The Rainbow Bend, Hittle, Carson, Graham, Eastman, Weathered, and Rock pools are the most important. The cumulative production of these pools ranges from 1½ to 13½ million barrels. Most of the oil and gas in the county occurs in structural highs, although some of the most pronounced structures are barren. Gas is produced from a shallow sand in the lower part of the Permian, from sands in the Kansas City-Lansing groups, from shoestring sand bodies in the Cherokee shale locally called "Bartlesville," from some porous zones in the upper part of the Mississippian limestone, and from porous zones in the upper part of the Ordovician limestone. The Graham No. 1 well in the NE¼ sec. 9, T. 33 S., R. 3 E., which was completed in July, 1924, and had an initial production of 900 barrels per day, was the first commercial producer from the Ordovician ("Siliceous") limestone in the county. During 1943, 24 wildcats were drilled in Cowley county. One was an oil producer and 23 were dry holes (Hoot, 1944). The oil and gas fields in Cowley county are shown in figure 14.

Gas was discovered in the **Arkansas City** area in 1906. Much gas was produced from a sandstone in the Admire shale encountered at depths ranging from 650 to 850 feet. Some of the gas wells in this area had a maximum open flow of about 8,000,000 cubic feet of gas a day. These wells were abandoned in 1920. Gas has also been produced southeast of Arkansas City in sec. 4, T. 35 S., R. 4 E., from a sandstone in the Kansas City group.

The **Baird** pool, in secs. 17 and 20, T. 34 S., R 3 E., has two wells producing oil from the "Bartlesville sand." The production of the pool in 1944 was 2,454 barrels. The **Baird East** pool, in the NW¼ sec. 15, T. 34 S., R. 3 E., was discovered in July, 1940. It has one well in which gas is produced from the "Bartlesville sand." The production from this pool in 1944 was 2,440 barrels. The depth to the "Bartlesville" in this area is about 3,200 feet.

The **Biddle** field is in sec. 12, T. 32 S., R. 4 E. and secs. 6 and 7, T. 32 S., R. 5 E. There are 20 wells producing oil from the "Stalnaker sand" at about 2,300 feet and from limestone in the Kansas City group at about 2,000 feet in depth. The production in 1944 was 28,047 barrels. Small amounts of gas have been produced in this field from the Admire shale at a depth of about 600 feet.

The **Brown** pool, in sec. 13, T. 31 S., R. 7 E., was discovered in September, 1922. One well produces oil from a limestone in the Kansas City group and another well produces gas from the same zone. The production in 1944 was 6,652 barrels; the cumulative production to December 31, 1944, was 213,797 barrels.

The **Burden** oil pool, discovered in January, 1926, has 32 wells in secs. 20, 29, 30, 31, and 32, T. 31 S., R. 6 E. Production is from the "Bartlesville sand" which lies at a depth of about 2,800 feet and has an average thickness of about 35 feet. The production from this pool in 1944 was 38,194 barrels.

The **Clark** pool, discovered in January, 1914, has four producing oil wells in sec. 6, T. 31 S., R. 4 E. Production is from the "Bartlesville sand," which averages about 15 feet in thickness and is about 2,800 feet below the surface. The production from the pool in 1944 was 9,024 barrels. The **Clover** pool, in sec 17, T. 31 S., R. 7 E., has one well which yielded 9,024 barrels of oil in 1944. The cumulative production to December 31, 1944, was 16,040 barrels.

The **Couch** pool, in secs. 12 and 13, T. 30 S., R. 5 E., was discovered in May, 1940. There are 22 wells producing oil from the "Bartlesville sand" at a depth of about 2,800 feet. The production in 1944 was 186,598 barrels; the cumulative production to December 31, 1944, was 767,684 barrels. The **Countryman** pool is in secs. 4 and 9, T. 33 S., R. 7 E. There are four wells in the pool; production is from the "Layton sand," which is encountered at a depth of about 1,950 feet and is 12 feet thick. The production in 1944 was 7,762 barrels.

The **Darien** pool, discovered in June, 1939, is in sec. 33, T. 30 S., R. 4 E. Five wells are producing oil from the Arbuckle, which is about 3,300 feet below the surface. The production from this pool in 1944 was 26,416 barrels. The cumulative production to December 31, 1944, was 251,856 barrels.

The **David** pool is in secs. 26, 35, and 36, T. 30 S., R. 4 E. and sec. 2, T. 31 S., R. 4 E. The pool, discovered in July, 1935, has 25 wells which produce oil from the "Bartlesville sand" at a depth of about 2,900 feet. The 1944 production from this pool was 65,268 barrels. The cumulative production to December 31, 1944, was 794,653 barrels. Oil was discovered in the **David South** field in secs. 11 and 15, T. 31 S., R. 4 E., in January, 1938. One well produces from the Arbuckle dolomite at a depth of 3,463 feet and four

wells produce from the "Bartlesville sand" at a depth of about 3,000 feet. The production from this field in 1944 was 7,876 barrels. The cumulative production to December 31, 1944, was 118,519 barrels.

The **Deichman** pool, in secs. 23 and 24, T. 31 S., R. 4 E., was discovered in December, 1941. It has eight wells producing oil from the "Bartlesville sand" which occurs at a depth of about 2,800 feet. Production from this pool in 1944 was 88,944 barrels; cumulative production to December 31, 1944, was 174,276 barrels.

Shallow gas was discovered near Dexter in 1903 (Haworth, 1905, p. 191). The shallow gas wells had open flows of 3,000,000 to 6,000,000 cubic feet of gas and rock pressures of 110 pounds (Bass, 1929, p. 167). Oil was discovered in Cowley county near Dexter in 1914. The **Dexter** oil pool is in secs. 13 and 24, T. 33 S., R. 6 E. and sec. 18, T. 33 S., R. 7 E. The only oil well now producing is in section 18. Production is from Mississippian limestone at a depth of 2,750 feet.

The **Dunbar** oil pool, in sec. 29, T. 30 S., R. 5 E., was discovered in 1938. In 1943 one well produced from Lansing-Kansas City rocks. This pool was abandoned in 1944.

There are 27 oil wells in the **Eastman** oil pool, in sec. 31, T. 30 S., R. 6 E. and secs. 5, 6, 7, and 8, T. 31 S., R. 6 E. The pool was discovered in January, 1924. Large amounts of gas were produced with the oil during the first few years after discovery of the pool. One well is reported to have had an initial open flow of 35,000,000 cubic feet. Production is from the "Bartlesville sand" at a depth of about 2,800 feet. The "Bartlesville" has a maximum thickness of 100 feet and is separated from the Mississippian limestone by about 100 feet of shale. The producing formation is a shoestring sand about one-half mile wide and 1½ miles long. The production from this pool in 1944 was 48,866 barrels.

Gas was discovered in the **Falls City** field, in secs. 16 and 17, T. 35 S., R. 7 E., in January, 1916. The first well had an initial open flow of 7 million cubic feet of gas from a sandstone at a depth of 1,480 feet. The first oil well was drilled in January, 1919. Eight wells are now producing oil from the "Stalnaker sand" at a depth of about 2,000 feet. The production from the Falls City oil pool in 1944 was 11,973 barrels. The cumulative production to December 31, 1944, was 1,221,733 barrels. The gravity of the oil is reported to be 41.2° Bé. (Bass, 1929, p. 174).

The **Ferguson West** pool, in secs. 20 and 21, T. 30 S., R. 8 E., was discovered in October, 1934. Oil is produced in 10 wells from sandstones in the Bronson group at depths of about 2,000 feet. The pool produced 6,362 barrels of oil in 1944.

The **Frog Hollow** pool, in secs. 16, 17, 20, and 21, T. 32 S., R. 5 E., was discovered in January, 1937. The pool has 43 wells which produce from the "Bartlesville sand" at a depth of about 3,000 feet. The production in 1944 was 395,744 barrels, and the cumulative production to December 31, 1944, was 1,905,586 barrels. The **Frog Hollow East** pool, in secs. 14 and 15, T. 32 S., R. 5 E., was discovered in April, 1941. Five wells produce oil from the "Bartlesville sand" at a depth of about 3,000 feet. The production from this pool in 1944 was 34,340 barrels. The cumulative production to December 31, 1944, was 107,874 barrels.

The **Geuda Springs** pool, discovered in March, 1936, has 12 wells producing from the "Bartlesville sand." The pool is in secs. 5, 8, and 9, T. 34 S., R. 3 E. Production in 1944 was 25,902 barrels. The cumulative production to December 31, 1944, was 370,844 barrels.

The **Gibson** pool, discovered in February, 1941, is in secs. 20 and 29, T. 34 S., R. 3 E. Eight wells produce oil from the "Bartlesville sand" at a depth of about 3,300 feet. In 1944 the production from this pool was 44,401 barrels. The cumulative production to December 31, 1944, was 153,586 barrels.

The **Graham** field is in secs. 3, 9, and 10, T. 33 S., R. 3 E. Oil was discovered in August, 1924, when a well was drilled to the Arbuckle at a depth of 3,518 feet. This well had an initial daily production of 1,000 barrels. By the end of 1925, 38 wells had been drilled in the field; 21 were producing from the Arbuckle, 12 were producing from the "Layton sand," and 4 were dry holes. The field now has nine wells which produced 24,350 barrels of oil in 1944. The cumulative production to December 31, 1944, was 2,565,162 barrels.

The **Grand Summit** field, discovered in 1926, is in secs. 3, 4, and 10, T. 31 S., R. 8 E. Gas was found at a depth of about 1,800 feet in the upper part of the Kansas City rocks, and oil was found about 200 feet lower, also in the Kansas City group. The wells had initial daily productions of about 5,000,000 cubic feet of gas and about 25 barrels of 42° Bé. gravity oil. In 1944 the field had 13 wells which produced 18,410 barrels of oil. No gas is now being produced.

The **Henderson** field is in secs. 26 and 27, T. 32 S., R. 3 E. Oil was discovered in May, 1942. Four wells now produce from the Kansas City limestone at a depth of about 2,690 feet and from the Arbuckle rocks at a depth of about 3,419 feet. The production in 1944 was 21,464 barrels of oil. The cumulative production to December 31, 1944, was 47,843 barrels.

The **Hittle** field, in secs. 21 and 28, T. 31 S., R. 4 E., has 65 producing wells. Oil was discovered in January, 1926, in a limestone in the Kansas City group at a depth of about 2,400 feet. Oil is also obtained from the Arbuckle limestone at a depth of about 3,280 feet. The production in 1944 was 663,034 barrels; the cumulative production to December 31, 1944, was 5,473,034 barrels.

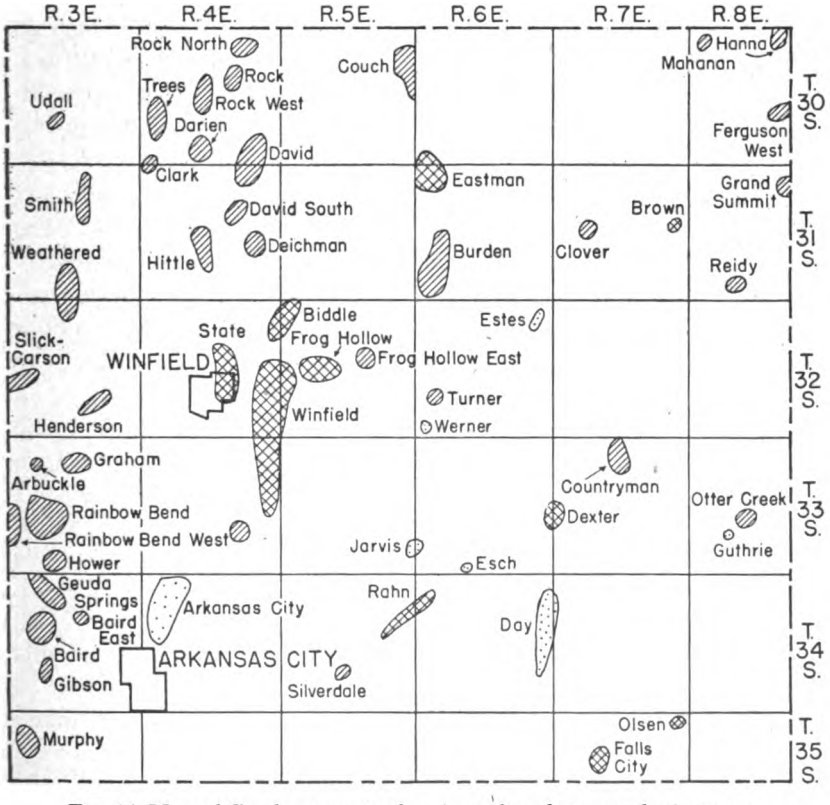

FIG. 14. Map of Cowley county showing oil and gas producing areas. Several abandoned areas are omitted. (Gas, dots; oil, diagonal lines; oil and gas, crossed diagonal lines.)

The **Hower** pool, discovered in December, 1935, is in secs. 32 and 33, T. 33 S., R. 3 E., and now has four producing oil wells. The production from this pool in 1944 was 7,597 barrels. The cumulative production to December 31, 1944, was 31,710 barrels.

The **Mahannah** pool, in sec. 6, T. 30 S., R. 8 E., was discovered in 1918. Production is from the "Burgess sand" at a depth of about 2,730 feet. The only oil produced from the pool in 1944 was 155 barrels in February. The cumulative production to December 31, 1944, was 47,686 barrels of oil.

The **Murphy** pool, in secs. 6, 7, and 8, T. 35 S., R. 3 E., was discovered in January, 1933. The oil is produced from the "chat" at the top of the Mississippian limestone. The average depth of the wells is 3,300 feet. In 1944, 12 wells produced 28,334 barrels.

The **Olsen** field is in sec. 1, T. 35 S., R. 7 E. Oil was discovered in this field in 1922. Initial productions between 50 and 75 barrels a day were obtained from a sandstone in the Marmaton group at a depth of about 2,375 feet. Some wells produced as much as 18,000,000 cubic feet of gas from a sandstone in the Lansing group at a depth of about 1,700 feet. There are now four oil wells in the field. Production for 1944 was 2,625 barrels.

The **Otter Creek** pool, in secs. 19 and 20, T. 33 S., R. 8 E., was discovered in October, 1943, and three wells were completed by the end of that year. The discovery well was the Northern Ordnance No. 1 Ramey, in the SW¼ sec. 20, T. 33 S., R. 8 E. Production is from the Kansas City-Lansing rocks. The cumulative production to December 31, 1944, was 3,103 barrels.

The **Otto** oil and gas field is in secs. 12, 13, 24, and 25, T. 34 S., R. 6 E. Oil was found in the Lewis and Hollis No. 1 Day well, in the NW¼ sec. 25, T. 34 S., R. 6 E., in the "chat" at a depth of 3,017 feet. Gas was found in several wells at depths ranging from about 1,100 to 1,450 feet. Some of the gas contains helium. The oil wells in this field have been abandoned but gas is still being produced.

The **Rahn** pool, discovered in December, 1939, is in secs. 12, 13, and 14, T. 34 S., R. 5 E. and sec. 7, T. 34 S., R. 6 E. Eighteen wells are producing oil from the "Bartlesville sand," which is about 30 feet thick and about 2,900 feet below the surface. The producing sandstone is a shoestring more than 2 miles in length and less than one-fourth mile in width. Twelve producing wells were completed in 1943. The production from this pool in 1944 was 177,382 barrels. Cumulative production to December 31, 1944, was 263,621 barrels.

The **Rainbow Bend** pool is in secs. 17, 20, 21, 28, and 29, T. 33 S., R. 3 E. The discovery well was drilled on the Johnson farm, in sec. 20, T. 33 S., R. 3 E., in December, 1923. It came in as a flowing well having an initial production of about 337 barrels per day. Production is from the "Burgess sand" in the basal part of the Cherokee shale. The "Burgess" ranges in thickness from 5 to 35 feet and lies at a depth of about 3,200 feet. The producing sand occurs in a structural high which conforms generally with the structure of the underlying Mississippian limestone. The Mississippian limestone is about 100 feet thinner on the axis of the fold than on the flanks. In 1944 the pool had 114 producing oil wells and the production was 221,559 barrels. The cumulative production to December 31, 1944, was 14,065,205 barrels, which is the largest cumulative production of any pool in Cowley county.

The **Rainbow Bend West** field, a westward extension of the Rainbow Bend pool, is in secs. 19 and 30, T. 33 S., R. 3 E. The field has three wells and production is from the "Burgess sand" and from the Arbuckle dolomite at a depth of about 3,500 feet. The production in 1944 was 11,296 barrels.

The **Reidy** pool, in sec. 31, T. 31 S., R. 8 E., was abandoned in 1943. Previously there were three wells which produced from a limestone in the Kansas City group.

The **Rock** oil pool, in secs. 11, 14, and 15, T. 30 S., R. 4 E., was discovered in September, 1937. Production is from the "Bartlesville sand" which is about 45 feet thick and about 2,800 feet below the surface. The pool has 30 producing wells. The production in 1944 was 36,723 barrels, and the cumulative production to December 31, 1944, was 1,642,791 barrels. The **Rock North** pool, 1 mile north of the Rock pool in secs. 2 and 3, T. 30 S., R. 4 E., was discovered in September, 1937. The pool has five wells which produce oil from the "Bartlesville sand" at a depth of about 2,800 feet. The production in 1944 was 8,180 barrels. The cumulative production to December 31, 1944, was 93,673 barrels. The **Rock West** pool, 1 mile west of the Rock pool in secs. 16 and 21, T. 30 S., R. 4 E., was discovered in October, 1937. Production is from the "Bartlesville sand" which has a thickness of about 12 feet and is encountered at a depth of about 2,780 feet. In 1944 there were 16 wells in this pool and the production was 107,624 barrels. The cumulative production to December 31, 1944, was 713,706 barrels.

The **Silverdale** pool was discovered in February, 1944. The discovery well was the Gralapp et al. No. 1 Dunn, in the NE¼ SE¼ sec. 28, T. 34 S., R. 5 E. Production is from the "Bartlesville sand" which is 52 feet thick and occurs about 3,019 feet below the surface. The pool produced 145 barrels of oil in February, 93 barrels in March, 155 barrels in May, and 90 barrels in June, a total of 483 barrels to December 31, 1944.

The **Slick-Carson** field is in secs. 19 and 20, T. 32 S., R. 3 E.; oil was discovered in the field in January, 1925. Production is from the "Layton sand" in the upper part of the Kansas City group at a depth of about 2,700 feet and from the Arbuckle limestone at a depth of about 3,450 feet. The field has 16 producing wells. The production in 1944 was 39,804 barrels. Cumulative production to December 31, 1944, was 3,253,704 barrels.

The **Smith** pool, in secs. 3, 10, and 15, T. 31 S., R. 3 E., was discovered in January, 1917. Seven wells are producing oil from the "Bartlesville sand" at an average depth of 3,000 feet. The production from this pool in 1944 was 4,765 barrels.

The **State** field is in secs. 9, 15, 16, 22, 23, and 27, T. 32 S., R. 4 E. The discovery well, drilled in January, 1926, on land owned by the State of Kansas, had an initial production of nearly 12,000 barrels of oil per day from the Arbuckle limestone at a depth of 3,500 feet (Bass, 1929, p. 142). Most of the production in this field is from the Arbuckle, but several wells produce oil from the "Layton sand" at a depth of about 2,300 feet. In 1944 the production from 19 wells was 42,824 barrels of oil.

The **Trees** pool, in secs. 19 and 30, T. 30 S., R. 4 E., was discovered in January, 1934. Production is from the "Bartlesville sand" which is encountered at a depth of about 2,975 feet and is about 25 feet thick. The production in 1944 from 10 wells was 21,311 barrels.

The **Turner** pool, discovered in June, 1937, is in sec. 30, T. 32 S., R. 6 E. Production is from the "Layton sand" at a depth of about 2,332 feet. There are four producing wells in the pool; the production in 1944 was 15,424 barrels. The cumulative production to December 31, 1944, was 218,073 barrels.

Oil was discovered in July, 1935, in the **Weathered** field, in secs. 28 and 33, T. 31 S., R. 3 E. and sec. 4, T. 32 S., R. 3 E. There are 20 wells producing from the Arbuckle limestone, 2 wells producing from the Mississippian limestone, 2 wells producing from the Kan-

sas City-Lansing rocks, and 1 well producing from the "Stalnaker sand." The production from this field in 1944 was 57,778 barrels. The cumulative production to December 31, 1944, was 2,336,802 barrels.

The **Winfield** field, in secs. 13, 23, 24, 25, 26, 35, and 36, T. 32 S., R. 4 E., secs. 18, 19, 30, and 31, T. 32 S., R. 5 E., and secs. 1, 11, 12, 13, 14, 23, and 24, T. 33 S., R. 4 E., was opened in November, 1914. Haworth (1903, pp. 37, 38) reported that gas was discovered about a quarter of a mile east of Winfield in 1902. The Winfield field comprises 5,000 acres. Oil is produced from a sandstone in the Admire group at a depth of about 600 feet, from the "Peacock sand" at about 1,400 feet, from the "Layton sand" at a depth of about 2,300 feet, from the "Bartlesville sand" at about 3,050 feet, and from the Arbuckle limestone at about 3,300 feet (Ver Wiebe, 1943, p. 351). Much gas is produced from the "Peacock sand." In 1944, 75,389 barrels of oil were produced from this field.

Maximum oil production in Cowley county was in 1925, when 7,038,874 barrels were produced. In that year production in the Rainbow Bend pool reached its peak, nearly 4 million barrels. In 1926, 3,943,061 barrels of oil were produced in the county. Production has gradually declined, and in 1944, 2,631,760 barrels of oil were produced. The cumulative production of oil in Cowley county to December 31, 1944, was 36,131,760 barrels. In 1944 there were 683 producing oil wells.

Oil and gas production statistics for recent years are given in tables 27 and 28.

CRAWFORD COUNTY

There are several small oil and gas pools in the western part of Crawford county. Oil and gas are produced from the "Bartlesville sand" which ranges in depth from 300 feet in the southwestern part of the county to 600 feet in the northwestern part. Oil was discovered in the northwestern part of Crawford county in 1917. Gas has been produced for many years in the vicinities of Walnut, Monmouth, and McCune.

Surface Rocks

The consolidated rocks exposed in Crawford county belong to the Pennsylvanian system. They consist of alternating beds of limestone and shale, about 15 beds of coal, and several beds of sandstone. The rocks have an average westerly dip of about 12

TABLE 27.—*Reported monthly production of oil in Cowley county, Kansas, in barrels*

Month	1941		1942		1943		1944	
	No. of wells	Production	No. of wells	Production	No. of wells	Production	No. of wells	Production
January	659	224,234	680	235,945	684	241,602	687	224,967
February	658	236,705	681	225,512	681	239,868	688	212,976
March	663	227,580	685	216,934	680	237,587	688	229,896
April	665	236,218	682	226,515	685	241,693	688	194,250
May	664	236,462	685	219,580	686	225,147	690	230,454
June	666	241,846	685	267,670	684	236,371	690	219,300
July	666	230,409	685	240,112	684	232,447	690	207,235
August	669	233,694	685	250,697	684	225,420	690	223,820
September	672	236,218	684	259,062	685	215,717	689	216,090
October	668	238,135	687	248,416	689	211,611	683	217,527
November	669	233,481	675	234,728	688	217,968	681	225,870
December	675	241,724	683	240,811	683	212,797	681	229,431
Totals		2,816,706		2,865,982		2,738,228		2,631,816

TABLE 28.—*Natural gas production in Cowley county, Kansas*

Year	Thousands of cubic feet
1939	298,857
1940	406,409
1941	274,878
1942	318,849
1943	400,802

feet per mile. The Hertha limestone, which crops out in the extreme northwestern part of the county, is the youngest consolidated rock in Crawford county. The Cherokee shale which crops out in the southeastern part of the county is the oldest exposed rock.

The Bourbon shale (fig. 8) is exposed in the northwestern part of Crawford county. It consists of about 75 feet of shale, some very thin limestones, and a sandstone 3 or 4 feet thick in the basal part. Marmaton rocks are exposed in Crawford county and are about 250 feet thick. Shale ranging in color from light gray through bluish and dark gray to black is the predominant rock of the Cherokee shale (fig. 9). It is clayey, silty, micaceous, sandy, or carbonaceous. There are several sandstones, a few thin limestones, and 15 beds of coal. The Bluejacket sandstone, locally called the "Columbus" sandstone, ranges in thickness from 20 to 50 feet and is underlain by the Columbus coal. Measured thicknesses of the Cherokee shale in Crawford county range from 316 to 455 feet.

Subsurface Rocks

Subsurface geologic conditions along the southern boundary of Crawford county are shown diagrammatically on plate 4. Depths at which some stratigraphic horizons were reached in the La Salle Oil Company No. 1 Gable well, in the SE¼ NW¼ sec. 20, T. 28 S., R. 25 E., are given in table 29.

Mississippian rocks.—The Mississippian rocks in Crawford county are composed of limestone, some of which is flinty, and shale. The Warsaw, Burlington-Keokuk, Reeds Spring, and St. Joe limestones, the Northview shale, and the Compton limestone are present in the county. The Chattanooga shale, which commonly lies at the base of the Mississippian, is very thin or is locally absent in Crawford county. The Mississippian rocks range in thickness from 300 to 400 feet. They lie unconformably on Ordovician rocks.

Ordovician rocks.—Silurian, Devonian, and the upper part of Ordovician rocks are absent in Crawford county. Deep wells have penetrated a thick section of interbedded limestone and sandstone of Ordovician age. The formations of the Ordovician present in the county are the Cotter dolomite, the Jefferson City dolomite, the Roubidoux sandstone, and the Gasconade-Van Buren dolomites, including the Gunter sandstone. The Cotter dolomite is absent in the eastern part of the county. The total thickness of Ordovician rocks ranges from about 685 feet in the northeastern part of the county, where the Cotter is absent, to 800 feet in the southwestern

part, where the Cotter is about 100 feet thick. The Roubidoux sandstone has an average thickness of about 175 feet and is an important fresh water-bearing sandstone.

Cambrian rocks.—Cambrian rocks have a total thickness of about 430 feet in the northeastern part of Crawford county and about 340 feet in the southwestern part. Cambrian formations present in the county are the Eminence and Bonneterre dolomites and the Lamotte sandstone.

Pre-Cambrian rocks.—Cuttings from wells that have penetrated pre-Cambrian rocks in Crawford county seem to consist of hard red unaltered granite. The average depth to pre-Cambrian rocks in the county is about 2,000 feet.

TABLE 29.—*Depths to some formations in the La Salle Oil Company No. 1 Gable well, SE¼ NW¼ sec. 20, T. 28 S., R. 25 E., Crawford county, Kansas*

Formation	Depth, in feet
Top of Warsaw limestone	350
Top of Keokuk-Burlington limestone	425
Top of Reeds Spring-St. Joe limestone	550
Top of Northview shale	660
Top of Compton limestone	705
Top of Cotter-Jefferson City dolomite	725
Top of Roubidoux formation	950
Top of Gasconade-Van Buren formation	1,150
Top of Gunter sandstone member	1,380
Top of Eminence dolomite	1,410
Top of Bonneterre dolomite	1,500
Top of Lamotte sandstone	1,700
Top of pre-Cambrian granite	1,838

OIL AND GAS DEVELOPMENTS

The oil and gas fields of Crawford county as designated by the Oil Field Nomenclature Committee of the Kansas Geological Society are listed in table 30. The locations of the fields are shown in figure 15.

Many gas wells have been drilled in Crawford county. All commercial wells are in the extreme western part of the county. Oil is produced from narrow elongated lenses of "Bartlesville sand." The sandstone ranges from 20 to 40 feet in thickness and lies at a depth of about 600 feet in the Walnut area in the northwestern part of the county and at a depth of about 300 feet in the McCune area in the southwestern part.

TABLE 30.—*Oil and gas fields in Crawford county, Kansas*
(As designated by the Oil Field Nomenclature Committee of the Kansas Geological Society, November 15, 1944)

Name	Location
Brazilton (Abandoned)	T 28 S, R 22 E, secs. 35, 36
Fair Oak	T 28 S, R 22 E, sec. 33
Girard	T 29 S, R 23 E, secs. 13, 14
Green Elm (Abandoned)	T 29 S, R 22 E, sec. 31
	T 30 S, R 22 E, sec. 6
Hepler (Abandoned)[1]	T 27 S, R 21 E, secs. 25, 36
	T 27 S, R 22 E, secs. 28 to 31
	T 28 S, R 21 E, sec. 1
	T 28 S, R 22 E, sec. 6
McCune	T 30 S, R 21 E, sec. 36
	T 30 S, R 22 E, secs. 18, 19, 30, 31
	T 31 S, R 21 E, sec. 1
	T 31 S, R 22 E, secs. 6, 7
McCune Townsite	T 31 S, R 22 E, secs. 16, 17
Monmouth	T 31 S, R 22 E, secs. 11 to 14
St. Paul-Walnut[2]	T 28 S, R 21 E, secs. 13, 14, 23, 24, 26, 35
	T 29 S, R 21 E, secs. 2, 11, 14, 23
Walnut Southeast	T 28 S, R 22 E, secs. 16, 17, 20, 21, 29 to 32
	T 29 S, R 21 E, secs. 1, 12, 13
	T 29 S, R 22 E, sec. 31

[1] Also in Bourbon county (see table 12)
[2] Also in Neosho county (see table 75); includes fields formerly known as Walnut, St. Paul, and Island.

The **McCune** pool was discovered in 1932. The first wells produced gas, but oil was soon found. The oil is produced from the "Bartlesville sand" at a depth of about 300 feet. The "Bartlesville," which has an average thickness of about 25 feet, is about 180 feet below the Fort Scott limestone and about 180 feet above the Mississippian limestone. The McCune pool is a shoestring type pool and has several hundred producing oil wells, some of which had initial productions of 100 barrels per day. The production declined rapidly to 10 or 12 barrels per day.

The Engle water-flooding project, in sec. 7, T. 30 S., R. 22 E., in the McCune pool, was started in September, 1937 (Grandone, 1944, pp. 67-69). The first increase in the rate of oil production was in November, 1937. Twenty acres were flooded; there were 16 oil recovery wells. The cumulative oil production was 862 barrels per acre. Flooding was discontinued in August, 1939.

Two water-flooding projects are now in operation in the McCune pool (Grandone, 1944, pp. 69-75). The Max B. Miller & Co.,

Inc., McCune No. 1 project is in secs. 18 and 19, T. 30 S., R. 22 E. Injection of water was started in June, 1937, and the first increase in rate of oil production was in November, 1937. The cumulative oil production of 36 wells to November, 1942, was 3,940 barrels per acre. The Max B. Miller & Co., Inc., McCune Flood No. 2 project is in sec. 30, T. 30 S., R. 22 E. Twelve acres were flooded, and oil was produced from 13 oil recovery wells. Water injection was started on October 17, 1941, and the first oil increase was noted in February, 1942. The cumulative oil production to November 1, 1942, was 815 barrels per acre.

Reported monthly production of oil in Crawford county in 1941, 1942, and 1943 is shown in table 31. Natural gas production figures for the years 1939 to 1943 are given in table 32.

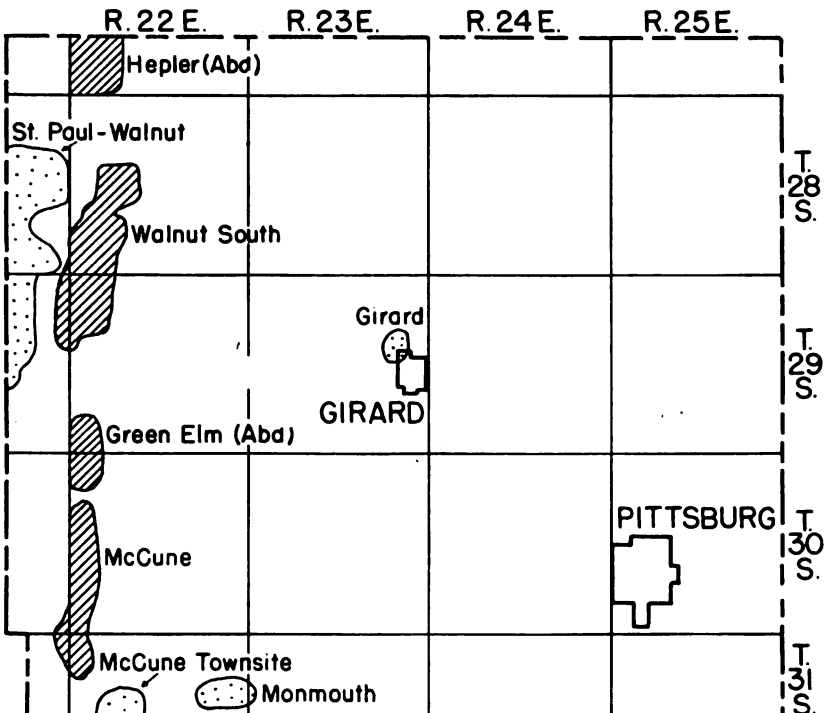

FIG. 15. Map of Crawford county showing oil and gas producing areas. Fair Oak field, in sec. 33, T. 28 S., R. 22 E., is not shown. (Gas, dots; oil, diagonal lines.)

TABLE 31.—*Reported monthly production of oil in Crawford county, Kansas, in barrels*

Month	1941	1942	1943
January	2,901	1,575	2,374
February	3,680	1,646	2,298
March	3,212	2,473	1,955
April	3,065	2,766	2,762
May	3,440	2,441	2,292
June	3,274	2,688	1,916
July	3,124	2,454	2,907
August	3,383	2,802	1,891
September	2,713	2,428	1,823
October	2,087	2,564	2,728
November	2,811	1,977	1,879
December	2,619	1,128	1,382
Totals	36,309	26,942	26,207

TABLE 32.—*Natural gas production in Crawford county, Kansas*

Year	Thousands of cubic feet
1939	30,000
1940	107,499
1941	154,817
1942	140,634
1943	70,000

DICKINSON COUNTY

Oil has been found in two areas in Dickinson county. The Lost Springs field was extended into the southeastern part of the county several years ago and the Bonaccord pool was discovered in 1943.

SURFACE ROCKS

Cretaceous rocks crop out in a small area in the northwestern corner of Dickinson county. The consolidated bedrock at the surface in the remainder of the county is Permian in age. The exposed Permian section extends from the lower part of the Wellington shale of the Sumner group to the lower part of the Barneston limestone of the Chase group (fig. 6). The valley of Smoky Hill river contains a rather thick fill of alluvium, and dune sand covers a few square miles a short distance west of Abilene on the north side of the river.

SUBSURFACE ROCKS

Subsurface geologic conditions in the central part of Dickinson county are shown in plate 2.

Pennsylvanian rocks.—The top of Pennsylvanian rocks in Dickinson county is about 600 feet below the base of the Barneston limestone. The Wabaunsee group, consisting chiefly of shale and relatively thin limestone beds, is about 350 feet thick. Lenticular sandstones occur in the basal part, lying on or a few feet above the Topeka limestone. The Shawnee group, about 350 feet thick, is composed largely of limestone, especially in the lower part. The Douglas group is about 100 feet thick in the county. One or more lenticular sandstone bodies occur in the Douglas section, which in some wells consists entirely of sandstone and in others entirely of shale. The thickness of the combined Lansing, Kansas City, and Bronson groups, which are composed chiefly of limestone, is about 550 feet. A rather persistent thin shale about 225 feet from the top of the Lansing group probably marks the top of the Kansas City group. The basal part of the Kansas City is probably marked by a persistent zone of sandstone and conglomerate approximately 420 feet below the top of the Shawnee group. The Bourbon shale in Dickinson county is about 35 feet thick, and the Marmaton and Cherokee rocks range from about 60 to 150 feet in thickness. About 35 feet of shale which occurs locally above the Mississippian limestone is probably Cherokee shale.

Pennsylvanian rocks in Dickinson county overlap and overstep Mississippian limestone beds, as indicated by the thicker lower Pennsylvanian and Mississippian section in the western part of the county.

Mississippian rocks.—The Mississippian limestones in Dickinson county range from about 100 to 150 feet in total thickness. They are underlain by about 150 feet of Chattanooga shale.

Pre-Chattanooga rocks.—About 165 feet of "Hunton" limestone seemingly underlies all of Dickinson county. The Maquoketa shale is about 75 feet thick in the county. It is underlain by about 100 feet of Viola limestone. About 90 feet of sandstone, gray and red shale, and limestone occur below the Viola limestone and above the Arbuckle rocks. These rocks are correlated with the St. Peter (Simpson) formation. It is probable, however, that the St. Peter sandstone comprises only the approximate lower half. The undifferentiated Arbuckle rocks in Dickinson county consist of about 250 feet of limestone and dolomite.

Oil Developments

An active drilling campaign took place in Dickinson county in 1919 and 1920 but all tests were unsuccessful. Later the Lost Springs pool was found to extend into southeastern Dickinson county. In 1943 the Bonaccord oil pool was discovered.

The **Bonaccord** oil pool is in secs. 30 and 31, T. 14 S., R. 1 E. The discovery well, which was completed late in August, 1943, is in the Cen. S½ SE¼ SW¼ sec. 30, T. 14 S., R. 1 E. A daily potential production of 223 barrels was reported. Oil was found in the "Burgess sand," the top of which was encountered at 2,483 feet. Later two additional producing wells were drilled in the NE cor. NW¼ sec. 31, T. 14 S., R. 1 E. and in the SW¼ NE¼ SW¼ sec. 30, T. 14 S., R. 1 E. Smaller initial productions were reported for the later wells. During the last five months of 1943, 3,047 barrels of oil were produced. By January, 1944, production had declined to about 7½ barrels per day.

The **Lost Springs** oil pool extends from Marion county into sec. 34, T. 16 S., R. 4 E., Dickinson county. Production is from the "chat" in the upper part of the Mississippian limestone. Production figures for the Lost Springs pool are included in table 63.

DONIPHAN COUNTY

Oil or gas in commercial quantities has not been found in Doniphan county. As in other northeastern Kansas counties, not enough tests have been drilled into deeper rocks to condemn the area.

Surface Rocks

Glacial drift covers much of the surface of Doniphan county. All the consolidated rocks that are exposed or are present immediately below the drift are of Pennsylvanian age. The outcropping Pennsylvanian rocks in the county include beds from the Reading limestone in the Wabaunsee group to the upper part of the Lawrence shale in the Douglas group (fig. 7). Their total thickness is about 630 feet.

Subsurface Rocks

Pennsylvanian rocks.—The Pennsylvanian section in the western part of Doniphan county is about 2,000 feet thick; in the eastern part, where the surface rocks are older, the total thickness of Pennsylvanian rocks is about 1,500 feet.

Mississippian rocks.—The total thickness of Mississippian limestone formations in Doniphan county ranges from about 250 feet in the northwestern corner to more than 300 feet in the southeastern part (Lee, 1939, pl. 1). According to Lee and Payne (1944, figs. 7 and 17), the Ste. Genevieve limestone lies next below Pennsylvanian rocks throughout most of the area. The rock next below the Pennsylvanian in a narrow north-south belt in the west-central part of the county is believed to be the St. Louis limestone. Spergen limestone is the uppermost Mississippian formation in the northwestern part of the county. The Warsaw, Burlington, Gilmore City, Sedalia, and Chouteau limestones are believed to comprise the

TABLE 33.—*Data on wells in Doniphan county, Kansas*

Name of well	Location	Remarks	Total depth in feet
Valley Petroleum Co. No. 1 Mann	SE¼ NW¼ sec. 21, T. 1 S., R 19 E.	Top Mississippian rocks at 1,975 feet; top Chattanooga shale at 2,205 feet; top "Hunton" limestone at 2,281 feet; stopped in "Hunton"	2,315
Doniphan Oil and Gas Co. No. 1 Albers	Cen. SW¼ SE¼ sec. 14, T. 3 S., R. 19 E.	Top Mississippian limestone at 1,715 feet (?)	1,725
Gall et al. No. 1 Caudel	NW¼ NW¼ SE¼ sec. 18, T. 3 S., R 20 E.	Stopped in "Hunton" limestone	2,090
———— No. 1 Stout	Sec. 19, T. 3 S., R. 20 E.	Stopped in Cherokee shale	1,500
———— No. 2 Stout	Cen. NW¼ sec. 30, T. 3 S., R. 20 E.	Top of Mississippian at 1,775 feet; top of Chattanooga shale at 2,010 feet; stopped in Chattanooga shale.	2,120
Garden Construction Co. No. 1 Elliott	SE¼ SW¼ sec. 31, T. 3 S., R. 20 E.	Top of Arbuckle limestone at 2,898 feet	2,950
Southwest Oil and Gas Co. No. 1 Nity	SE cor. sec. 19, T. 4 S., R. 21 E.	Stopped in Cherokee shale	1,571
Diamond Prospecting Co. Doniphan	Sec. 5, T. 5 S., R. 21 E.	Diamond drill hole, drilled in 1878; stopped in Cherokee shale	998

remainder of the Mississippian limestone section in the county (Lee, 1940, pl. 8; Lee and Payne, 1944, fig. 17).

According to Lee (1943, fig. 14), the thickness of the Chattanooga shale in Doniphan county increases westward from about 100 feet to more than 150 feet.

Pre-Chattanooga rocks.—According to Lee (1943, fig. 12), the interval between the base of the Chattanooga shale and the top of the Maquoketa shale in Doniphan county ranges from about 300 feet in the southeastern part to nearly 550 feet in the northwestern part. The interval from the top of the Maquoketa shale to the top of the St. Peter sandstone ranges from about 275 to 350 feet. The increase in thickness is toward the northwest (Lee, 1943, fig. 11). The thickness of rocks between the top of the St. Peter sandstone and pre-Cambrian rocks ranges from about 450 feet in the northwestern part of the county to 650 feet or more in the eastern part (Lee, 1943, fig. 9).

Oil and Gas Exploration

Doniphan county has been very inadequately tested for oil and gas. Data on eight wells in the county are given in table 33.

DOUGLAS COUNTY

Small quantities of oil and gas have been produced in Douglas county for a number of years. Oil production is from the "Squirrel sand" and is restricted to the Baldwin area in the southeastern part of the county. The "Squirrel sand" is in the upper part of the Cherokee shale and is about 800 feet below the surface in southeastern Douglas county.

Surface Rocks

The exposed consolidated rocks in Douglas county are of Pennsylvanian age, and belong to the Shawnee, Douglas, Pedee, and Lansing groups. The youngest of these is the Topeka limestone and the oldest is the Plattsburg limestone or perhaps a few feet of the Bonner Springs shale. Glacial drift is attenuated in the northern part of the county. The valleys of Kansas river and Wakarusa creek are filled with sand and gravel to depths as great as 80 feet or more.

The Deer Creek and Oread limestones of the Shawnee group (fig. 7) cap prominent escarpments. Lenticular sandstones are common in the upper parts of the Calhoun, Tecumseh, and Kan-

waka shales. Several limestones are useful key beds for surface or shallow subsurface structural mapping in the western part of the county. The thickness of the Shawnee group in Douglas county is about 300 feet. The Douglas group is composed chiefly of shale and sandstone. The Haskell limestone, in the middle part of the Douglas section, is a useful key bed. Thick lenticular sandstones occur both above and below the Haskell limestone. A disconformity below the Ireland sandstone cuts out the Haskell limestone in the southeastern part of the county. The thickness of the Douglas group in the county ranges from about 200 to 270 feet.

Post-Missourian erosion removed Pedee rocks (fig. 8) from the northeastern part of Douglas county, but about 60 feet of shale lying between the Stanton limestone and the Tonganoxie sandstone in the southeastern part of the county is correlated with the Weston shale. In the same area a thin limestone is believed to be the Iatan. Rocks of the Lansing group are exposed in the northeastern part of the county in the vicinity of Eudora and eastward along the south side of Kansas river valley. The Stanton limestone is well exposed there. The thickness of Lansing rocks in Douglas county is about 100 feet.

Subsurface Rocks

Douglas county lies on the southeastern flank of the North Kansas basin. The Chattanooga shale oversteps Devonian rocks, the Maquoketa shale, and the upper beds of the Kimmswick limestone from the northwest (Lee, 1943, fig. 7, wells 5 and 6). Subsurface geologic conditions along the southern boundary of Douglas county are shown in plate 2.

Pennsylvanian rocks.—Pennsylvanian rocks in Douglas county older than those of the Lansing group are known only through study of well logs and cuttings. The total thickness of the Lansing, Kansas City, and Bronson groups in the county is about 350 feet. The thickness of the Bourbon, Marmaton, and Cherokee section ranges from about 700 feet in the eastern part of the county to slightly more than 800 feet in the northwestern part.

Mississippian rocks.—The total thickness of Mississippian limestone formations in Douglas county ranges from about 250 feet to slightly more than 400 feet (Lee, 1943, fig. 16). The Spergen (?), Warsaw, Burlington, Sedalia, and Chouteau formations are believed to be present in the county (Lee, 1940, pl. 4). The Chattanooga shale ranges in thickness from about 50 feet in the south-

eastern and southwestern parts of Douglas county to about 100 feet in the northwestern part (Lee, 1943, fig. 14).

Devonian rocks.—In the Smith et al. No. 1 Smith well, in sec. 28, T. 12 S., R. 19 E., 70 feet of Devonian limestone was identified, but in the Duffens et al. No. 1 Stanley well, in sec. 3, T. 14 S., R. 21 E., the Chattanooga shale lies on the Kimmswick limestone (Middle Ordovician).

Ordovician and Cambrian rocks.—Rocks of Silurian age are believed to be absent in Douglas county and the Maquoketa shale (Upper Ordovician) is present only in a small area in the northwestern part of the county (Lee, 1943, fig. 11). In the No. 1 Smith well 115 feet of Kimmswick limestone was penetrated, and in the No.1 Stanley well 104 feet of Kimmswick (including probably some Decorah at the base) was identified. The Smith well was drilled through 10 feet of Decorah shale and 75 feet of St. Peter sandstone. A thickness of 54 feet of St. Peter sandstone was found in the Stanley well. Thicknesses of units of the Arbuckle identified in this well are: undifferentiated Cotter and Jefferson City dolomites, 106 feet; Roubidoux formation, 167 feet; undivided Gasconade and Van Buren dolomites, including a slight thickness of Gunter sandstone in the basal part, 206 feet; Eminence dolomite, 175 feet; and Bonneterre dolomite, 91 feet (Lee, 1943, fig. 5). Seven feet of Lamotte sandstone lies on pre-Cambrian crystalline rocks in this well.

Oil and Gas Developments

Although several deep test wells have been drilled in Douglas county, oil and gas have not been found in rocks older than the Cherokee shale. Known structural conditions in rocks older than the Chattanooga shale, however, suggest the probability that stratigraphic traps may exist in the Devonian or Kimmswick rocks.

The **Baldwin** oil pool extends from southeastern Douglas county into Franklin county. It is in sec. 36, T. 14 S., R. 20 E.; secs. 28, 31, 32, and 33, T. 14 S., R. 21 E.; secs. 1, 2, 3, 9, 11, 12, 13, 14, 15, 22, 23, and 24, T. 15 S., R. 20 E.; and secs. 4, 5, 6, 7, 8, 9, 10, 15, 16, and 17, T. 15 S., R. 21 E. Oil production is from the "Squirrel sand" about 800 feet below the surface. The pool was discovered in 1919.

The **Eudora** gas pool is in secs. 17, 18, 19, 20, 29, and 30, T. 13 S., R. 21 E. The **Eudora East** gas pool extends into Johnson county

and is in secs. 2, 3, 4, and 9, T. 13 S., R. 21 E. Production in these pools is from the "Squirrel sand" at a depth of about 700 feet.

The **Lawrence** gas-producing area lies northeast of Lawrence and extends into Leavenworth county. Gas was discovered in 1944 in the Huber No. 1 Community well in the NW¼ sec. 33, T. 12 S., R. 20 E.. The "Squirrel sand" at a depth of 670 feet yields this gas. The well was gauged at 85,000 cubic feet of gas per day.

Peak oil production in Douglas county was in 1927 when 23,901 barrels of oil were produced. Table 34 gives oil and gas production statistics for Douglas county.

TABLE 34.—*Oil and gas production in Douglas county, Kansas*

Year	Oil, in barrels[1]	Gas, in Thousands of cubic feet
1939		7,522
1940		9,380
1941	7,020	29,499
1942	5,760	26,120
1943	3,054	35,997

[1] Estimated

ELK COUNTY

The first gas well in Elk county was completed on the Johnson farm near Elk Falls on July 4, 1901. Oil was discovered near Longton in 1902, and oil and gas are still produced in this area. Production in Elk county has been relatively important since about 1921. Most of the gas has been produced in the southern half of the county. The southwestern part of the county is the principal oil-producing area.

SURFACE ROCKS

The youngest consolidated rocks exposed in Elk county belong to the Chase group. They crop out in the western part of the county. The oldest rocks exposed belong to the Douglas group and crop out in the eastern part of the county.

Permian rocks.—Only the lower formations of the Chase group (fig. 6), the Matfield shale and the Wreford limestone, are present in Elk county. They cap the hills in the western part of the county. The Council Grove group in Elk county consists of about 125 feet of limestone and shale. Rocks of the Admire group consist of shale, thin beds of limestone, and some coal. They have a total thickness of about 90 feet.

Pennsylvanian rocks.—The Wabaunsee group (fig. 7) consists of shale, sandstone, and thin beds of limestone; it has a total thickness of about 300 feet in Elk county. The average thickness of the Shawnee group in the county is about 425 feet. The Douglas group consists chiefly of shale and sandstone, and includes thin beds of limestone and some coal. The Douglas rocks have a total thickness of about 300 feet in Elk county. Only the upper part of the group crops out.

Subsurface Rocks

Subsurface geologic conditions in the southern part of Elk county are shown diagrammatically in plate 4.

Pennsylvanian rocks.—The total thickness of rocks between the top of the Pedee group and the base of the Cherokee shale is about 1,300 feet in Elk county. The Lansing group has a total thickness of about 150 feet. It consists of two limestones and a shale. Oil and gas are produced from three sandstones in the Vilas shale. The upper of these sandstones is known as the "Bush-Denton" or "Ferguson," the middle as the "Longton" or "Webb," and the lower as the "Encill sand." The Kansas City group has a thickness of about 350 feet in the county and consists chiefly of limestone and shale. A sandstone in the upper part of the group, known as "Layton," yields oil and gas. The Bronson group is about 90 feet thick in the county. The Bourbon rocks consist chiefly of shale and sandy shale and are about 60 feet thick.

The Marmaton group in Elk county is about 250 feet thick and consists of alternating beds of limestone and shale and includes some sandstone and coal beds. The "Old Red sand" in the Nowata shale, the "Weiser sand" in the Bandera shale, and the Little Osage shale member of the Fort Scott limestone yield oil and gas in Elk county. The Cherokee shale consists chiefly of shale, sandstone and a few thin beds of limestone and coal. Its total thickness in the county is about 300 feet. The "Bartlesville sand," about 180 feet below the Fort Scott limestone, and the "Burgess sand," near the base of the Cherokee shale, yield oil and gas.

Mississippian rocks.—The total thickness of Mississippian limestones in Elk county ranges from 150 to 350 feet (Lee, 1939, pl. 1). The formations are the Warsaw, Keokuk, Burlington, Reeds Spring, and St. Joe limestones and the Northview-Compton formations (undivided shale and limestone) (Lee, 1940). Lee (1939, pl. 1) has shown that the Mississippian rocks are thinner over anti-

clinal structures. Examples are the Dexter-Otto anticline, which extends into the northwestern part of Elk county, and the Longton anticline in the eastern part of the county. Oil and gas are produced from a weathered zone in the upper part of the Mississippian. The thickness of the Chattanooga shale in Elk county is about 50 feet (Lee, 1940, pl. 3).

Ordovician and Cambrian rocks.—The Ordovician and Cambrian rocks in Elk county have not been completely subdivided. The Cotter dolomite, which lies directly below the Chattanooga shale, is the youngest Ordovician rock in the county. Oil and gas are produced from a porous zone in the upper part of the Cotter. The thickness of the Ordovician and Cambrian rocks ranges from about 750 feet to 1,165 feet.

Pre-Cambrian rocks.—Pre-Cambrian rocks were penetrated at a depth of 2,950 feet in the Halstead and Company No. 1 Osborn well in the NW¼ NW¼ sec. 8, T. 31 S., R. 11 E.

Oil and Gas Developments

Elk county has been a producer of oil and gas since 1902. Oil production in the county reached a peak in 1927 when nearly 900,000 barrels were produced. In 1935 production had declined to 580,556 barrels and in 1943 it was 226,606 barrels. Oil and gas accumulations in Elk county are due to the presence of anticlinal structures. No shoestring sands are known.

Table 35 gives information on the oil and gas fields in Elk county. The oil and gas producing areas are shown on figure 16.

Important gas-producing areas are Longton and Elk City. Most of the gas is produced from the "Encill sand" in the Kansas City group, the "Burgess" and "Bartlesville" sands in the Cherokee shale, and the Mississippian limestone. Some production is from the "Peru," "Wayside," and "Weiser" sands in the Marmaton group. The average depth to the "Encill sand" in the central part of the county is about 1,300 feet. The maximum open flow production of some gas wells in these areas was more than 90,000,000 cubic feet per day. The initial rock pressure was about 550 pounds.

A part of the **Longton** area is being used as a gas storage reservoir. Gas is stored in a sandstone near the top of the Kansas City group in an area of 1,150 acres in T. 32 S., R. 12 E. The sand has an average thickness of about 34 feet and lies at a depth of about 660 feet. The pool had produced a total of 3 billion cubic feet of

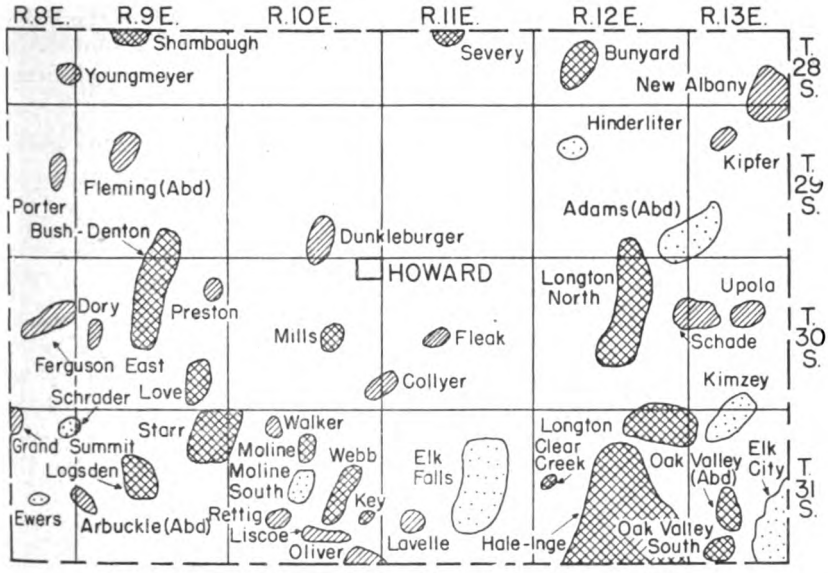

Fig. 16. Map of Elk county showing oil and gas producing areas. (Gas, dots; oil, diagonal lines; oil and gas, crossed diagonal lines.)

gas. The initial rock pressure was 260 pounds. The total initial open flow from 25 wells was 30 million cubic feet.

The total production from the **Elk City** pool, in T. 31 S., R. 13 E., has been about 21½ billion cubic feet of gas. The producing formation is the "Burgess sand," which has an average thickness of about 33 feet and is at a depth of about 1,360 feet. The "Bartlesville sand" in this area has a thickness of about 30 feet and lies at an average depth of about 1,330 feet. The total open flow from 70 producing wells was 1¾ billion cubic feet. The open flows ranged from 15 to 90 million cubic feet. The initial rock pressure was 520 pounds. A gas storage project is being planned in this pool.

The Cities Service Oil Company has a water-flooding project in the **New Albany** area (Grandone, 1944, pp. 75-78). An area of 150 acres in sec. 34, T. 28 S., R. 13 E. and sec. 3, T. 29 S., R. 13 E. is being flooded. The producing zone is the "Wayside sand" which is about 20 feet thick and occurs at a depth of about 560 feet. Water was first injected on July 2, 1937; the first important increase in the rate of oil production was in February, 1938. The project has 56 injection wells and 74 oil-recovery wells. The cumulative production to November 1, 1942, was 1,469 barrels per acre.

The **Webb** and **Bush-Denton** oil fields are important; they also yield some gas. Oil was produced from the Arbuckle limestone ("Siliceous lime") in the **Key** and **Shambaugh** pools. Both of these pools are now abandoned.

Reported monthly production of oil in Elk county during 1941, 1942, 1943, and 1944 is given in table 36. Table 37 gives gas production figures for the years 1939 to 1943.

TABLE 35.—*Oil and gas fields in Elk county, Kansas*

Name	Kind of pool	Location	1944 production, in barrels	No. of producing wells
Adams	gas	T 29 S, R 12 E, sec. 36		
(Abandoned)		T 29 S, R 13 E, secs. 20, 29 to 31		
Arbuckle	oil	T 31 S, R 8 E, sec. 24		
(Abandoned)		T 31 S, R 9 E, secs. 19, 30		
Bunyard	oil and gas	T 28 S, R 12 E, secs. 28, 29, 32		
Bush-Denton	oil and gas	T 29 S, R 9 E, secs. 21, 22, 26 to 28, 33 to 35	28,806	40
		T 30 S, R 9 E, secs. 3 to 5, 9, 10		
Clear Creek	oil and gas	T 31 S, R 12 E, sec. 18		
Collyer	oil	T 30 S, R 10 E, secs. 25, 36	15,143	8
		T 30 S, R 11 E, secs. 30, 31		
Dory	oil	T 30 S, R 9 E, secs. 17 to 20	2,631	3
Dunkleberger	oil	T 29 S, R 10 E, secs. 24, 27, 33, 34	29,413	20
Elk City[1]	gas	T 31 S, R 13 E, secs. 15, 22, 27, 34		
Elk Falls	gas	T 31 S, R 11 E, secs. 10, 11, 14, 15, 22, 23, 27		
Ewers	gas	T 31 S, R 8 E, sec. 23		
Ferguson East	oil	T 30 S, R 8 E, secs. 13, 14, 23, 24	2,105	1
Fleak	oil	T 30 S, R 11 E, sec. 21		
Fleming	oil	T 29 S, R 9 E, secs. 8, 9, 16, 17		
(Abandoned)				
Grand Summit[2]	oil	T 31 S, R 8 E, secs. 3, 4, 10	18,410	13
Hale-Inge[3]	oil and gas	T 31 S, R 12 E, secs. 9, 10, 15, 16, 20 to 22, 26 to 29, 32 to 35		
Heck	gas	T 29 S, R 10 E, secs. 17, 18		
(Abandoned)				
Hinderliter	gas	T 29 S, R 12 E, secs. 8, 17		
Key	oil and gas	T 31 S, R 10 E, secs. 25, 26		
Kimzey	gas	T 30 S, R 13 E, secs. 32, 33		
		T 31 S, R 13 E, secs. 5, 6		
Kipfer	oil	T 29 S, R 13 E, sec. 8		

Lavelle	oil and gas	T 31 S, R 11 E, sec. 29		
Liscoe	oil	T 31 S, R 10 E, secs. 26 to 28, 33, 34		
Logsden	oil and gas	T 31 S, R 9 E, secs. 15, 16, 21, 22		
Longton	oil and gas	T 30 S, R 12 E, sec. 35 T 31 S, R 12 E, secs. 1 to 3, 11, 12 T 31 S, R 13 E, secs. 6, 7		
Longton North	oil and gas	T 29 S, R 12 E, sec. 34 T 30 S, R 12 E, secs. 2, 3, 10, 11, 15, 16, 21, 22, 27, 28, 33, 34		
Love	oil and gas	T 30 S, R 9 E, secs. 25, 26, 35, 36 T 30 S, R 10 E, secs. 30, 31		
Mills	oil and gas	T 30 S, R 10 E, secs. 14, 15, 22, 23	1,905	4
Moline	oil and gas	T 31 S, R 10 E, secs. 9, 10, 15, 16	5,937	15
Moline South	gas	T 31 S, R 10 E, secs. 15, 16, 21, 22		
New Albany	oil	T 28 S, R 13 E, secs. 33, 34 T 29 S, R 13 E, secs. 3, 4, 9, 10		
Oak Valley (Abandoned)	oil and gas	T 31 S, R 13 E, secs. 20, 29		
Oak Valley South	oil and gas	T 31 S, R 13 E, sec. 31		
Oliver[3]	oil and gas	T 31 S, R 10 E, secs. 35, 36		
Porter	oil	T 29 S, R 8 E, secs. 12, 13	12,012	11
Preston	oil	T 30 S, R 9 E, sec. 12		
Rettig	oil	T 31 S, R 10 E, secs. 20, 28, 29		
Schade	oil and gas	T 30 S, R 12 E, secs. 12, 13 T 30 S, R 13 E, sec. 18		
Schrader	gas	T 31 S, R 8 E, secs. 12, 13		
Severy[4]	oil	T 28 S, R 11 E, sec. 21	25,980	41
Shambaugh	oil and gas	T 28 S, R 9 E, secs. 20, 21		
Starr	oil and gas	T 31 S, R 9 E, secs. 1, 2, 11 to 14 T 31 S, R 10 E, secs. 6, 7		
Upola	oil	T 30 S, R 13 E, secs. 16, 17, 20, 21		
Walker	oil	T 31 S, R 10 E, secs. 4, 5	1,889	3
Webb	oil and gas	T 31 S, R 10 E, secs. 14, 15, 22, 23, 26, 27	58,943	75
Youngmeyer	oil	T 28 S, R 8 E, secs. 24, 25	2,341	1

[1] Also in Montgomery county (see table 70)
[3] Also in Cowley county (see fig. 14)
[3] Also in Chautauqua county (see table 20)
[4] Also in Greenwood county (see table 42)

TABLE 36.—*Reported monthly production of oil in Elk county, Kansas, in barrels*

Month	1941		1942		1943		1944	
	No. of wells	Production	No. of wells	Production	No. of wells	Production	No. of wells	Production
January	269	33,520	256	25,023	230	18,798	227	16,740
February	270	29,7 5	252	25,733	230	19,558	224	16,008
March	276	35,466	253	27,254	224	20,166	226	16,864
April	276	36,314	252	26,645	226	20,319	226	14,100
May	275	33,759	244	24,881	225	18,007	226	16,988
June	271	31,901	242	24,699	220	17,551	226	16,740
July	270	30,112	241	24,516	222	19,345	226	14,415
August	270	27,497	230	23,093	227	19,345	226	18,011
September	271	28,578	232	22,174	222	18,402	221	14,610
October	270	29,018	224	18,859	226	18,463	221	15,810
November	270	24,452	227	23,428	226	18,859	221	14,130
December	264	27,497	230	19,284	225	17,794	221	13,950
Totals		367,889		213,592		226,607		188,366

TABLE 37.—*Natural gas production in Elk county, Kansas*

Year	Thousands of cubic feet
1939	756,675
1940	962,558
1941	961,647
1942	654,686
1943	627,246

FRANKLIN COUNTY

Franklin county has been producing oil and gas for more than 40 years. The oil fields lie generally in the eastern half of the county in the vicinities of Rantoul, Peoria, and Wellsville. There are scattered gas fields near Ottawa and in the northwestern part of the county. All oil and gas production has been from rocks of Pennsylvanian age. The producing rocks lie at an average depth of about 750 feet. Water-flooding operations are being introduced.

Surface Rocks

The consolidated outcropping rocks in Franklin county are of Pennsylvanian age. There are some unconsolidated surficial beds ranging in age from Tertiary (?) to Recent on the uplands and in the stream valleys. The oldest exposed rocks are along stream valleys in the southeastern part of the county and the youngest Pennsylvanian rocks are on the uplands in the northwestern part.

The Douglas group (fig. 7) consists chiefly of clastic material, including a large amount of sandstone. The Ireland sandstone member of the Lawrence shale is more fully developed in Franklin county than in counties farther north. The Douglas rocks in Franklin and neighboring counties have been described recently by Bowsher and Jewett (1943). The Weston shale of the Pedee group (fig. 8) ranges in thickness from a featheredge to 75 feet or more in Franklin county. The Iatan limestone is not known to be present. There is an exposure of the Weston shale at the southeast corner of sec. 15, T. 17 S., R. 19 E.

The Stanton limestone of the Lansing group (fig. 8) comprises about 45 feet of limestone and shale. The Rock Lake shale member near the top consists largely of sandstone, and the Eudora shale, near the base of the formation, is chiefly black platy shale. The Stoner limestone member, middle part of the Stanton formation, forms rather prominent bluffs and is generally less than 20 feet thick. The Vilas shale, which ranges in thickness from 2 to 10 feet or more, contains thin limestone beds in places where it is thickest. The Plattsburg limestone in Franklin county ranges from about 16 to 24 feet or more in thickness and is composed largely of massive limestone which is buff when weathered. The lower unit, the Merriam limestone member, although generally thin or even absent, locally is thicker than the upper member, the Spring Hill limestone.

The oldest exposed rocks in Franklin county are those in the upper part of the Kansas City group (fig. 8). Rocks older than the Chanute shale are not exposed in the county and the Westerville limestone is seemingly absent. The upper few feet of the Chanute shale, the Iola limestone, the Lane shale, the Wyandotte limestone, and the Bonner Springs shale are exposed along streams in the southeastern part of the county. Rocks of this group are characterized by the thick Lane and generally thick Bonner Springs shales and by the conspicuous scarp-making Wyandotte limestone. The Bonner Springs shale ranges in thickness from as little as 5 feet, in sec. 1, T. 19 S., R. 21 E., to 56 feet or more. The Bonner Springs formation contains much sandstone. The Wyandotte limestone, about 30 feet thick, is somewhat variable in lithology but consists mostly of irregularly bedded light-colored fossiliferous limestone.

Subsurface Rocks

Geologic conditions along the northern boundary of Franklin county are shown on plate 2.

Pennsylvanian rocks.—Pennsylvanian rocks below the base of the Oread limestone are about 1,300 feet thick in Franklin county. The presence locally of as much as 100 feet of Weston shale presents a situation somewhat different from that in some near-by areas. This condition is due to the difference in the amount of material removed by erosion from the top of Missourian rocks before deposition of Douglas beds. Lansing, Kansas City, Bronson, Bourbon, and Marmaton rocks in Franklin county are not different particularly from the same rocks in near-by counties. Cherokee rocks are about 350 feet thick in Franklin county. The "Squirrel sand," in the upper part of the Cherokee section, is the most prolific oil and gas reservoir that has been found in Franklin county.

Mississippian rocks.—The total thickness of Mississippian limestones in Franklin county is about 300 feet. The Warsaw limestone is believed to be the uppermost Mississippian formation present in most of the county, but the Spergen limestone has been identified in the northeastern part (Lee and Payne, 1944, fig. 17). In the central-western part of the county, post-Mississippian erosion reached the upper part of the Burlington-Keokuk section (pl. 2). According to Lee (1940, pl. 8), the Chouteau and Sedalia limestones underlie all of Franklin county.

The Chattanooga shale, of late Devonian or early Mississippian

age, is believed to be present under all of Franklin county. The thickness is about 50 feet. In most of Franklin county, the Chattanooga shale is in contact with the Viola dolomite. The Viola is absent in the southeastern part of the county, however, and the Chattanooga lies on the St. Peter formation. The St. Peter is believed to be absent in the extreme southeastern corner of the county and the Chattanooga rests upon Arbuckle rocks in this area (fig. 4).

Older Paleozoic rocks.—Devonian and Silurian rocks are believed to be absent in most of Franklin county, but a few feet of Devonian limestone has been identified in the northern part of the area. The Kimmswick and Decorah formations (Middle Ordovician) are present in all but the southeastern part of the county. The greatest thickness of these rocks is about 100 feet. Except in the southeastern part of the county, the St. Peter sandstone is covered by younger Ordovician rocks. The extreme southeastern corner of the county seems to be high enough on the Chautauqua arch for the St. Peter sandstone to have been removed before burial under the Chattanooga shale. The thickness of the St. Peter sandstone ranges from a few feet to about 50 feet. Arbuckle rocks thicken eastward in Franklin county, a condition that was brought about by pre-St. Peter beveling of the upper formations. The thickness of Arbuckle rocks ranges from about 450 to about 800 feet.

Oil and Gas Developments

Oil and gas were first produced commercially in Franklin county in about 1904. In 1905, 55 oil wells and 4 gas wells were completed. The first production was near Rantoul. Peak production was reached in 1926.

The oil and gas fields in Franklin county as designated by the Oil Field Nomenclature Committee of the Kansas Geological Society are listed in table 38. Most of the oil and gas production in Franklin county is from an area that is included in the **Paola-Rantoul** field as designated by that committee. This area includes most of the eastern half of Franklin county and a large part of Miami county. Some gas is produced from scattered pools in the western part of Franklin county. Production of both oil and gas is chiefly from the "Squirrel sand" in the upper part of the Cherokee shale, but other Pennsylvanian sandstones, including the "Prue" and "Bartlesville," are productive.

TABLE 38.—*Oil and gas fields in Franklin county, Kansas*
(As designated by the Oil Field Nomenclature Committee of the Kansas Geological Society, November 15, 1944)

Name	Location
Baldwin[1]	T 15 S, R 20 E, secs. 22 to 24
	T 15 S, R 21 E, secs. 19 to 21, 28 to 30
Greeley[2]	T 19 S, R 21 E, secs. 16, 17
Lane (Abandoned)	T 19 S, R 21 E, secs. 5, 7, 8
LeLoup	T 15 S, R 20 E, secs. 34, 35
	T 16 S, R 20 E, secs. 2, 3, 10, 11
Norwood	T 15 S, R 20 E, secs. 19, 20, 29, 30
Ottawa	T 16 S, R 19 E, secs. 13, 23 to 26, 33 to 36
	T 16 S, R 20 E, secs. 5 to 8, 17 to 20, 27 to 34
	T 17 S, R 19 E, secs. 1 to 4, 10 to 12
	T 17 S, R 20 E, secs. 3 to 9, 16
Paola-Rantoul[3]	T 15 S, R 21 E, secs. 31 to 33
	T 16 S, R 20 E, secs. 13, 24, 25, 36
	T 16 S, R 21 E, secs. 3 to 10, 15 to 22, 27 to 34
	T 17 S, R 20 E, secs. 1, 2, 11 to 14, 23 to 26, 35, 36
	T 17 S, R 21 E, secs. 3 to 10, 15 to 22, 27 to 34
	T 18 S, R 20 E, secs. 1 to 3, 11 to 13
	T 18 S, R 21 E, secs. 3 to 10, 15 to 22, 27, 34
	T 19 S, R 21 E, secs. 3, 4, 9, 10
Pomona	T 16 S, R 17 E, secs. 25, 36

[1] Also in Douglas county, T. 14 S., R. 20 E., sec. 36; T. 14 S., R. 21 E., secs. 28, 31 to 33; T. 15 S., R. 20 E., secs. 1 to 3, 9 to 14; T. 15 S., R. 21 E., secs. 4 to 10, 15 to 21.
[2] Also in Anderson county (see table 6)
[3] Also in Miami county (see table 67); includes fields formerly known as Wellsville, Stanton, Paola, Big Lake, Osawatomie, Rantoul North, and Rantoul South

In March, 1941, the Kirby Oil Company started a water-flooding project near Rantoul in sec. 17, T. 17 S., R. 21 E. Three sandstones are flooded. They are the "Squirrel" at 332 feet, the "Prue" at 488 feet, and the "Bartlesville" at 567 feet. It is reported that the first important increase in the rate of oil production took place two months after water injection began, and that in 20 months 91,203 barrels of oil were produced as the result of injecting 622,086 barrels of water (Grandone, 1944, pp. 78, 79). The recovery of oil amounted to 2,224 barrels per acre.

Many wells were drilled in Franklin county in the early 1920's but little attention was given to geologic conditions and many dry holes resulted. Initial daily productions of some wells were as high as 250 barrels. Most of the producing oil wells were long-lived and profitable, and generally yielded 5 to 40 or 50 barrels per day for several years. Production in general has dropped, and the daily productions range from a fraction of a barrel to a few barrels.

The introduction of water flooding is expected to greatly increase the production of oil. Peak production of oil in the county was in 1926 when 78,053 barrels were produced.

Monthly production of oil in Franklin county for 1941, 1942, and 1943 is given in table 39. Gas production statistics for the years 1939 to 1943 are given in table 40.

TABLE 39.—*Reported monthly production of oil in Franklin county, Kansas in barrels*

Month	1941	1942	1943
January	4,629	8,412	10,686
February	5,251	8,212	11,228
March	4,737	10,542	13,040
April	6,051	13,722	12,280
May	7,062	13,447	11,643
June	7,101	15,020	10,716
July	9,564	15,724	12,485
August	8,207	15,385	12,788
September	10,735	15,106	13,037
October	6,702	16,025	12,862
November	8,193	13,350	12,215
December	7,087	14,455	9,765
Totals	85,319	159,400	142,745

TABLE 40.—*Natural gas production in Franklin county, Kansas*

Year	Thousands of cubic feet
1939	396,365
1940	390,832
1941	412,800
1942	318,139
1943	273,075

GEARY COUNTY

Neither oil nor gas has been discovered in Geary county, but there has not been sufficient testing to prove the area barren. This county has an area of 407 square miles, but according to available records only 11 test holes have been drilled. The geology of Geary county has been described in a report by Jewett (1941).

SURFACE ROCKS

With the exception of loess (?), alluvium, and other unconsolidated surficial deposits of probable Pleistocene and Recent age,

the surface rocks in Geary county are of early Permian (Wolfcampian) age. The youngest Permian rock in the county is the Winfield limestone or perhaps the lower few feet of the Odell shale. The oldest exposed bedrock is the Eskridge shale which crops out along Deep creek in the northeastern part of the county.

The Winfield limestone of the Chase group (fig. 6) occurs only in the northwestern and southwestern parts of Geary county. The total thickness of rocks of the Chase group in the county is about 350 feet. Approximately the lower 300 feet is well exposed at numerous places in the slopes of the Flint Hills. In Geary county, as elsewhere along the outcrop line of Wolfcampian beds in Kansas, rocks of the Chase group are characterized by highly colored shales and thick flinty limestones. Limestone beds in the lower part of the Fort Riley member of the Barneston formation form a very noticeable natural "rim rock" near the crest of the Flint Hills in a large part of the county.

Rocks of the Council Grove group (fig. 6) have an aggregate thickness of approximately 300 feet in Geary county. Rocks in the upper part of this group are well exposed in the slopes of the Flint Hills. Rocks older than the Eskridge shale do not crop out in the county. The Council Grove rocks are characterized by highly colored shales and by limestones that weather light to nearly white in color and contain little or no flint. The individual limestone members do not exceed 10 feet in thickness.

Subsurface Rocks

Geary county lies on the west flank of the Nemaha anticline. Studies by Lee (1943, figs. 15, 16) indicate that the Mississippian limestone formations and the Chattanooga shale were removed from the extreme northeastern part of the county by pre- or early Pennsylvanian erosion. In most of the county the Chattanooga shale is believed to lie on the "Hunton" limestone, but in the extreme eastern part the Chattanooga or younger rocks lie on the Viola limestone.

Permian and Pennsylvanian rocks.—The maximum thickness of Permian rocks in Geary county is about 750 feet. The total thickness of Permian and Pennsylvanian rocks ranges from about 1,500 feet in the extreme northeastern part of the county to about 2,250 feet in the southwestern part (Moore and Jewett, 1942, fig. 2).

Mississippian rocks.—According to Lee and Payne (1944, fig. 17), the total thickness of Mississippian limestone formations in Geary county ranges from a featheredge to more than 100 feet. The Chattanooga shale ranges in thickness from a featheredge to more than 200 feet (Lee, 1943, fig. 14).

Pre-Chattanooga rocks.—In Geary county the "Hunton" limestone has an average thickness of about 300 feet. The Maquoketa shale is about 85 feet thick and is underlain by about 120 feet of Viola dolomite. The Simpson (St. Peter) sandstone includes a few feet of greenish shale in the upper part, a sandstone, and about 45 feet of red shale in the lower part. The total thickness of the Simpson is about 75 feet. About 10 feet of sandstone overlying granite in the Pioneer Petroleum No. 1 Chase well, in the SE cor. SE¼ sec. 10, T. 12 S., R. 7 E., is believed to be the Lamotte sandstone.

Two wells in Geary county have been drilled into pre-Cambrian rocks. The Pioneer Petroleum No. 1 Chase well reached granite at 2,925 feet. The Wright et al. No. 1 Younkin well, in the Cen. N. line NE¼ NW¼ sec. 17, T. 11 S., R. 5 E., reached granite at 2,940 feet.

Oil and Gas Exploration

Neither oil nor gas has been discovered in Geary county. Table 41 gives data on test drilling for oil and gas in Geary county (from Jewett, 1941, p. 110).

GREENWOOD COUNTY

Many wells were drilled in Greenwood county in 1918, but oil production did not become important until 1921. The geology and development of the shoestring oil fields of Greenwood county have been discussed by Cadman (1927) and Bass (1936).

Surface Rocks

Permian rocks.—The Forence flint, Matfield shale, and Wreford limestone in the lower part of the Chase group (fig. 6) crop out in the extreme northwestern part of Greenwood county. The thickness of these rocks is about 175 feet. The Council Grove group has an average thickness of about 300 feet in the county, and the Admire group is about 150 feet thick.

TABLE 41.—*Test wells drilled for oil and gas in Geary county, Kansas*[1]

Well name	Location S., T., R.	Completion date, total depth, ft.	Lowest formation penetrated
Brinkley et al. No. 1 Fawley	NW cor. NE 16-10-5E	8/9/27 2,501	Maquoketa
Wright et al. No. 1 Younkin	CNL NE NW 17-11-5E	9/24/30 3,240	Pre-Cambrian
Kerby & Wright No. 1 Kurtze	CNL SW SE 18-11-5E	6/4/27 2,652	Hunton
Carter Oil No. 1 Munson	NE NW NW 10-12-5E	9/28/05 1,930	Mississippian
Pioneer Petroleum No. 1 Chase Ranch	SE cor. SE 10-12-7E	1/15/29 3,638	Pre-Cambrian
Pioneer Petroleum No. 1 Zumbrum	SW cor. NE 28-12-7E	 1,895	Cherokee
Scheu & Teague No. 1 Aye	NW SW NW 10-12-8E	8/2/39 2,239	Maquoketa
Manhattan Oil No. 1 Foster	SW NE NW 26-13-5E	8/2/27 2,382	Hunton
Liberty-Texas Co. No. 1 Foster	NE cor. SW 30-13-6E	8/24/26 2,412	Marmaton?
Empire Gas & Fuel No. 1 Stellwagen	NE SE SW 9-13-8E	4/27/17 2,763	Hunton?
L. E. Dornes et al. No. 1 Fechner	CSE NE 27-13-8E	11/15/33 1,220	Douglas group

[1] Compiled by R. P. Keroher.

Pennsylvanian rocks.—The average thickness of the Wabaunsee group (fig. 7) in Greenwood county is about 420 feet. The Shawnee group has an average thickness of about 425 feet. The upper part of the Lawrence shale of the Douglas group is exposed in the extreme southeastern part of the county.

SUBSURFACE ROCKS

Subsurface geologic conditions in the northern part of Greenwood county are shown diagrammatically in plate 3.

Pennsylvanian rocks.—The Douglas group includes beds of shale, sandstone, and thin limestone, and is about 300 feet thick in Greenwood county. The Pedee group consists of shale and some

sandstone and is unconformably overlain by sandstone and shale of the Douglas group. It is convenient to designate the combined Douglas and Pedee rocks as Douglas-Pedee where the boundary cannot be recognized. The Lansing group consists of about 360 feet of shale and limestone. The Kansas City group consists largely of limestone but includes some shale and sandstone. Its average thickness is about 350 feet. The Bronson group, which is about 100 feet thick, consists mostly of limestone. The Bourbon shale has an average thickness of about 60 feet. The Marmaton group consists of about 250 feet of alternating limestone and shale. The Cherokee shale consists of light and dark gray shale, black shale, lenses of sandstone, and a few thin beds of limestone and coal. Sandstone lenses occur locally near the top of the Cherokee. Sandstone lenses called "Cattleman" occur 50 to 75 feet above the top of the "Bartlesville shoestring sands," which are about 100 feet above the base of the Cherokee. Common thicknesses of the "Bartlesville" are between 50 and 100 feet. Locally the "Bartlesville" rests on Mississippian rocks (Bass, 1936, p. 23). In the eastern part of the county a sandstone is present at the base of the Cherokee shale. It is separated from the overlying "Bartlesville sand" by shale.

Mississippian rocks.—Mississippian limestones in Greenwood county range from about 250 to 400 feet in total thickness (Lee, 1940). They consist of limestone, cherty limestone, and shale. The Warsaw, Keokuk, Burlington, Reeds Spring, and St. Joe limestones and the Northview-Compton shales have been identified in a well in sec. 33, T. 25 S., R. 10 E. (Lee, 1940). The Mississippian limestones are underlain by the Chattanooga shale which ranges in thickness from about 40 to 100 feet. The Chattanooga rests unconformably on Ordovician rocks.

Ordovician and Cambrian rocks.—Ordovician and Cambrian rocks have not been completely subdivided in Greenwood county. These rocks have a total thickness of about 700 to 1,000 feet and overlie pre-Cambrian rocks. The Chattanooga shale is directly underlain by Viola limestone. The Viola limestone and Arbuckle rocks are separated by the St. Peter (Simpson) sandstone. Arbuckle rocks consist of massive beds of dolomite, limestone, and sandstone which are commonly referred to as "Siliceous lime."

Oil and Gas Developments

Most of the oil produced in Greenwood county is from elongated lenses of sand in the lower part of the Cherokee shale at an average

depth of about 2,000 feet. The individual lenses are arranged approximately end to end, separated by narrow gaps, so that they form collectively long narrow systems, each 20 to 50 miles long and only a half mile to 1½ miles wide. These elongated sand bodies are commonly referred to as shoestrings. The sand lenses are not at one stratigraphic horizon, but all are confined to a restricted stratigraphic zone. Some oil is produced in the county from the Mississippian limestone.

The Sallyards pool was discovered in 1917 (Bass, 1936, p. 60). A few years later other pools were opened in rapid succession—the Teeter and Aagard in 1921 and the Seeley, Burkett, and Browning in 1922 (Loomis, 1923). The Sallyards, Polhamus, Thrall-Aagard, Burkett, Seeley-Wick, and Madison pools form a field 30 miles in length and a mile or less in width. This productive area is called the "Golden Lanes." Another sand trend about 15 miles long is parallel to the "Golden Lanes" and about 5 miles northwest of them. Two other trends, about 8 miles apart, cross these main trends in a direction nearly at right angles. These sandstones have an average thickness of about 30 feet, and are in the "Bartlesville sand" zone at depths of 2,000 to 2,500 feet. Repressuring has been in progress in the Madison pool since 1937.

The oil and gas fields in Greenwood county are shown in figure 17 and are listed in table 42.

The **Virgil** field was one of the first fields to produce oil from the Mississippian limestone in Kansas. The discovery well in this field, the Cosden Oil and Gas Company No. 1 Wayham in the SE¼ sec. 14, T. 24 S., R. 12 E., was completed on October 12, 1916. The initial production was about 15 barrels. By 1929, 193 oil wells and 10 gas wells were producing in this field. The average initial production of the oil wells was about 28 barrels per day. Some production is from the "Bartlesville sand" but the important production is from a porous zone at or near the top of the Mississippian limestone at a depth of about 1,700 feet. The Virgil field is located on a surface structure having a closure of more than 60 feet. There were 93 producing wells in this field in 1944, and the production in that year was 100,394 barrels.

There are four active water-flooding projects in Greenwood county (Grandone, 1944, pp. 81-91). The Phillips Petroleum Company Aagard project is in the SE¼ NW¼ sec. 14, T. 24 S., R. 9 E., in the **Thrall-Aagard** field. The Aagard pool was discovered in

1924 and oil was produced by primary methods until 1930, when a gradual increase in the oil production rate was caused by water infiltration from abandoned oil wells. This accidental flood caused an increase in oil production from a daily average of 17 barrels to 61 barrels. The controlled water-flooding project was started in March, 1937; the first oil increase was in August, 1937, and the rate of oil production reached a peak during the latter part of that

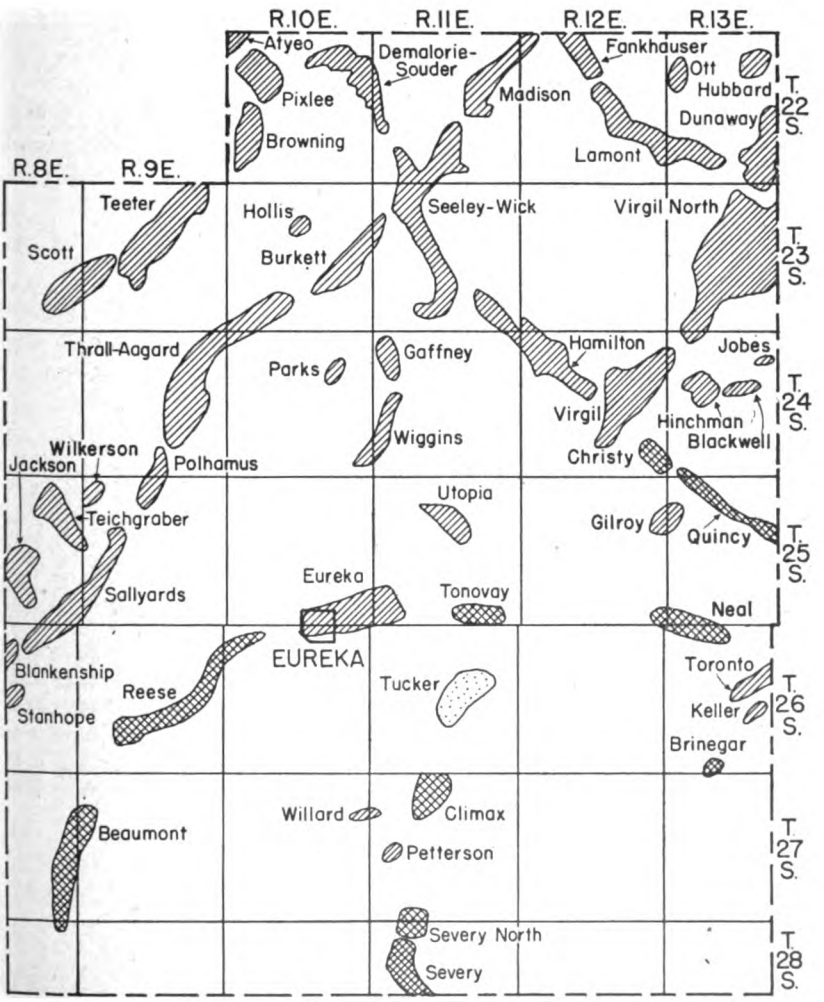

FIG. 17. Map of Greenwood county showing oil and gas producing areas. (Gas, dots; oil, diagonal lines; oil and gas, crossed diagonal lines.)

TABLE 42.—*Oil and gas fields in Greenwood county, Kansas*

Name	Location	Discovery date	1944 production, in barrels	No. of wells	Producing horizon	Depth, in feet
Beaumont	T 27 S, R 8 E, secs. 12, 13, 24 to 26, 35, 36 T 27 S, R 9 E, secs. 7, 18 T 28 S, R 8 E, sec. 1		126,441	30		
Blackwell	T 24 S, R 13 E, secs. 15, 16		1,803	3		
Blankenship[1]	T 26 S, R 8 E, secs. 3, 10					
Brinegar	T 26 S, R 13 E, secs. 32,33 T 27 S, R 13 E, sec. 5		5,330	27		
Browning	T 22 S, R 10 E, secs. 17 to 20, 29 to 31		145,547	90	"Bartlesville"	2,314
Burkett	T 23 S, R 10 E, secs. 13, 23, 24, 26, 27 T 23 S, R 11 E, secs. 7, 18		610,193	102	"Bartlesville"	2,000
Christy	T 24 S, R 12 E, secs. 25, 36		1,216	3		
Climax	T 27 S, R 11 E, secs. 3, 4, 9				Mississippian	1,900
Demalorie-Souder	T 22 S, R 10 E, secs. 1 to 3, 10 to 13	1924	254,066	125	"Bartlesville"	2,150
Dunaway[2]	T 22 S, R 13 E, secs. 22, 27, 28, 34 T 23 S, R 13 E, sec. 3		53,452	44	"Bartlesville"	1,800
Eureka	T 25 S, R 10 E, secs. 25, 26, 34 to 36 T 25 S, R 11 E, secs. 30 to 32 T 26 S, R 10 E, secs. 1 to 3		2,848	11		
Gaffney	T 24 S, R 11 E, secs. 6, 7, 18		10,173	3		
Gilroy	T 25 S, R 12 E, secs. 12, 13 T 25 S, R 13 E, secs. 7, 18					
Hamilton	T 23 S, R 11 E, secs. 25, 26, 35, 36 T 23 S, R 12 E, sec. 31 T 24 S, R 11 E, sec. 1 T 24 S, R 12 E, secs. 5 to 8, 16	1929	94,074	89	"Bartlesville"	1,765
Hinchman	T 24 S, R 13 E, secs. 16, 17, 19		10,690	10		
Hollis	T 23 S, R 10 E, secs. 10, 15		3,173	2		
Hubbard	T 22 S, R 13 E, secs. 3, 9, 10					

Jackson	T 25 S, R 8 E, secs. 22, 23, 27, 34, 35		1,586	2		
Keller	T 26 S, R 13 E, sec. 22		6,403	7		
Lamont	T 22 S, R 12 E, secs. 15, 22 to 26, 36		103,589	106		
	T 22 S, R 13 E, secs. 28 to 30, 32					
Madison	T 22 S, R 11 E, secs. 1, 10, 11, 12, 14, 15, 22, 23	1921	129,414	103	"Bartlesville"	1,800
	T 22 S, R 12 E, sec. 6					
Neal	T 25 S, R 12 E, sec. 36					
	T 25 S, R 13 E, secs. 31, 32					
	T 26 S, R 13 E, secs. 4, 5, 6					
Ott	T 22 S, R 13 E, secs. 7, 18					
Parks	T 24 S, R 10 E, secs. 11, 14					
Peterson	T 27 S, R 11 E, secs. 17, 19, 20		582	1		
Pixlee	T 22 S, R 10 E, secs. 5 to 9, 17	1923	41,606	43	"Bartlesville"	2,327
Polhamus	T 24 S, R 9 E, secs. 27, 34		25,122	44		
	T 25 S, R 9 E, secs. 3, 4, 9					
Quincy[3]	T 24 S, R 13 E, sec. 31	1926	123,053	110	"Bartlesville"	1,420
	T 25 S, R 13 E, secs. 5, 6, 8 to 10, 15					
Reese	T 26 S, R 9 E, secs. 12 to 14, 22 to 24, 28, 29		27,401	26		
	T 26 S, R 10 E, secs. 5 to 7					
Sallyards	T 25 S, R 8 E, secs. 24, 25, 35, 36	1921	115,616	130	"Bartlesville"	2,350
	T 25 S, R 9 E, secs. 17, 19, 20, 30, 31					
	T 26 S, R 8 E, secs. 1 to 3, 10, 11					
Scott	T 23 S, R 8 E, secs. 24 to 26		74,451	66		
	T 23 S, R 9 E, secs. 19, 30					
Seeley-Wick	T 22 S, R 11 E, secs. 22, 27 to 30, 32 to 35	1922	422,034	319	"Bartlesville"	1,930
	T 23 S, R 11 E, secs. 4 to 9, 16, 17, 21, 22, 27 to 29, 32, 33					
Severy North	T 27 S, R 11 E, secs. 32, 33					
	T 28 S, R 11 E, secs. 4, 5					
Smith-Jobe	T 24 S, R 13 E, sec. 10		3,103	2		

TABLE 42.—*Oil and gas fields in Greenwood county, Kansas—Concluded*

Name	Location	Discovery date	1944 production, in barrels	No. of wells	Producing horizon	Depth, in feet
Stanhope	T 26 S, R 8 E, secs. 15, 22					
Teeter[4]	T 23 S, R 9 E, secs. 1 to 3, 10 to 12, 14 to 17, 20 to 22, 28	1922	208,413	193	"Bartlesville"	2,400
Teichgraber	T 25 S, R 8 E, secs. 1, 2, 11 to 13 T 25 S, R 9 E, sec. 18		15,886	18		
Thrall-Aagard	T 23 S, R 9 E, sec. 36 T 23 S, R 10 E, secs. 28 to 33 T 24 S, R 9 E, secs. 13, 14, 22 to 24, 26, 27 T 24 S, R 10 E, sec. 6 T 25 S, R 9 E, secs. 23, 36		464,287	252		
Tonovay	T 25 S, R 11 E, secs. 34 to 36					
Toronto[3]	T 26 S, R 13 E, secs. 10, 15, 16, 22					
Tucker	T 26 S, R 11 E, secs. 14, 15, 22, 23					
Utopia	T 25 S, R 11 E, secs. 9, 10, 15					
Virgil	T 24 S, R 12 E, secs. 1, 2, 10 to 16, 21 to 24, 27 T 24 S, R 13 E, secs. 6, 7	1916	100,394	93	"Bartlesville" "Mississippi lime"	1,550 1,700
Virgil North[3 5]	T 23 S, R 13 E, secs. 2 to 4, 9, 10, 14 to 17, 20 to 22, 27 to 29, 31 to 33 T 24 S, R 13 E, sec. 5		403,785	284		
Wiggins	T 24 S, R 10 E, secs. 25, 36 T 24 S, R 11 E, secs. 18, 19, 30, 31		33,585	45		
Wilkerson	T 25 S, R 9 E, secs. 6, 7		7,455	13		
Willard	T 27 S, R 10 E, sec. 12 T 27 S, R 11 E, sec. 7		4,989	3		

[1] Also in Butler county (see table 16)
[2] Also in T. 22 S., R. 13 E., sec. 14, Coffey county
[3] Also in Woodson county (see table 89)
[4] Also in Chase county (see fig. 12)
[5] Also in T. 13 S., R. 23 E., secs. 7 and 18, Coffey county

year. The productive zone is the "Bartlesville sand" which has an average thickness of about 50 feet and is encountered at a depth of about 2,100 feet. The cumulative oil production to November 1, 1942, was 4,510 barrels per acre.

The Phillips Petroleum Company Gard water-flooding project, also in the Thrall-Aagard field, extends through secs. 14, 22, and 23, T. 24 S., R. 9 E. The producing formation is the "Bartlesville sand" which has an average thickness of about 50 feet and lies at a depth of about 2,100 feet. Water was first injected in September, 1941. The project had 12 injection wells and 18 producing wells in 1942. The cumulative production to November, 1942, was 125 barrels of oil per acre.

The Phillips Petroleum Company Burkett water-flooding project is in the NW¼ sec. 24, T. 23 S., R. 10 E., in the **Burkett** pool. The producing zone is the "Bartlesville sand" which has an average thickness of about 35 feet and lies at a depth of about 2,100 feet. The first water was injected in August, 1942, and no increase in the rate of oil production had been noted to November, 1942.

The Phillips Petroleum Company Gore water-flooding project, in sec. 35, T. 23 S., R. 11 E. in the **Hamilton** pool, includes an area of only 10 acres and has one water-input well and three producing wells. This project was started in 1938 for subsurface brine disposal. Oil had been produced by primary methods for a number of years, and when the brine was injected into the oil-producing zone through a disposal well an increase in the rate of oil production was brought about. The project was acquired by Phillips in October, 1941. The "Bartlesville sand," the producing zone, lies at a depth of about 1,833 feet and has an average thickness of about 25 feet. The first water injection was in January, 1938, and the first increase in the oil-production rate was in June, 1938. The cumulative production to November, 1942, was 2,503 barrels of oil per acre.

Reported monthly production of oil in Greenwood county in 1941, 1942, 1943, and 1944 is given in table 43. Yearly gas production figures for 1939 to 1943 are given in table 44.

JACKSON COUNTY

Neither oil nor gas in commercial quantities has been produced in Jackson county. Several wells have been drilled. Porosity in Mississippian and "Hunton" rocks has been reported, and a show

TABLE 43.—*Reported monthly production of oil in Greenwood county, Kansas, in barrels*

Month	1941		1942		1943		1944	
	No. of wells	Production	No. of wells	Production	No. of wells	Production	No. of wells	Production
January	2,495	257,267	2,498	266,371	2,392	252,082	2,390	289,540
February	2,499	265,641	2,498	278,789	2,390	264,266	2,381	279,618
March	2,500	267,437	2,498	313,314	2,385	274,662	2,383	302,343
April	2,497	280,180	2,458	277,641	2,384	277,900	2,384	280,890
May	2,501	279,210	2,434	267,005	2,383	273,732	2,382	309,535
June	2,493	276,220	2,442	290,016	2,378	285,198	2,378	304,110
July	2,496	273,053	2,408	286,917	2,366	273,512	2,378	294,252
August	2,491	263,502	2,400	278,140	2,369	285,400	2,383	325,965
September	2,512	277,145	2,403	280,024	2,378	281,723	2,377	303,150
October	2,493	276,669	2,398	278,267	2,380	278,722	2,377	318,959
November	2,500	266,331	2,392	270,248	2,380	293,071	2,378	308,190
December	2,493	280,992	2,691	275,459	2,380	284,446	2,377	315,208
Totals		3,263,647		3,362,191		3,324,714		3,631,760

TABLE 44.—*Natural gas production in Greenwood county, Kansas*[1]

Year	Thousands of cubic feet
1939	500
1940	1,000
1941	7,000
1942	8,000
1943	8,000

[1] Estimated

of oil was reported in the upper part of the "Hunton" limestone in a well in sec. 27, T. 7 S., R. 15 E.

Surface Rocks

Glacial deposits, some of which are several feet thick, occur in all parts of Jackson county. Consolidated bedrocks of Permian and Pennsylvanian ages are exposed. The youngest Permian rocks in the county are beds in the lower part of the Chase group and the oldest outcropping Pennsylvanian rock is the White Cloud shale.

Permian rocks.—The Wreford limestone caps hills in the northwestern part of Jackson county. Older Permian rocks (fig. 6) crop out in most of the western two-thirds of the county. The Cottonwood limestone underlies an extensive dip slope in an area east of the Wreford-capped hills. Permian rocks in this county are similar in thickness and lithology to the same strata in near-by counties.

Pennsylvanian rocks.—Pennsylvanian rocks crop out in the eastern and southern parts of Jackson county. The oldest well-exposed rock is the Burlingame limestone (fig. 7). The Tarkio and Burlingame limestones are the most prominent limestones among the outcropping Pennsylvanian beds.

Subsurface Rocks

Subsurface geologic conditions in the northern part of Jackson county are represented diagrammatically in plate 1. The county lies in the Forest City basin immediately east of the Nemaha anticline.

Pennsylvanian rocks.—Rocks of Pennsylvanian age in Jackson county have a maximum total thickness of about 2,250 feet. The section is thickest in the northern part of the county which is nearer the deepest part of the Forest City basin. The northward increase in thickness is chiefly in lower Pennsylvanian rocks. In the southwestern part of the county the interval between the base of the Bronson group and the Mississippian rocks is about 800 feet, but the same interval is nearly 1,000 feet in the northern part.

Mississippian rocks.—The total thickness of the Mississippian limestones ranges from less than 100 feet in the northwestern corner of Jackson county to more than 300 feet in the northeastern corner (Lee and Payne, 1944, fig. 17). The Spergen limestone is the uppermost Mississippian limestone formation that has been identified in the county. It lies next below Pennsylvanian rocks in

the northeastern part. Westward the Pennsylvanian sediments overstep the Warsaw limestone onto undifferentiated Burlington-Keokuk formation, the uppermost Mississippian rock in most of the county (Lee and Payne, 1944, figs. 4 and 17).

The Chattanooga shale in Jackson county ranges in thickness from slightly more than 150 feet in the southeastern part to more than 250 feet in the western part (Lee, 1940, fig. 14).

Pre-Chattanooga rocks.—The "Hunton" limestone in Jackson county increases in thickness to the northwest toward the deeper part of the North Kansas basin. According to Lee (1943, fig. 12), the thickness range is from about 150 feet in the southeast corner to about 450 feet in the northwest corner. Lee (1943, fig. 13) has shown that Silurian rocks (lower part of the "Hunton" limestone) range in thickness from about 100 feet in the southeastern corner to about 300 feet in the northeastern corner.

The interval between the top of the Maquoketa shale (uppermost Ordovician) and the top of the St. Peter sandstone in Jackson county is believed to range from less than 200 feet in the southern and southeastern parts to about 300 feet in the northwestern corner (Lee, 1943, fig. 11). The thickness of rocks between the top of the St. Peter sandstone (upper part of Lower Ordovician) and pre-Cambrian rocks probably ranges from less than 100 feet in the northwestern part to about 500 feet in the southeastern part (Lee, 1943, fig. 9). The thickness of the St. Peter sandstone is probably much less than 100 feet. In the southern part of the county a few feet of Lamotte sandstone probably lies on the pre-Cambrian floor.

Depths at which some key horizons were reached in five wells in Jackson county are listed in table 45.

JEFFERSON COUNTY

Oil and gas production became important in Jefferson county in 1940 when the McLouth pools were discovered. The geology of the McLouth area and the development of the McLouth field have been thoroughly discussed by Lee (1941) and by Lee and Payne (1944).

Surface Rocks

Glacial drift is attenuated in all parts of Jefferson county, but in most of the area consolidated Pennsylvanian bedrocks are well exposed. The youngest Pennsylvanian rock in the county is the Reading limestone (fig. 7) or a slightly higher bed which is present

TABLE 45.—*Depths, in feet, to some key horizons in five wells in Jackson county, Kansas*

Formation	Lincoln Liberty Life No. 1 Rogers NE¼ SE¼ sec. 23, T. 5 S., R. 16 E.	Garvin et al. Lutz SW cor. NW¼ NW¼ sec. 27, T. 7 S., R. 15 E.	Goens Wabense NE¼ NW¼ sec. 3, T. 8 S., R. 14 E.	McLaughlin and Sons No. 1 Kelley, SW¼ NE¼ sec. 24, T. 8 S., R. 15 E.	Haverbach et al. No. 1 Uhl, NE cor. NE¼ sec. 26, T. 9 S., R. 14 E.
Top of Shawnee group	.....	490	700	345	.....
Top of Douglas group	.....	800	1,060	650	740
Top of Lansing group	.....	1,015	1,260	888	1,015
Base of Bronson group	.....	1,365	1,590	1,215?	1,595
Base of Fort Scott limestone	.....	1,555	1,800	1,500	1,915?
Top of Mississippian rocks	2,080	2,180	2,400	2,115	2,125
Top of Chattanooga shale	2,330	2,475	2,592	2,275	2,365
Top of "Hunton" limestone	2,533	2,635	2,832	2,480	2,680
Top of Maquoketa shale	.....	.....	.....	.....	2,815
Top of Viola limestone	.....	.....	.....	.....	2,880

in the northwestern part of the county; the oldest exposed rocks are the upper beds of the Douglas group which crop out in the southeastern part. The Tarkio and Burlingame limestones cap prominent escarpments east of the Reading limestone exposures. The Shawnee group is well exposed in Jefferson county. Its thickness is about 300 feet. The Ervine Creek and Plattsmouth limestones are the thickest limestones and are the most prominent cliff-making ledges. The upper part of the Lawrence shale is the oldest exposed rock in the county.

SUBSURFACE ROCKS

Jefferson county lies in the Forest City basin and on the northeastern flank of the North Kansas basin.

Pennsylvanian rocks.—In the northwestern part of Jefferson county, where the youngest Pennsylvanian rocks are present, the thickness of the Pennsylvanian section is slightly more than 2,000 feet. In the southeastern part of the county Pennsylvanian rocks are slightly more than 1,000 feet thick. As elsewhere in this part of Kansas, the base of the Oread limestone and the base of the Hertha limestone are convenient subsurface marker beds. Rocks between the base of the Hertha limestone and the Mississippian rocks in Jefferson county range in thickness from about 700 feet in the central-eastern part of the county (the McLouth field) to nearly 900 feet in the northwestern part (Lee, 1943, fig. 17A).

Mississippian rocks.—Limestones of Mississippian age in Jefferson county range in total thickness from about 250 feet in the northwestern part of the county to about 350 feet in the northeastern part (Lee, 1943, fig. 16). The St. Louis limestone has been identified as the youngest Mississippian formation in the county (Lee and Payne, 1944, figs. 4, 17). This limestone lies next below Pennsylvanian beds in the northeastern part of the county and occurs as pre-Pennsylvanian outliers in the central part. West of the area in which the St. Louis limestone is next below the Pennsylvanian deposits, the Spergen and Warsaw formations are overlain by Pennsylvanian rocks. In the southwestern part of the county Pennsylvanian rocks lie on the Burlington-Keokuk limestones.

The Chattanooga shale ranges in thickness from about 75 feet in the southeastern part of Jefferson county to more than 150 feet in the northwestern part (Lee, 1943, fig. 14).

Pre-Chattanooga rocks.—Devonian rocks are 173 feet thick in the McLouth field (Lee and Payne, 1944, p. 48). The thickness increases toward the northwest and decreases toward the southeast. In the McLouth area Lee and Payne (1944, p. 47, fig. 3) found 15 to 20 feet of sandstone in the basal part of the Devonian section. A few feet of Maquoketa shale was found immediately below Devonian rocks. In a part of the area the Maquoketa shale and about 20 feet of the Kimmswick limestone were removed by erosion. The Kimmswick limestone was found to range in thickness from 125 to 150 feet (Lee and Payne, 1944, pp. 48, 49). It lies disconformably on the St. Peter sandstone which is about 70 feet thick in the McLouth area. The Arbuckle rocks (Ordovician and Cambrian) are about 700 feet thick in the McLouth area. The thickness increases toward the southeast and decreases toward the northwest.

Oil and Gas Developments

The **McLouth** field has been discussed thoroughly by Lee (1941) and by Lee and Payne (1944). Three stratigraphic zones yield oil or gas: the McLouth sand in the basal part of the Cherokee shale, a zone at the top of Mississippian rocks, and a dolomitic zone in the Burlington-Keokuk limestone about 150 feet below the top of Mississippian rocks.

The McLouth area extends into Leavenworth county and is in secs. 16, 17, 20, 21, 22, 27, 28, 29, 30, 32, 33, and 34, T. 9 S., R. 20 E.,

and in secs. 3, 4, 5, 6, and 8, T. 10 S., R. 20 E. The North McLouth gas pool in secs. 16, 17, 20, 21, 29, and 30, T. 9 S., R. 20 E., yields gas from the McLouth sand and oil is found in the same rock on the north and south margins of the area (Lee and Payne, 1944, pl. 3). The McLouth gas pool occupies a larger area, in secs. 22, 27, 28, 32, 33, and 34, T. 9 S., R. 20 E. and secs. 3, 4, and 5, T. 10 S., R. 20 E. Gas is produced from the McLouth sand. Oil was found in the Mississippian dolomite in the McLouth oil pool in secs. 4 and 5, T. 10 S., R. 20 E., and oil was found in the McLouth sand in sec. 3. T. 10 S., R. 20 E. (the Bankers Life pool), Leavenworth county.

Oil and gas production figures for Jefferson county are given in tables 46 and 47.

TABLE 46.—*Reported monthly production of oil in Jefferson county, Kansas, in barrels*

Month	1941	1942	1943[1]
January	86	6,191	11,005
February	86	4,810	10,726
March	86	6,766	15,283
April	86	6,503	14,725
May	86	6,760	14,539
June	1,017	7,016	17,081
July	2,647	7,025	15,562
August	1.853	6,818	17,205
September	3,819	6,680	13,113
October	3,152	7,325	11,267
November	2,786	6,080	11,735
December	3,968	6,850	10,130
Totals	19,672	78,824	162,371

[1] Includes production from Leavenworth county

TABLE 47.—*Natural gas production in Jefferson county, Kansas*

Year	Thousands of cubic feet
1939	.....
1940	.....
1941	1,631,445
1942	4,878,124
1943	2,788,470

JOHNSON COUNTY

Oil and gas are being produced in small amounts in several parts of Johnson county. Productive sandstones are found in the Marmaton and Cherokee groups. A report on the geology of John-

son and Miami counties (Newell, 1935) includes areal geologic maps and describes in detail the outcropping rocks in the two counties. The subsurface geology of Johnson county has been discussed by Ockerman (1935) and Lee (1943) in papers on the subsurface rocks in northeastern Kansas.

Surface Rocks

Pennsylvanian rocks crop out in all parts of Johnson county except where concealed by glacial drift or other surficial deposits. Pennsylvanian groups present include the Douglas, Pedee, Lansing, Kansas City, and Bronson (figs. 7, 8). The youngest Pennsylvanian rock in the county is the Tonganoxie sandstone which crops out on the uplands in the western part of the county; the oldest outcropping rock is the Winterset limestone member of the Dennis formation which crops out in the valley of Indian creek along the eastern edge of the county and in the bed of Turkey creek in northeastern Johnson county.

A large part of Johnson county is immediately underlain by the Stanton limestone. The Plattsburg and Wyandotte limestones crop out in many places along the valley walls of streams which have cut into the upland that is floored by the Stanton limestone. There are several useful key beds in the outcropping rocks. Among the more easily identified beds are black platy and fissile shale in the Eudora shale member of the Stanton limestone; the Merriam limestone, basal member of the Plattsburg formation; and the Paola limestone, basal member of the Iola formation.

Subsurface Rocks

Subsurface geologic conditions along the southern border of Johnson county are shown diagrammatically in plate 2.

Pennsylvanian rocks.—The average thickness of Pennsylvanian rocks in Johnson county is about 1,000 feet. The thickness of the Pennsylvanian section from the top of the Lansing group, which includes the surface rocks over a large part of the county, to the top of the Mississippian limestones is about 1,050 feet.

Mississippian rocks.—The total thickness of Mississippian limestone formations in Johnson county ranges from about 350 feet in the northwestern part to slightly more than 450 feet (Lee, 1943, fig. 13). The average thickness of the Chattanooga shale in the county is somewhat less than 50 feet (Lee, 1943, fig. 14).

Pre-Chattanooga rocks.—A thin section of Devonian rock is believed to underlie all of Johnson county. Lee (1943, fig. 7) identified 36 feet of Cooper and undifferentiated limestones in the McCain No. 1 Doane well in sec. 34, T. 12 S., R. 22 E., and 15 feet of Devonian sandstone in the Adolf Thurow No. 1 Green well in sec. 25, T. 14 S., R. 22 E. Fifteen feet of Devonian sandstone was found in a well in Missouri a few miles east of the southern corner of Johnson county.

Silurian rocks, the Maquoketa shale, and a part of the Kimmswick limestone were removed by erosion from this area before the time of deposition of Devonian sediments. The Kimmswick limestone was found to be 113 feet thick in the Doane well and 24 feet thick in the Green well. Twenty-seven feet of Decorah shale was found in the Doane well and 20 feet was found in the Green well.

The St. Peter sandstone underlies Johnson county. The thickness everywhere probably is less than 100 feet. The Arbuckle limestone is 802 feet thick in the Seminole Oil Company No. 1 Harrington well in sec. 12, T. 14 S., R. 22 E. The Arbuckle rocks increase in thickness to the southeast. Lee (1943, fig. 5) has shown that pre-St. Peter rocks in Johnson county probably include Cotter dolomite, Jefferson City limestone, Roubidoux formation, Gasconade and Van Buren dolomites, Gunter sandstone, Eminence and Bonneterre dolomites, and Lamotte sandstone. There probably is a thin wedge of Potosi dolomite between the Eminence and Bonneterre dolomites in the eastern part of the county.

Pre-Cambrian rocks were reached at 2,400 feet in the Seminole Oil Company No. 1 Harrington well. Table 48 shows the depths at which some key horizons were reached in three wells in Johnson county. Data are in part from Lee (1943, fig. 7).

Oil and Gas Developments

Gas has been produced for several years in the **Craig-Monticello** gas field in T. 12 S., R. 23 E. For the last few years, however, a part of the field has been used for underground gas storage. Production in this field is from sandstones in the Bourbon, Marmaton, and Cherokee sections. The principal production came from upper Cherokee rocks. In sec. 15, T. 12 S., R. 23 E., small gas wells were developed in the Knobtown sandstone in the upper part of the Bourbon shale, a few feet below the Hertha limestone at depths ranging from about 200 to 300 feet. The Reid No. 1 Hodge well, in

TABLE 48.—*Depths at which some key horizons were reached in three wells in Johnson county, Kansas*

Horizon	McCain No. 1 Doane, sec. 34, T. 12 S., R. 22 E	Adolf Thurow No. 1 Green, sec. 25, T. 14 S., R. 22 E.	Seminole Oil Company No. 1 Harrington, sec. 12, T. 14 S., R. 22 E.
Base of Hertha limestone	312	401	340
Base of Fort Scott limestone	568	652	753
Top of Mississippian limestone	1,000	1,038	1,025
Top of Chattanooga shale	1,387	1,447	1,395
Top of Devonian limestone	1,429	1,528	.....
Base of Devonian limestone	1,465	1,543	.....
Top of Kimmswick (Viola) limestone	1,465	1,543	1,435
Top of Decorah and Plattin limestone	1,578	1,567	.....
Top of St. Peter sandstone	1,605	1,587	1,535
Top of Arbuckle limestone	.....	1,654	1,598
Top of pre-Cambrian rocks	.....	.....	2,400

the SW¼ SW¼ sec. 15, T. 12 S., R. 23 E., yielded gas from the Knobtown "sand" and an upper Cherokee sandstone. The Webb No. 1 fee well, in the NE¼ SE¼ of the same section, found gas in the same two zones. Gas was found in Bourbon sandstone and in an upper Cherokee sandstone in secs. 2, 22, 23, 26, 27, 28, 33, 34, 35, and 36, T. 12 S., R. 23 E., and smaller amounts of gas were found in the "Peru sand" in some locations. In a part of this field, especially in secs. 25, 26, and 27, a gas-bearing sandstone, as much as 60 feet thick, was reported in the lower part of the Bourbon shale.

Gas is produced from several zones in the northeastern part of T. 12 S., R. 25 E. The "Bartlesville sand" at a depth of 692 feet is reported to have yielded an initial flow of 331,000 cubic feet of gas in a well in the NW¼ NE¼ NE¼ sec. 9, T. 12 S., R. 25 E.

Gas has been found in the Knobtown sandstone in secs. 5, 6, 7, 8, and 9, T. 13 S., R. 25 E., in the **Dallas** area. Most of the wells were drilled in about 1938. Several wells are producing at the present time. The Knobtown in this field lies at depths ranging from about 100 to less than 200 feet. The Dallas oil field, now abandoned, is in secs. 2, 3, 4, 9, 10, 11, 14, 15, and 22, T. 13 S., R. 25 E. Oil was produced from upper Cherokee sandstone between depths of 400 and 500 feet.

Scattered gas production, chiefly from the "Squirrel sand," is found in the southern part of Johnson county. Initial production as high as 500,000 cubic feet has been reported.

The **Prairie Center** gas field (the Sunflower Ordnance Works now includes the site of the old town Prairie Center), in secs. 19, 20, 28, 29, 30, 31, 32, 33, and 34, T. 13 S., R. 22 E. and secs. 3, 4, and 5, T. 14 S., R. 22 E., is the newest gas field in the county. This field was drilled in 1942, and is being extended to the south. Production is from Bourbon, Marmaton, and upper Cherokee rocks. Wells having initial productions of about 500,000 cubic feet have been reported.

The Denton and Coopér No. 2 Wood well, drilled in the fall of 1928 in sec. 14, T. 14 S., R. 22 E., was reported to have had an initial production of 100 barrels of oil daily. Production came from a Marmaton sandstone. In 1939 several oil wells having reported initial daily productions ranging from 5 to 100 barrels were drilled in sec. 15, T. 14 S., R. 22 E. in the **Gardner** field. This field is still producing a small amount of oil. Production is from the "Bartlesville sand."

The **East Eudora** gas field extends into the northwestern corner of Johnson county.

Cumulative production figures and the total number of oil and gas wells in Johnson county are not available. Monthly oil production figures and yearly gas production figures are given in tables 49 and 50.

TABLE 49.—*Reported monthly oil production in Johnson county, Kansas, in barrels*

Month	1942	1943
January	63	124
February		189
March		252
April	189	126
May	209	63
June	99	63
July	126	189
August	63	126
September	126	63
October	63	
November	189	126
December	.....	.....
Totals	1,127	1,321

TABLE 50.—*Natural gas production in Johnson county, Kansas*

Year	Thousands of cubic feet
1939	157,742
1940	236,114
1941	136,923
1942	272,624
1943	193,075

LABETTE COUNTY

Oil and gas have been produced in Labette county for many years. The Wilmoth gas field, in sec. 9, T. 35 S., R. 19 E., was discovered in November, 1917. Large quantities of gas have been produced in the southeastern part of the county since 1921. Oil and gas are produced from the Bandera shale, the Fort Scott limestone, the Cherokee shale, the Mississippian limestone, and the Arbuckle dolomite. An oil and gas exploration map of Labette county has been published by the Geological Survey (Abernathy, 1939).

The Geological Survey is investigating oil shales in the Bourbon shale which crop out in a wide area in Labette and Neosho counties. These shales may prove to be a source of oil in the future.

SURFACE ROCKS

All exposed consolidated rocks in Labette county are of Pennsylvanian age. The youngest consolidated rock is the Chanute shale in the Kansas City group (fig. 8). It is exposed in the northwestern part of the county. The Bronson group and the Bourbon shale crop out in a broad belt across the northwestern part of the county. The eastern boundary of the outcrop of the Bourbon shale is at a point north of Parsons on the Neosho county line. Because the limestones in the Kansas City and Bronson groups become thin and inconspicuous southward, it is convenient to use the northern Oklahoma classification in the southern half of western Labette county. This classification includes the Chanute shale, Drum limestone, Cherryvale shale, Dennis limestone, Coffeyville shale, and Seminole sandstone.

The Marmaton group (fig. 8) crops out in a broad band across the northeastern and southern parts of Labette county. The outcrop in the northern part of the county extends from the vicinity of Parsons to the Crawford county line, and in the southern part of the county it extends from a point south of Chetopa to the south-

western corner of the county on the Oklahoma line. The shale formations of this group underlie broad plains, whereas the limestone formations make more or less prominent escarpments across the regional dip slope of the beds. The Fort Scott limestone (locally called "Oswego") crops out in a narrow band across the southeastern corner of Labette county from the vicinity of Oswego to Bartlett. The outcrop makes a prominent escarpment in most places. The escarpment of the Pawnee limestone is relatively inconspicuous, although it is prominent farther south in Nowata county, Oklahoma. The Altamont limestone makes a prominent escarpment and the Lenapah makes a weak bench; these cross the county a little to the west of the Pawnee outcrop.

The Cherokee shale (fig. 9) is the surface rock in the southeastern corner of Labette county. The western limit of its outcrop is a line running northeast and southwest through Oswego. Shale is predominant in the Cherokee. The area of Cherokee outcrop in Labette county is, therefore, a lowland plain floored with residual soil in which there are few rock exposures.

Subsurface Rocks

Subsurface geologic conditions in the northern part of Labette county are shown on plate 4. Depths at which some formations were reached in a well in Labette county are given in table 51.

Pennsylvanian rocks.—The Lenapah limestone is about 30 feet thick in the subsurface in the western part of Labette county. The Nowata shale consists of about 40 feet of clayey and sandy shale. The Altamont limestone consists of two beds of light-gray limestone, each about 10 feet thick, separated by about 4 feet of black fissile shale. The Bandera shale is about 122 feet thick. It includes sandy shale and sandstone. The Pawnee limestone, locally known as the "Pink" limestone, ranges in thickness from about 22 to 34 feet. The Labette shale ranges in thickness from 55 feet in the northwestern part of the county to 90 feet in the southwestern part. A thin bed of coal occurs in the upper part of the Labette shale and a thin limestone lies near the base of the shale. In the northeastern part of Labette county the Fort Scott limestone consists of two limestones separated by black shale. The upper limestone is about 20 feet thick and the lower limestone is about 8 feet thick. The black shale is about 5 feet thick. In the southwestern part of the county three or more limestones seemingly constitute the Fort Scott limestone. These limestones and separating shales

TABLE 51.—*Depths to some formations in the Glower et al. No. 1 Forkner well, NE¼ SE¼ sec. 17, T. 33 S., R. 23 E., Labette county, Kansas*

Formation	Depth, in feet
Top of Spergen limestone	316
Top of Warsaw limestone	331
Top of Burlington-Keokuk limestone	393
Top of Reeds Spring limestone	528
Top of St. Joe limestone	660
Top of Northview shale	675
Top of Compton limestone	680
Top of Cotter dolomite	685
Top of Jefferson City dolomite	792
Top of Roubidoux formation	1,065
Top of Gasconade dolomite	1,262
Top of Eminence formation	1,496
Top of Bonneterre dolomite	1,617
Top of Lamotte sandstone	1,806

have a maximum thickness of about 100 feet. The upper limestone has a maximum thickness of 41 feet, the middle limestone has a maximum thickness of 34 feet, and the lower limestone has a thickness of 15 feet. The upper black shale is about 4 feet thick and the lower black shale is about 8 feet thick.

The Cherokee shale ranges in thickness from 395 to 560 feet. The shale thickens regularly toward the southwest in Labette county, but local variations in thickness are common. Sandstone commonly occurs in thin lenticular beds, and it is present in the lower part of the Cherokee in thick and massive beds. These beds include the "Bartlesville," Bluejacket ("Columbus"), and Little Cabin ("Burgess") sandstones. The most persistent limestone in the Cherokee shale is the Ardmore, which occurs about 80 feet below the base of the Fort Scott limestone in the eastern part of the county and about 40 feet below the Fort Scott in the western part. The Ardmore is a single bed of fossiliferous limestone about 3 feet thick.

Mississippian rocks.—About 350 feet of Mississippian rocks overlies the Chattanooga shale in Labette county. As pointed out by Lee (1939), these rocks were deposited on the nearly flat surface of the Chattanooga shale and later were gently folded and elevated. Subsequent erosion removed part of the Mississippian rocks from the elevated areas. The Mississippian formations in Labette county include the Spergen, Warsaw, Keokuk-Burlington, Reeds Spring, and St. Joe limestones, the Northview shale,

and the Compton limestone. The Chattanooga shale has an average thickness of about 20 feet; locally it ranges from 2 to 50 feet. The top of the Chattanooga is about 800 feet below the surface in the southeastern part of the county, and the depth increases to 1,340 feet in the northwestern part. The Chattanooga shale lies unconformably on Ordovician rocks.

Ordovician and Cambrian rocks.—Ordovician rocks in Labette county include the Cotter and Jefferson City dolomites, the Roubidoux formation, the Gasconade dolomite, and the Van Buren formation. Cambrian rocks include the Eminence and Bonneterre dolomites and the Lamotte sandstone.

Oil and Gas Developments

Oil and gas are widely distributed over Labette county. Producing wells have been drilled on about 167 square miles of the county whose total area is about 637 square miles. According to available records, 1,710 wells have been drilled; 911 of these have produced oil or gas.

The oil and gas fields in Labette county as designated by the Oil Field Nomenclature Committee of the Kansas Geological Society are listed in table 52.

Oil and gas are produced in Labette county from the Bandera shale, the Fort Scott limestone, and the Cherokee shale, of Pennsylvanian age; the Warsaw limestone of Mississippian age; and the Arbuckle limestone of Cambro-Ordovician age.

Much gas has been produced in the vicinity of Dennis from a sandstone in the Bandera shale known locally as the "Dennis sandstone." The "Dennis" lies about 340 feet below the surface. About 125 wells have been drilled to the "Dennis sandstone." According to the records, only 10 of these were dry holes. Black shales in the Fort Scott limestone yield gas in Labette county. A total of 136 holes have penetrated the Fort Scott limestone; of these 68 produced gas, 16 are now producing gas, and 52 were dry holes. No oil has been produced from this formation in the county.

Much oil and gas is produced from the "Bartlesville sand" in the Cherokee shale in Labette county. Gas is produced locally from coal beds in the Cherokee shale. Some areas of "Bartlesville" production are arranged in definite trends. The thickness of the "Bartlesville sand" ranges from about 2 to 50 feet. This sandstone zone is separated from the Mississippian limestone by 40 to 100

feet of shale. Gas was produced from the Cherokee shale in 314 wells (of which 77 are now producing) and oil was produced from the Cherokee in 70 wells (of which 43 are now producing); 271 dry holes have been drilled into the Cherokee shale.

A producing zone occurs in the "chat" that lies on Mississippian limestone. This "chat" is composed largely of fragments of chert; it is restricted in its occurrence to the flanks of "Mississippi lime" hills. The upper part of the Mississippian limestone contains porous beds that yield large amounts of gas. The "Mississippi lime" has been tested by 426 holes in Labette county. Of these, 105 produced gas, 14 produced oil, and 310 were dry holes; 23 of the gas wells are still producing.

Oil is produced from siliceous limestone in the upper part of the Arbuckle rocks. This zone has been penetrated by 63 wells in Labette county. Many of these wells had a "showing" of oil or gas; commercial quantities of oil were found in 15, all of which are still producing.

Oil has been produced since 1917 in the **Price** pool in sec. 12, T. 33 S., R. 17 E. and secs. 7 and 8, T. 33 S., R. 18 E. The reservoir rock is the "Bartlesville sand" at a depth of about 600 feet. Initial daily productions of the wells ranged from 10 to 50 barrels; present daily production ranges from 2 to 4 barrels per well. More than 60 producing wells have been drilled in this pool.

The **Kincaid** oil pool, in the E½ sec. 23, the SW¼ sec. 24, and the NW¼ sec. 25, T. 32 S., R. 17 E., has yielded much oil. No records are available as to the date of discovery or the amount of production. About 40 wells produced oil from the "Bartlesville sand" at a depth of about 750 feet. All these wells have been abandoned .

Oil has been produced since 1909 in the **Benham** pool in the N½ sec. 2, T. 32 S., R. 17 E. About 12 wells in this pool have produced oil from the "Bartlesville sand" at a depth of about 675 feet. Initial daily productions ranged from 10 to 40 barrels. Three of the wells are still producing and have a daily production of about 2 barrels per well.

The most recently discovered oil pool in Labette county is the **Chetopa** pool in sec. 36, T. 34 S., R. 20 E. The discovery well, the Remington No. 3, was drilled by the Chetopa Oil and Gas Company in March, 1936. This pool now has 17 wells. Production is from the Arbuckle limestone, which lies about 850 feet below the sur-

face. The producing zone is a soft siliceous limestone about 3 feet thick which lies just below a hard brown limestone cap rock. Only two dry holes have been drilled in the pool. Daily initial productions ranged from 30 to 120 barrels per well. At the present time about 1,000 barrels of oil per month are being produced in this pool.

Gas was first produced in the **Dennis** area, in secs. 10, 11, 13, 14, 23, 24, 25, and 26, T. 31 S., R. 18 E., in 1914. The producing sand, known as the "Dennis," lies in the Bandera shale at a depth of about 340 feet and ranges in thickness from 12 to 50 feet. More than 100 wells have been drilled in this area. Initial daily productions ranged from 100,000 to 500,000 cubic feet. The field is now abandoned.

The **Oswego** gas pool, a small pool in secs. 9 and 16, T. 33 S., R. 21 E., is now abandoned. Most of the wells were drilled in 1930. The producing zone was the top of the Mississippian limestone at a depth of about 580 feet. The pool had eight gas wells; initial productions of these wells ranged from 100,000 to 150,000 cubic feet per day.

The **Lush** gas-producing area, west of Altamont in secs. 4 and 5, T. 33 S., R. 19 E., has yielded gas since 1930. The producing formations are the Fort Scott limestone, the "Bartlesville sand," and the Mississippian limestone. The Fort Scott limestone is about 270 feet below the surface, the "Bartlesville sand" about 540 feet, and the Mississippian limestone about 775 feet. The "Bartlesville sand" ranges in thickness from 12 to 60 feet. The initial flow of gas in the wells ranged from 40,000 to 500,000 cubic feet. Seventeen wells have been drilled in this area, nine to the "Bartlesville sand" and eight to the Mississippian limestone. One of the latter wells was dry in the "lime," but it was plugged back and gas was produced from the Fort Scott limestone. The area is still producing, but the pressure is so low that a booster station is required to deliver the gas into the Cities Service high-pressure gas line.

The **Mortimer** gas-producing area is in secs. 2, 11, and 12, T. 31 S., R. 17 E., in the northwestern corner of the county. The date of discovery is not known; however, much drilling was done in 1913 and activity continued until 1927. The area is now abandoned. Gas was produced from the Fort Scott limestone at a depth of about 600 feet, the "Bartlesville sand" at a depth of about 840 feet, and the Mississippian limestone at a depth of about 1,020 feet. In this area 42 holes were drilled to the "Bartlesville sand"; 22 of

TABLE 52.—*Oil and gas fields in Labette county, Kansas*

(As designated by the Oil Field Nomenclature Committee of the Kansas Geological Society, November 15, 1944)

Name	Location
Angola	T 33 S, R 18 E, secs. 14 to 17, 20 to 23, 26 to 29, 32 to 36
	T 34 S, R 18 E, secs. 1, 2
Altamont	T 32 S, R 19 E, secs. 26 to 29, 32 to 35
	T 33 S, R 19 E, secs. 2 to 11, 17
Banzet	T 35 S, R 19 E, secs. 2 to 4, 9, 10, 15, 16
Bartlett	T 34 S, R 20 E, secs. 3, 4, 9, 10, 14 to 16, 22, 23
Chetopa[1]	T 34 S, R 20 E, sec. 36
Chetopa Townsite	T 34 S, R 21 E, secs. 26, 27, 34, 35
	T 35 S, R 21 E, secs. 2, 3, 10, 11
Coffeyville-Cherryvale[2]	T 31 S, R 17 E, secs. 2, 11 to 14, 23, 24, 26, 35, 36
	T 32 S, R 17 E, secs. 1, 2, 11 to 14, 23 to 26, 35, 36
	T 32 S, R 18 E, secs. 4 to 9, 17 to 19, 30, 31
	T 33 S, R 17 E, secs. 1, 2, 11 to 14, 23 to 26, 35, 36
	T 34 S, R 17 E, secs. 1, 2, 26, 35
	T 35 S, R 17 E, secs. 2, 11, 14
Country Club (Abandoned)	T 31 S, R 19 E, secs. 13 to 15, 22 to 24
Dartnell	T 31 S, R 17 E, secs. 1, 12, 13, 24, 25, 36
	T 31 S, R 18 E, secs. 5 to 8, 17 to 21, 28 to 33
Dennis[3]	T 31 S, R 18 E, secs. 1 to 3, 10 to 15, 22 to 26, 35, 36
	T 31 S, R 19 E, secs. 19, 20, 29 to 31
Edna	T 34 S, R 18 E, secs. 12, 13, 23, 25, 26, 35, 36
	T 34 S, R 19 E, secs. 5 to 8, 16 to 20, 29 to 32
	T 35 S, R 18 E, secs. 1, 2, 11 to 14
Gossard	T 33 S, R 19 E, secs. 25, 36
	T 33 S, R 20 E, secs. 30 to 32
	T 34 S, R 19 E, sec. 1
	T 34 S, R 20 E, secs. 5, 6
Idenbro[4]	T 31 S, R 19 E, secs. 35, 36
	T 32 S, R 19 E, secs. 1, 2, 11
Lake Creek	T 34 S, R 19 E, sec. 36
	T 35 S, R 19 E, secs. 1, 2, 11, 12
Mound Valley	T 32 S, R 18 E, secs. 9 to 11, 13 to 23, 26 to 30, 32 to 35
Mound Valley South	T 33 S, R 18 E, secs. 1, 2, 10 to 14, 23 to 26, 36
	T 33 S, R 19 E, secs. 17 to 20, 26 to 35
	T 34 S, R 19 E, secs. 3, 4
Oswego	T 33 S, R 21 E, secs. 8 to 10, 15 to 17, 20 to 22, 27 to 29
Powers (Abandoned)	T 31 S, R 20 E, sec. 21

Price	T 33 S, R 17 E, sec. 12
	T 33 S, R 18 E, secs. 4, 5, 7 to 9, 17 to 20, 29, 30
Tackett (Abandoned)	T 32 S, R 19 E, sec. 7
Tomey	T 35 S, R 20 E, secs. 2, 3, 10, 11
Valeda	T 34 S, R 17 E, secs. 11 to 14, 23 to 26, 35, 36
	T 34 S, R 18 E, secs. 5 to 8, 16 to 21, 28 to 33
	T 35 S, R 17 E, secs. 1, 12, 13
	T 35 S, R 18 E, secs. 4 to 9, 16 to 18

[1] Formerly called Wackerle
[2] Also in Wilson and Montgomery counties (see tables 70 and 86)
[3] Also in Neosho county (see table 75)
[4] Formerly called Moore

these were dry. One dry hole was drilled to the Arbuckle limestone in the NW¼ of section 11.

The **Dack** gas area is in secs. 5 and 6, T. 31 S., R. 18 E. In this area 25 wells have been drilled, of which 6 are still producing gas, 3 produced oil, and 7 were dry holes. No records are available of the other 9 wells. Most of the wells were drilled in 1927. The producing formations are the Fort Scott limestone, about 935 feet below the surface, and the Mississippian limestone at a depth of about 1,080 feet.

The **Timber Hills** gas area is in secs. 2, 11, 12, 13, and 14, T. 32 S., R. 17 E. and secs. 7 and 8, T. 32 S., R. 18 E. Gas was discovered in this area in 1905; however, production did not begin until 1910. For many years Cherryvale, in Montgomery county, was supplied with large quantities of gas from this area. More than 200 wells have been drilled in this area. Production is from the Fort Scott limestone, the "Bartlesville sand," and the top of the Mississippian limestone. The depth to the Fort Scott limestone in these wells ranges from 575 to 675 feet, the "Bartlesville sand" from 705 to 860 feet, and the Mississippian limestone from 880 to 890 feet. A small amount of gas is still produced in this area.

The **Mound Valley** gas-producing area, in secs. 14, 15, 16, 20, 21, 22, 23, 26, 27, 28, and 29, T. 32 S., R. 18 E., is the largest gas-producing area in Labette county. Gas has been produced here since 1905. More than 125 wells have been drilled to the "Bartlesville sand"; only 15 of these were dry holes. The thickness of the "Bartlesville" in this area ranges from 6 to 60 feet. Some well logs record two sandstones separated by about 30 feet of shale. Both of these sandstones, known as "Upper Bartlesville" and "Lower Bartlesville," may be productive. The initial flows of gas ranged from 100,000 to 4,500,000 cubic feet per day; the rock pressure was

about 250 pounds. Gas is still being produced in some of the wells, but the pressure is only about 10 pounds. Seventeen wells were drilled to the top of the Mississippian limestone. Three of these yielded gas but they are now abandoned.

The **Chetopa** gas pool is in sec. 36, T. 34 S., R. 20 E. The discovery well, the Chetopa Oil and Gas Company No. 1 Wright, was drilled in December, 1935. Ten gas wells have been drilled; initial daily productions ranged from 100,000 to 500,000 cubic feet. The rock pressure was about 225 pounds. Gas-producing zones are in the upper part of the Mississippian limestone and in porous rock about 20 feet below the top of the "lime." The top of the Mississippian limestone is about 500 feet below the surface. This pool is on a closed structure.

The **Gossard** gas pool, discovered in 1906, is in sec. 36, T. 33 S., R. 19 E., sec. 31, T. 33 S., R. 20 E., and sec. 6, T. 34 S., R. 20 E. Production is from the "Bartlesville sand" which lies at a depth of about 450 feet and ranges in thickness from about 17 to 61 feet. Initial daily productions of wells ranged from 100,000 to 1,000,000 cubic feet. A total of 21 gas wells and 3 dry holes have been drilled. One of the dry holes penetrated the Arbuckle limestone and was drilled to a total depth of 1,075 feet. A few wells still produce.

The **Traxon** gas-producing area is in secs. 18, 19, 20, 29, and 30, T. 34 S., R. 18 E. About 45 wells, 20 of which were dry holes, have been drilled in this area. The gas-producing zones are in the Fort Scott limestone, the "Bartlesville sand," and the upper part of the Mississippian limestone. Five deep tests, all of which were dry, were drilled to the Arbuckle limestone in sec. 30, T. 34 S., R. 18 E. The Fort Scott limestone is about 360 feet below the surface in this area, the "Bartlesville sand" about 600 feet, the top of the Mississippian limestone about 825 feet, and the Arbuckle limestone about 1,200 feet. A small amount of gas is still produced in this field.

The **Edna** oil and gas producing area is in secs. 24, 25, 26, 35, and 36, T. 34 S., R. 18 E. and sec. 19, T. 34 S., R. 19 E. The town of Edna has secured gas from this area for several years. Most of the drilling has been done since 1921. About 40 holes have been drilled, 12 of which were dry. Production is from the Fort Scott limestone, the "Bartlesville sand," and the upper part of the Mississippian limestone. Most of the gas is produced from the "Bartlesville sand," and oil was produced from this sand in four wells in section 24. Gas is produced from the upper part of the Mississippian limestone

in two wells, from the Fort Scott limestone in two wells, and from the "Bartlesville sand" in eight wells. Oil and gas are still produced in this area. The Fort Scott limestone is about 300 feet below the surface, the "Bartlesville sand" about 580 feet, and the top of the Mississippian limestone about 800 feet.

Oil and gas production statistics for Labette county are given in tables 53 and 54.

TABLE 53.—*Reported monthly production of oil in Labette county, Kansas, in barrels*

Month	1941	1942	1943
January	1,368	803	1,390
February	1,102	738	837
March	1,206	844	948
April	1,107	996	1,019
May	1,186	964	613
June	1,133	778	800
July	1,464	1,087	814
August	1,167	778	865
September	1,603	1,814	1,507
October	1,079	1,937	1,847
November	1,017	1,247	1,326
December	1,388	1,085	930
Totals	14,820	13,071	12,896
Average number of wells	11	15	12

TABLE 54.—*Natural gas production in Labette county, Kansas*

Year	Thousands of cubic feet
1939	438,386
1940	346,960
1941	425,971
1942	332,416
1943	405,750

LEAVENWORTH COUNTY

The extension of the McLouth field into Leavenworth county has made that county somewhat important in the production of oil and gas. Gas had been produced in scattered areas for several years before the discovery of the McLouth pools. In December, 1944, the Lawrence gas-producing area was extended from Douglas county into Leavenworth county.

The geology and development of the McLouth gas and oil field have been described in detail by Lee (1941) and by Lee and Payne (1944).

Surface Rocks

Outcropping consolidated rocks in Leavenworth county are of Pennsylvanian age. The youngest of these formations is the Deer Creek limestone or possibly the lower part of the Tecumseh shale, and the oldest is the Wyandotte limestone. Much of the county is mantled with glacial drift.

Pennsylvanian rocks.—The soil on the surface of more than half the area of Leavenworth county is immediately underlain by rocks of the Douglas group (fig. 7). This area of rolling topography is east and south of the sinuous escarpment capped by the Oread limestone. The outcrop line of the Oread extends from the northeastern corner of the county along Missouri river to the vicinity of Leavenworth and northwestward to the southwest corner of the county. West of the Oread escarpment is a less conspicuous line of hills capped by the Lecompton limestone. Hills capped by Deer Creek limestone are in the northwestern part of the county. Rocks older than those of the Douglas group are exposed in the county along Kansas and Missouri rivers. The oldest exposed bedrock in the county crops out along Kansas river near Lenape and Loring. The Shawnee group in the county is about 350 feet thick, and the Douglas group ranges from about 180 to 280 feet.

Rocks of the Pedee group (fig. 8) are well exposed in the vicinity of Leavenworth where the Weston shale and the thin overlying Iatan limestone have a combined thickness of about 45 feet. Locally the entire Pedee section and in some places older rocks have been removed by erosion that preceded Douglas deposition. In those places the Tonganoxie sandstone lies on some part of the Stanton limestone. The Lansing group in the county is about 80 feet thick. Strata in the upper part of the Kansas City group show unusual development along Kansas river in the vicinity of Lenape and Loring. Shale units several feet thick become only a few inches thick in short lateral distances, and limestones, particularly the Farley limestone, change abruptly in thickness and lithology.

Subsurface Rocks

Leavenworth county is in the Forest City basin and on the southeastern margin of the North Kansas basin. The Chattanooga

shale oversteps beveled Devonian rocks from the northwest (Lee, 1943, fig. 7, wells 13-15). The Maquoketa shale is believed to be absent except in the northwestern part of the county (Lee, 1943, figs. 11, 12).

Pennsylvanian rocks.—The average thickness of the Pennsylvanian section in Leavenworth county is about 1,000 feet. The thickness of rocks between the Hertha limestone and the top of Mississippian rocks ranges from a little less than 700 feet to slightly more than 800 feet.

Mississippian rocks.—According to Lee and Payne (1944, fig. 17), the Mississippian limestone formations in Leavenworth county have an average total thickness of about 400 feet. The thickness of the Chattanooga shale in the county ranges from about 50 to 75 feet (Lee, 1943, fig. 5).

Pre-Chattanooga rocks.—Depths to some key horizons in deeper rocks in the McLaughlin and Sons No. 1 Thorpe well, in the Cen. NE¼ NE¼ sec. 27, T. 10 S., R. 20 E., are given in table 55. Data are from Lee (1943, fig. 7).

TABLE 55.—*Depths to some key horizons in the McLaughlin and Sons No. 1 Thorpe well, cen. NE¼ NE¼ sec. 27, T. 10 S., R. 20 E., Leavenworth county, Kansas*

Horizon	Depth, in feet
Top of Mississippian limestone	1,397
Top of Chattanooga shale	1,734
Base of Chattanooga shale and top of Devonian rocks (Cooper limestone)	1,794
Base of Devonian rocks and top of Kimmswick (Viola) limestone	1.953
Top of Decorah shale	2.067
Top of St. Peter sandstone	2.093
Top of Arbuckle rocks	2,154

According to Lee (1943, fig. 12), the interval between the base of the Chattanooga shale and the top of the Maquoketa shale in Leavenworth county ranges from about 100 to 225 feet. The Maquoketa shale is present only in the northwestern part of the county. Lee's studies (1943, figs. 9, 11) indicate that the average thickness of the rocks between the top of the Maquoketa shale and the top of the St. Peter sandstone in northwestern Leavenworth county is about 200 feet, and the thickness of rocks between the

top of the St. Peter sandstone and the pre-Cambrian ranges from about 650 feet in the northwestern part of the county to about 800 feet in the southeastern part.

Oil and Gas Developments

Gas has been produced in Leavenworth county for many years. By 1927 the **Six Corners** gas field, in secs. 14, 15, 22, and 23, T. 12 S., R. 23 E., had become practically exhausted and was put into use for subsurface gas storage.

The **Bankers Life** oil pool, in the McLouth area in sec. 3, T. 10 S., R. 20 E., was discovered in May, 1941. Production is from the McLouth sand which lies near the base of the Cherokee shale. The discovery of gas in October, 1941, in the NE¼ sec. 12, T. 10 S., R. 20 E., opened the **Ackerland** gas pool. This pool is in secs. 1 and 12, T. 10 S., R. 20 E. and in secs. 6 and 7, T. 10 S., R. 21 E. Gas is produced from the McLouth sand. Oil is produced from the McLouth sand in secs. 6 and 7, T. 10 S., R. 21 E. in the Ackerland oil pool, which is slightly east of the Ackerland gas pool. The **McLouth** gas pool extends into Leavenworth county in secs. 22 and 27, T. 9 S., R. 20 E. and sec. 3, T. 10 S., R. 20 E. Production is from the McLouth sand. The **Jarbalo** gas pool is in sec. 8, T. 10 S., R. 21 E.

The Roberts gas pool is included in the **Roberts-Maywood** gas-producing area of Leavenworth and Wyandotte counties. The Leavenworth county part of this pool is in sec. 12, T. 11 S., R. 22 E. Production is from the "Squirrel sand."

The **Linwood** gas-producing area is in secs. 1, 11, 12, 13, and 14, T. 12 S., R. 21 E.; sec. 31, T. 11 S., R. 22 E.; and secs. 6 and 7, T. 12 S., R. 22 E. Gas production is from the "Squirrel sand," and some gas has been reported from the Knobtown sandstone. Late in 1944 the **Lawrence** gas-producing area was extended from Douglas county into Leavenworth county, when gas was found in the "Squirrel sand" in the Huber No. 1 Mohler well in the NW¼ NE¼ sec. 22, T. 12 S., R. 20 E. The well was gauged at 627,000 cubic feet of gas per day. Gas for local use has been produced in this vicinity for several years and the area has potentialities for being relatively important.

Reported monthly production of oil in Leavenworth county in 1941 and 1942 is given in table 56, and gas production figures for the years 1939 to 1943 are given in table 57.

TABLE 56.—*Reported monthly production of oil in Leavenworth county, Kansas, in barrels*

Month	1941	1942	1943[1]
January		2,308	
February		2,264	
March		2,178	
April		1,989	
May		2,452	
June	1,020	1,918	
July	2,298	1,980	
August	2,037	1,620	
September	1,359	1,560	
October	1,564	1,560	
November	2,045	1,680	
December	2,697	1,455	
Totals	13,020	22,964	

[1] Production for 1943 is included with Jefferson county (table 46)

TABLE 57.—*Natural gas production in Leavenworth county, Kansas*

Year	Thousands of cubic feet
1939	39,000
1940	30,403
1941	34,052
1942	29,946
1943	37,750

LINN COUNTY

Three wells were drilled in Miami county in 1860, and a short time later several wells were drilled north of Mound City in Linn county. Small amounts of oil and gas were produced from these wells. Important amounts of oil and gas have been produced in Linn county for many years. The oil production in 1926 was 89,208 barrels. Production has declined from this maximum, but many wells have been especially long-lived. Water flooding is being practiced and Linn promises to be of further importance in oil production. The production of oil in 1943 was more than 50 percent greater than in 1942. Gas is widespread in the county. A small amount of oil has been produced from near the top of the Mississippian limestone. All other production is from Pennsylvanian rocks. Deep tests in the county have been unsuccessful.

The oil and gas resources of Linn county have been described by Jewett (1940a) in a report which contains a map showing loca-

tions of known wells and gives the stratigraphic depths of many wells.

Surface Rocks

With the exception of a few feet of unconsolidated deposits of Recent, Pleistocene, and Tertiary (?) age, the surface rocks of Linn county are of Pennsylvanian age. The youngest consolidated rock is the Plattsburg limestone, basal formation in the Lansing group (fig. 8), which underlies a small area in the extreme northwestern part of the county. The oldest exposed rock is the upper part of the Labette shale.

The Kansas City group in Linn county includes shales and comparatively thin limestones. Its total thickness is about 210 feet. Rocks of this group crop out in the western part of the county, and are characterized by thick, more or less sandy, gray and yellow shales. There is a persistent sandstone in the Chanute shale, and a bed of coal occurs below the sandstone. The average thickness of Bronson rocks in the county is slightly more than 200 feet. Limestone constitutes more than half the thickness. The rocks of this group form the boldest escarpments in the county, and the upper formation (Dennis limestone) lies immediately below the soil in a large area. Rocks of this group are characterized by flinty and oölitic limestones in the Dennis and Swope formations and by black platy shale in the lower parts of the same formations. There are several key horizons which are useful in mapping surface structures.

The Bourbon shale ("Big shale" of drillers) in Linn county ranges in thickness from about 80 to 200 feet. Massive sandstone occurs locally in the upper part of the Bourbon, and locally there are several feet of alternating thin beds of shale and dark limestone. This upper part constitutes the Knobtown sandstone in the central part of the county. The Hepler sandstone, lying at the base of the Bourbon shale, ranges from about 2 to 25 feet in thickness.

The Marmaton group of limestone and shale is about 200 feet thick at outcrops in Linn county. Locally the upper three formations have been partly or entirely removed by erosion before deposition of the overlying Bourbon shale. The lower part of the Labette shale and the Fort Scott limestone do not crop out in the county. The other formations of this group (fig. 8) are present at the surface in the eastern and southeastern parts of the county. The Bandera and Labette formations contain lenses of sandstone.

Subsurface Rocks

Hundreds of wells, most of which did not reach the oldest Pennsylvanian rocks of the region, have been drilled in Linn county. However, several wells have penetrated older rocks and eight wells are known to have reached rocks older than those of Mississippian age. Depths to some key horizons in the Holeman and Edwards No. 9 Pollman well are given in table 58. Linn county lies in the northern part of the area of the Chautauqua arch. Subsurface geologic conditions along the southern boundary of the county are shown in plate 3.

Pennsylvanian rocks.—Subsurface Marmaton rocks are about 250 feet thick and consist of limestone, shale, and sandstone. Gas is produced from the Bandera and Labette formations and oil from the Bandera formation. The Cherokee shale includes five or more gas and oil producing zones which are chiefly lenticular sandstones that are known as the "Squirrel," "Upper Bartlesville," "Lower Bartlesville," and "Burgess" ("Tucker") sandstones. "Shale gas" is produced from black platy shale in the upper few feet of the Cherokee section in several parts of Linn county.

Mississippian rocks.—Mississippian rocks in Linn county were discussed by Lee (in Jewett, 1940a, pp. 14-17). Depths to Mississippian rocks range from less than 450 feet below valleys in the eastern part of the county to about 1,000 feet on the uplands in the western part. The average thickness of Mississippian rocks is slightly more than 350 feet in the northwestern part and 390 feet in the southeastern part. The Mississippian rocks are slightly less than 300 feet thick in some areas in the central part of the county. The Mississippian section includes Meramecian rocks comprising the St. Louis limestone, the Spergen or Upper Warsaw limestone, and the Warsaw limestone, having a total thickness of about 155 feet; Osagian rocks, including the undifferentiated Keokuk and Burlington limestones and the Sedalia (?) limestone, having a total thickness of about 150 feet; and Kinderhookian rocks, including the Chouteau limestone, about 100 feet thick. The Chattanooga shale, also probably of Kinderhookian age, has an average thickness of about 20 feet.

In Linn county the Chattanooga shale lies on rocks of early Ordovician age. It is probable that younger Ordovician, Silurian, and Devonian rocks were deposited and later eroded from this part of the Chautauqua arch area.

Ordovician rocks.—According to Keroher (in Jewett, 1940a, pp. 12-14), who studied cuttings from the Holeman and Edwards No. 9 Pollman well in the SE¼ sec. 35, T. 19 S., R. 24 E., Ordovician rocks in Linn county include 168 feet of undifferentiated Cotter and Jefferson City dolomites; 145 feet of Roubidoux formation; and 135 feet of undifferentiated Gasconade and Van Buren dolomites and Gunter sandstone.

Cambrian rocks.—We have no record of wells in Linn county that have penetrated the full thickness of Cambrian rocks. The Holeman and Edwards No. 9 Pollman well was drilled through 150 feet of undifferentiated Proctor and Eminence dolomites and 90 feet into the Bonneterre dolomite (Jewett, 1940a, pl. 2). From studies of cuttings from wells in near-by areas, it is believed that the Bonneterre dolomite in Linn county is about 125 feet thick and that the Lamotte sandstone is probably about 40 feet thick.

TABLE 58.—*Depths to some key stratigraphic horizons in the Holeman and Edwards No. 9 Pollman well, SE¼ sec. 35, T. 19 S., R. 24 E., Linn county, Kansas*

Horizon	Depth, in feet
Top of Mississippian limestone	460
Top of Chattanooga shale	812
Base of Chattanooga shale and top of Arbuckle rocks (Cotter-Jefferson City dolomites)	822
Top of Roubidoux formation	990
Top of Gasconade and Van Buren dolomites	1,135
Top of Proctor and Eminence dolomites	1,275
Top of Bonneterre dolomite	1,425

OIL AND GAS DEVELOPMENTS

The shallower rocks in Linn county have been explored extensively for oil and gas, but deeper rocks, especially those of Ordovician age, have been tested inadequately. Several years ago a small amount of oil was found in the weathered upper part of the Mississippian limestone in the southwestern part of the county near Blue Mound, but elsewhere production has come from Pennsylvanian rocks. Oil or gas or both have been found in the Bandera formation, the upper few feet of the Cherokee shale, the "Squirrel sand," the "Bartlesville sand," the "Tucker sand" (in the basal part of the Cherokee shale), and the upper part of the Mississippian limestone. Oil discoveries have been restricted generally to the northern and western parts of the county. There are gas wells

in many parts of the county; therefore, it is difficult to divide the county into definite fields or producing areas. Areas of greater concentration are discernible, however. Table 59 lists the oil and gas fields of Linn county as designated by the Oil Field Nomenclature Committee of the Kansas Geological Society.

The **Goodrich-Parker** oil-producing area extends from the northeastern part of T. 20 S., R. 22 E. southwestward to the vicinity of the village of Goodrich and westward for a distance of 2 miles. It is a "shoestring" about 7 miles long and one-half to 1 mile wide. Oil production is from the "Squirrel sand."

The **Cadmus-LaCygne** oil-producing area is in the southern part of T. 19 S., R. 23 E. and the northern part of T. 20 S., R. 23 E. Oil production is chiefly from sandstone in the Bandera formation. The Wallace Oil Company began a water-flooding project on the Laura Lee lease in the NW¼ sec. 10, T. 20 S., R. 23 E. in December, 1940. It is reported that before water flooding was started, the lease had been depleted of oil recoverable by primary methods. To November 1, 1942, the lease produced 1,617 barrels of oil from seven wells as the result of injecting 55,415 barrels of water (Grandone, 1944, p. 95).

The **Centerville** oil-producing area is in the central-eastern part of T. 21 S., R. 21 E. and the central-western part of T. 21 S., R. 22 E. It also includes a "shoestring" which extends from sec. 9, T. 21 S., R. 22 E. to sec. 20, T. 21 S., R. 23 E. Oil is produced chiefly from the "Squirrel sand." In 1935 the Texas Company started a water-flooding project in secs. 13, 14, and 24, T. 21 S., R. 22 E. in the Centerville area. In 1942 there were 59 oil wells and 43 water input wells in the project. The entire property yielded 8 barrels of oil per day when water flooding was begun. A notable increase of oil production took place 12 months after water injection began. Between December 6, 1935, and November 1, 1942, 84,189 barrels of oil were produced as the result of injecting 739,913 barrels of water (Grandone, 1944, pp. 91, 92).

The **Blue Mound** oil-producing area is northwest of Blue Mound. In sec. 19, T. 22 S., R. 22 E. a small amount of oil has been produced from the top of the Mississippian limestone at a depth of about 800 feet. Most of the production has come from Pennsylvanian rocks at shallower depths.

The **Mound City** oil pool was one of the first discovered in Kansas. Oil production was from the "Squirrel sand." The pro-

ducing oil wells were in secs. 5, 6, 7, and 8, T. 22 S., R. 24 E. These wells were pumped intermittently for many years.

In several parts of Linn county oil has been produced from sandstones, locally called "Bartlesville," which lie a few feet below the Ardmore limestone in the upper middle part of the Cherokee shale.

TABLE 59.—*Oil and gas fields in Linn county, Kansas*

(As designated by the Oil Field Nomenclature Committee of the Kansas Geological Society, November 15, 1944)

Name	Location
Beagle[1]	T 19 S, R 22 E, sec. 22
Blue Mound	T 22 S, R 21 E, secs. 24 to 26, 35, 36
	T 22 S, R 22 E, secs. 19, 29 to 32
	T 23 S, R 21 E, secs. 1, 2, 12
	T 23 S, R 22 E, secs. 6, 7
Centerville[2]	T 21 S, R 21 E, secs. 13, 14, 23 to 26, 35, 36
	T 21 S, R 22 E, secs. 1 to 4, 7 to 24
	T 21 S, R 23 E, secs. 6, 7, 18 to 20, 28 to 30, 32 to 34
	T 22 S, R 23 E, secs. 2 to 4, 9, 10
Critzer	T 21 S, R 22 E, secs. 27 to 34
	T 22 S, R 22 E, secs. 2 to 5, 10 to 15, 24
	T 22 S, R 23 E, secs. 7, 17 to 21, 28, 29, 32, 33
Fontana South[1]	T 19 S, R 23 E, secs. 21 to 24
Goodrich-Parker[2]	T 19 S, R 22 E, secs. 23 to 27, 32 to 36
	T 19 S, R 23 E, secs. 19, 30
	T 20 S, R 21 E, secs. 24 to 26, 34 to 36
	T 20 S, R 22 E, secs. 2 to 5, 8 to 11, 15 to 17, 19 to 22, 27 to 30
	T 21 S, R 21 E, secs. 2, 11
LaCygne-Cadmus	T 19 S, R 23 E, secs. 21, 24 to 36
	T 19 S, R 24 E, secs. 19 to 22, 25 to 36
	T 19 S, R 25 E, secs. 29 to 32
	T 20 S, R 23 E, secs. 1 to 12, 15 to 18
	T 20 S, R 24 E, secs. 1 to 17, 21 to 24
	T 20 S, R 25 E, secs. 4 to 7, 18, 19
Mound City	T 21 S, R 23 E, secs. 25, 36
	T 21 S, R 24 E, secs. 23 to 26, 28 to 36
	T 21 S, R 25 E, secs. 18, 19, 28 to 33
	T 22 S, R 23 E, secs. 1, 11 to 15, 22 to 27
	T 22 S, R 24 E, secs. 1 to 30
	T 22 S, R 25 E, secs. 4 to 9, 16 to 21, 29 to 32
Prescott	T 23 S, R 24 E, secs. 1, 12
	T 23 S, R 25 E, secs. 5 to 8

[1] Also in Miami county (see table 67)
[2] Also in Anderson county (see table 6)

Gas is produced from at least seven zones in the Pennsylvanian rocks in Linn county. Sandstone in the Bandera shale yields gas in several areas, but most of the wells that have produced from this zone are in T. 20 S., R. 23 E., in the vicinity of Cadmus. The "Peru sand" of the Labette formation yields gas in pools in the vicinity of Pleasanton. "Shale gas," occurring in the upper few few feet of the Cherokee shale, is widespread in Linn county. Gas has been found in this zone in more than a dozen areas in the northeastern and eastern parts of the county (Jewett, 1940a, fig. 6). The "Squirrel sand" occurs slightly lower than the "shale gas" zone in the upper part of the Cherokee shale and yields gas in several areas in Linn county (Jewett, 1940a, fig. 5). Gas is found in the "Bartlesville sand" in nearly every township in the county. The gas occurs in two sandstone zones in the Cherokee shale below the Ardmore limestone. The "Bartlesville" is higher than the sandstone known as "Tucker" or "Burgess" in the basal part of the Cherokee section, which also yields gas in Linn county, principally south and west of Mound City and south of Pleasanton (Jewett, 1940a, fig. 3).

Monthly production of oil in Linn county for 1941, 1942, and 1943 is given in table 60, and gas production statistics for the years 1939 to 1943 are given in table 61.

LYON COUNTY

Oil is produced in the extreme southern part of Lyon county. Production is from "Bartlesville" shoestring sandstones and from sandstone of Ordovician age. Oil was discovered in the county in T. 21 S., R. 10 E. in 1922.

Surface Rocks

Surficial deposits in Lyon county include several feet of flint gravel, principally on the uplands, and finer alluvium in the stream valleys. The flint gravel beds, which are especially abundant in the southern part of the county, are probably of Tertiary age.

Permian rocks.—Permian rocks (fig. 6) of Wolfcampian age crop out in the western part of Lyon county. About 600 feet of lower Permian strata are exposed. The Florence limestone or a few feet of overlying sediments is the uppermost Permian rock in the county. In several exposures in Lyon county basal Permian

TABLE 60.—*Reported monthly production of oil in Linn county, Kansas, in barrels*

	1941	1942	1943
January	319	2,264	1,470
February	239	1,862	2,594
March	2,465	2,006	2,147
April	2,708	2,616	3,532
May	2,984	1,300	2,348
June	2,923	3,111	3,463
July	1,899	2,140	3,932
August	3,104	1,720	3,767
September	2,320	1,501	3,277
October	3,288	2,467	4,370
November	2,220	1,720	3,696
December	1,726	1,822	4,249
Totals	26,195	24,529	38,845

TABLE 61.—*Natural gas production in Linn county, Kansas*

Year	Thousands of cubic feet
1939	123,849
1940	119,577
1941	102,065
1942	96,988
1943	99,609

rocks are seemingly conformable with the underlying Brownville limestone. Elsewhere in Kansas local unconformities occur between rocks of the Permian and Pennsylvanian systems.

About 150 feet of rocks of the Chase group is exposed in western Lyon county. These rocks are characterized by bright-colored shales and massive limestones. The Florence and Wreford limestones contain abundant nodules of flint. In Lyon county, as in several other eastern Kansas counties, rocks assigned to the Council Grove group have a total thickness of about 300 feet. The percentage of limestone in this division is much larger than in the underlying Admire group. Highly colored shales similar to those in the overlying Chase group are characteristic of the Council Grove group, especially its upper part. The Cottonwood and Neva limestones are the most easily recognized limestones. The thickness of the Admire group in Lyon county is about 150 feet. These rocks are chiefly gray and yellow shale but the Towle shale is partly red. They contain limestones commonly less than 2 feet thick and minor amounts of sandstone.

Pennsylvanian rocks.—Upper Pennsylvanian sediments, including rocks of the Wabaunsee group and the upper part of the Shawnee group, crop out in the eastern part of Lyon county. The thickness of exposed Pennsylvanian rocks in the county is approximately 500 feet. Most of the named units of the Wabaunsee group (fig. 7), especially the limestones, are fairly easily recognized at their outcrops. The Tarkio limestone, however, one of the most readily determined strata farther north, has not been identified in Lyon county. Fairly light-colored limestones only a few feet thick and clayey and sandy shales are characteristic of Wabaunsee rocks in this part of the state. Fusulines are abundant in Wabaunsee rocks. The Topeka limestone and the upper part of the Calhoun shale are exposed in a small area in T. 20 S., R. 13 E. along a tributary to Neosho river. Elsewhere in Lyon county these rocks are buried beneath younger bedrock.

Subsurface Rocks

Subsurface geologic conditions along the northern boundary of Lyon county are shown in plate 2.

Pennsylvanian rocks.—The thickness of Pennsylvanian rocks in Lyon county varies from place to place because of slight lateral changes in thicknesses of rock units and because Pennsylvanian rocks that are present in the western part of the county have been removed from the eastern part by erosion. The westward-dipping surface rocks have been beveled by erosion. The average thickness of rocks from the top of the Topeka limestone to the base of the Pennsylvanian section is about 1,650 feet. Pennsylvanian rock groups in Lyon county are not greatly different in thickness and lithology from those of neighboring counties. Oil is produced in the southern part of the county from the "Bartlesville sand."

Mississippian rocks.—The total thickness of Mississippian limestone formations in Lyon county ranges from about 300 feet in the northwestern corner to slightly more than 450 feet in the central-eastern part (Lee, 1943, fig. 6). The Chattanooga shale has an average thickness of about 100 feet (Lee, 1940, pl. 3).

Pre-Chattanooga rocks.—In most of Lyon county the Chattanooga shale is believed to lie on the Viola limestone (Ockerman, 1935, fig. 2). In the northern part of the county the "Hunton" limestone underlies the Chattanooga shale and the pre-Chattanooga outcrops of the "Hunton" and Viola limestones were sepa-

rated by a narrow band of Maquoketa shale. In the northern part of the county the interval between the base of the Chattanooga shale and the top of the Maquoketa shale is about 100 feet (Lee, 1943, fig. 12). The total thickness of rocks between the top of the Maquoketa shale and the top of the St. Peter sandstone is probably less than 100 feet everywhere in the county (Lee, 1943, fig. 12) and the interval from the top of the St. Peter sandstone to the pre-Cambrian floor ranges from about 300 to 800 feet.

Oil and Gas Developments

The **Atyeo** oil pool is in secs. 19, 30, and 31, T. 21 S., R. 10 E.; secs. 24, 25, and 36, T. 21 S., R. 9 E.; and sec. 6, T. 22 S., R. 10 E., in Lyon, Chase, and Greenwood counties. Production in this pool is from the "Bartlesville sand." The depth to the "Bartlesville" is about 2,200 feet. The average daily production from 50 wells in December, 1944, was 174 barrels.

The **Fankhauser** oil pool is in secs. 29 to 33, T. 21 S., R. 12 E., Lyon county, and extends into secs. 4, 5, 9, 10, and 15, T. 22 S., R. 12 E., Greenwood county. In 1944, there were 60 producing wells in the pool. The average daily production from 60 wells in December, 1944, was 263 barrels. Production in this pool is from the "Bartlesville sand."

In the **Bradfield** pool, in secs. 24 and 25, T. 21 S., R. 10 E. in the southwestern part of the county, oil was produced from an Ordovician sandstone at depths ranging from about 2,200 to 2,600 feet.

Table 62.—*Reported monthly production of oil in Lyon county, Kansas, in barrels*[1]

Month	1941	1942	1943	1944
January	8,091	8,426	7,756	15,066
February	9,247	8,030	7,939	14,500
March	8,365	9,095	8,091	15,996
April	9,308	8,486	10,555	14,070
May	8,791	8,638	11,528	15,717
June	9,703	9,095	12,106	14,760
July	9,521	8,943	11,923	13,279
August	8,882	8,821	11,437	15,097
September	9,003	9,886	12,106	14,220
October	9,034	9,216	12,288	14,353
November	8,730	8,395	13,627	13,980
December	9,612	9,247	13,931	13,547
Totals	108,287	106,278	133,287	174,585

[1] Includes some production in Greenwood and Chase counties.

Some wells in the Bradfield area had initial productions of 1,000 barrels of oil per day. The pool was discovered in 1922.

In the **Ritchey-Moore** pool, in sec. 34, T. 21 S., R. 10 E., production was from Ordovician rocks at a depth of about 2,200 feet.

In 1925 the Bradfield pool yielded 27,515 barrels of oil. In 1926, after the Atyeo and Fankhauser pools were extended into Lyon county, 625,931 barrels of oil were produced in the county. The production in 1927 was 715,131 barrels; in 1944 it was 174,585 barrels. Cumulative oil production figures are not available.

Monthly oil production figures for 1941, 1942, 1943, and 1944 are given in table 62.

MARION COUNTY

Soon after the discovery of oil in the Elbing pool in Butler county, the Peabody, Covert-Sellers, and Florence-Urschel pools were discovered in Marion county. Oil in these pools occurs in Ordovician rocks at an average depth of about 2,400 feet. The oil fields lie above rather low surface anticlines. Inasmuch as the oil occurs in eroded Ordovician dolomites that are overstepped by Pennsylvanian and Mississippian rocks, it is proper to say that the oil occurs in stratigraphic traps as well as in anticlines. The geology of southern Marion and northern Butler counties was discussed by Thomas (1927).

Surface Rocks

Cretaceous sandstone and shale (Dakota and Kiowa) occupy small areas at the surface in western Marion county. Permian rocks crop out in the remaining part of the county. Exposed Permian rocks include those between the lower part of the Wellington shale and the strata a few feet below the base of the Barneston limestone (fig. 6). The Carlton limestone, in the lower part of the Wellington shale, crops out in a narrow band a few miles east of the eastern border of Cretaceous rocks. Limestones in the upper part of the Chase group crop out in steep escarpments in the eastern part of the county.

Subsurface Rocks

Marion county is on the west flank of the Nemaha anticline and on the margins of the Salina and Sedgwick basins. The northern part of the county is on the southern margin of the North Kansas basin (figs. 3 and 5).

Permian and Pennsylvanian rocks.—The average thickness of Permian and Pennsylvanian rocks in Marion county is about 2,500 feet. This section is thicker in the western part of the county and thinner in the eastern part.

Mississippian rocks.—Mississippian limestone formations are absent in the eastern part of T. 18 S., R. 5 E. and the east half of T. 19 S., R. 5 E. in extreme northeastern Marion county (Lee, 1939, pl. 1). The thickness of Mississippian limestone in the county, as shown by Lee's studies, ranges from a featheredge to slightly more than 300 feet in the extreme southwestern part.

The Chattanooga shale is absent in approximately the same area in Marion county in which Mississippian limestones are absent. The Chattanooga shale ranges in thickness from a fraction of a foot to about 250 feet. The greatest thickness is in the central-western part of the county (Lee, 1940, pl. 3).

Pre-Chattanooga rocks.—In Marion county the Chattanooga shale is in contact with the "Hunton" limestone, Maquoketa shale, and Viola limestone (McClellan, 1930; Ockerman, 1935, fig. 2). In the northeastern part of the county where the Chattanooga shale is absent, Pennsylvanian rocks are believed to truncate underlying rocks as old as the upper part of the Arbuckle limestone. The thickness of the "Hunton" limestone ranges from a featheredge to about 100 feet. It is believed to underlie only the northern part of the county. The maximum thickness of the Maquoketa shale in the county is believed to be about 100 feet and the greatest thickness of the Viola limestone is about the same. The maximum thickness of the St. Peter sandstone is perhaps less than 50 feet, and the average thickness of Arbuckle rocks is believed to be about 400 feet.

Oil and Gas Developments

Locations of principal oil and gas producing areas in Marion county are shown in figure 18. The "Mississippi lime" and the Viola limestone are the important producing rocks. A minor amount of oil has been produced from lower Pennsylvanian rocks in scattered localities.

The **Lost Springs** oil pool, discovered in 1926, is in the northeastern part of Marion county and extends into Dickinson county. Production is from the Mississippian limestone, the top of which is encountered at an average depth of about 2,365 feet. Average

initial production was about 135 barrels of oil per day and the maximum initial production was about 1,000 barrels. In 1943 the average daily total production from 142 wells was 1,926 barrels of oil.

The **Hillsboro** oil pool was discovered in October, 1928. The discovery well is the Davis No. 1A Weins well in the NW¼ sec. 7, T. 19 S., R. 3 E. Production is from the Viola limestone, but it is

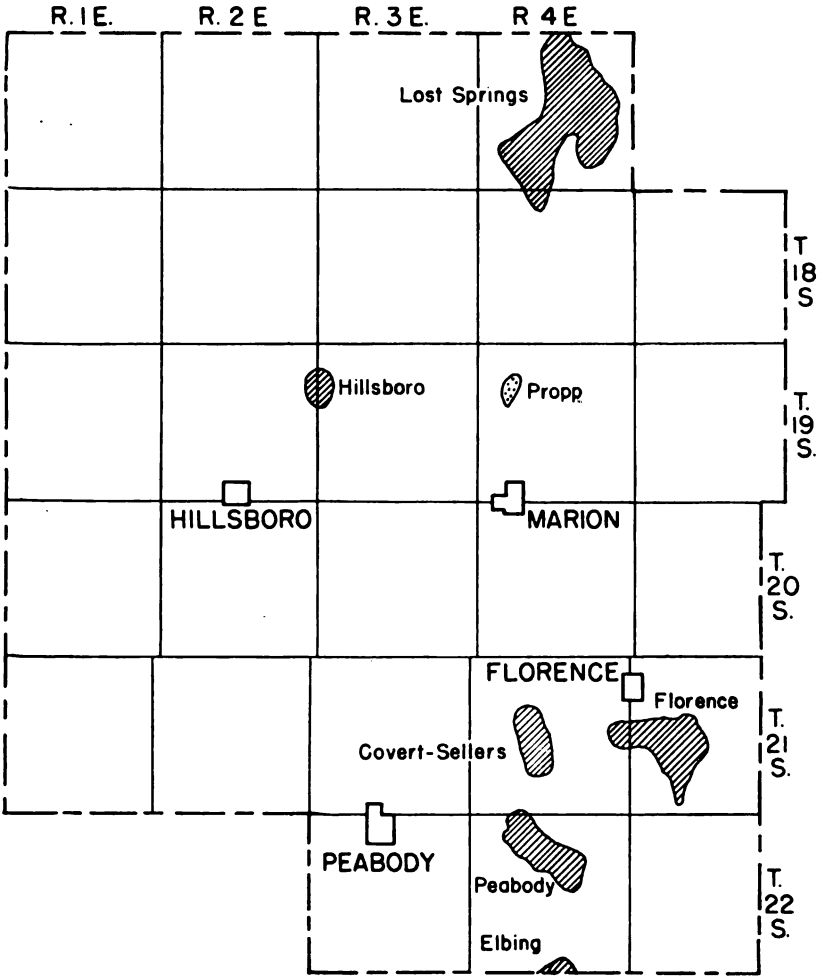

FIG. 18. Map of Marion county showing oil and gas producing areas. The Fanska oil pool, in sec. 6, T. 17 S., R. 1 E., is not shown. (Gas, dots; oil, diagonal lines.)

reported that the discovery well produced 332 barrels of oil from the "Mississippi lime" before it was deepened to the Viola. The average depth to the top of the producing zone in this area is about 2,820 feet. Initial production of some wells was as high as 400 barrels of oil per day. The average daily total production of nine wells in 1943 was 98 barrels of oil.

The **Propp** gas pool was discovered in April, 1926. Initial production of the discovery well was 4,000,000 cubic feet of gas per day. Production is from the "chat," in the upper part of the Mississippian limestone.

The **Covert-Sellers** oil pool was discovered in March, 1920, when the Ward and Wilhoit No. 1 Covert well, in the SW¼ NE¼ NW¼ sec. 28, T. 21 S., R. 4 E., encountered oil in the Viola limestone. In 1943 the average daily total production from 16 wells was 120 barrels of oil.

The **Florence** oil pool was discovered in 1920 by the Robinson and Loreau No. 1 Hupp-Greeley well, in the SW¼ SE¼ sec. 18, T. 21 S., R. 5 E. Oil was found in the Viola limestone.

The **Peabody** oil pool was discovered in 1920 by the Elmhurst Investment Company No. 1 O. Jolliffe well, in the SE¼ SE¼ sec. 9, T. 22 S., R. 4 E. The Viola limestone is the producing formation. In 1943 the total average daily production from 11 wells was 74 barrels of oil.

The **Elbing** oil pool is chiefly in Butler county, but it extends into T. 22 S., R. 4 E. in southern Marion county.

TABLE 63.—*Reported monthly production of oil in Marion county, Kansas, in barrels*[1]

Month	1941	1942	1943	1944
January	49,063	87,814	67,617	73,749
February	54,507	85,624	67,191	72,210
March	59,982	84,985	66,674	73,408
April	63,054	83,677	67,556	63,270
May	67,495	79,419	62,385	73,625
June	77,563	80,757	68,286	72,090
July	76,225	81,913	66,857	71,362
August	79,571	79,419	64,514	80,445
September	82,643	78,111	71,936	18,120
October	64,613	85,837	68,682	18,476
November	77,198	80,696	75,404	17,730
December	88,726	71,145	68,256	16,895
Totals	340,640	979,397	815,358	862,102

[1] Includes some production from Morris and Dickinson counties.

The **Fanska** oil pool, in sec. 6, T. 17 S., R. 1 E., was discovered in June, 1943. Production is from lower Pennsylvanian rocks at a depth of about 2,680 feet.

Monthly oil production figures are given in table 63. Yearly gas production is shown in table 64. A part of the production from the Lost Springs pool, all of which is included in table 63, came from Dickinson county.

TABLE 64.—*Natural gas production in Marion county, Kansas*

Year	Thousands of cubic feet
1939	79,335
1940	84,956
1941	69,699
1942	79,343
1943	94,984

MARSHALL COUNTY

Neither oil nor gas in commercial quantities has been found in Marshall county. The county lies in an area where regional structural conditions are such that one might expect to find structural oil traps in the more deeply buried rocks.

SURFACE ROCKS

In most of Marshall county the exposed rocks are of Permian age. A small area in the western part of the county is occupied by outcrops of Cretaceous sediments and a few feet of late Pennsylvanian rocks crop out in the eastern part of the county.

Cretaceous rocks.—A small upland area in T. 2 S., R. 6 E. and in the extreme northwest corner of T. 3 S., R 6 E. in western Marshall county is underlain by Dakota sandstone and shale.

Permian rocks.—In most of Marshall county the soil is immediately underlain by Permian rocks that embrace the section between the lower part of the Wellington shale and the lowermost Permian (fig. 6). Several limestones of Wolfcampian age are useful key beds for surface structural mapping. Outcropping Permian rocks in the county are similar to the same strata in Riley county and are more completely discussed under Riley county.

Pennsylvanian rocks.—The Dover limestone (fig. 7) and a few feet of other upper Pennsylvanian rocks crop out in eastern and southeastern Marshall county (Moore and Landes, 1937).

Subsurface Rocks

Marshall county lies on the west flank of the Nemaha anticline. Subsurface geologic conditions along the southern boundary of the county are shown in plate 1.

Permian and Pennsylvanian rocks.—The combined thickness of Permian and Pennsylvanian rocks in Marshall county ranges from less than 1,000 feet to more than 2,000 feet. The thinner section is in the eastern part of the county where Permian rocks have been eroded. Marshall county lies on the west flank of the Nemaha anticline where the Pennsylvanian section in much thinner than it is east of the anticline. West of the anticline the older Pennsylvanian section is reduced in thickness, but Pennsylvanian rocks above the base of the Kansas City group have about the same thickness on both sides of the anticline. Redbeds are characteristic of the lowermost Pennsylvanian rocks.

Mississippian limestones and the Chattanooga shale are probably absent in all parts of Marshall county.

Pre-Chattanooga rocks.—In Marshall county Pennsylvanian rocks overstep from the west the "Hunton" limestone, the Maquoketa shale, the Viola limestone, and the Simpson formation (St. Peter-Decorah). Arbuckle rocks are probably absent from all parts of the county.

The Geological Survey has records of nine test wells in Marshall county. Of these wells, four are reported to have reached pre-Cambrian rocks at depths ranging from 1,225 feet to 2,265 feet; two are believed to have stopped in St. Peter sandstone; two in the "Hunton" limestone; and one in Lansing rocks. Depths to some key horizons in a well in sec. 4, T. 4 S., R. 7 E. are given in table 65.

Table 65.—*Depths to some stratigraphic horizons in the Marshall Syndicate No. 1 Finn well, NW¼ NE¼ NE¼ sec. 4, T. 4 S., R. 7 E., Marshall county, Kansas*

Horizon	Depth in feet
Base of Pennsylvanian rocks and top of "Hunton" limestone	1,520
Top of Viola? limestone	1,758
Top of Galena dolomite	1,940
Top of Decorah shale	2,070
Top of Platteville limestone	2,120
Top of St. Peter sandstone	2,148
Top of pre-Cambrian rocks (?)	2,265
Total depth	3,935

MIAMI COUNTY

Miami county was one of the first counties in Kansas to produce oil and gas. Three wells drilled by Dr. G. W. Brown near Paola in 1860 were the first test wells drilled in the state. The first two wells were abandoned as dry holes at depths of about 100 feet (Haworth, 1908, p. 22). The third well was drilled deeper and the discovery of oil was reported. Natural gas was piped to Paola from a field 7 miles to the east as early as 1884. This was the first city in Kansas to be supplied with natural gas. All oil and gas production in Miami county is from Pennsylvanian rocks.

Repressuring operations to increase oil production were started in Miami county several years ago. Both air-pressure and water-flooding methods are practiced.

The surface geology of Miami county has been described by Newell (1935). His report contains an areal geologic map of the county and detailed descriptions of outcropping rocks.

Surface Rocks

With the exception of a few feet of unconsolidated deposits of Recent, Pleistocene, and Tertiary (?) age, the surface rocks of Miami county are of Pennsylvanian age. They include most of the Lansing group, all the Kansas City and Bronson groups, and most of the Bourbon shale (fig. 8). The upper part of the Stanton limestone of the Lansing group has not been identified in the county, although the entire formation is probably present under soil cover in the northwestern part of the county. The thickness of the exposed part of the Stanton limestone ranges from about 26 to 36 feet, the thickness of the Vilas shale from about 6 to 20 feet, and the thickness of the Plattsburg limestone from about 10 to 22 feet. These rocks are exposed in the northwestern part of the county.

Rocks of the Kansas City group, whose total thickness is about 175 feet, crop out in areas characterized by the prominent Wyandotte limestone escarpment and by the thick Lane shale section in the western part of the county. The Iola limestone escarpment is less conspicuous. The Wyandotte limestone is the formation next below the soil on the uplands in all the county except the southeastern and northwestern parts. The Westerville limestone seemingly is absent in Miami county. The total thickness of rocks of the Bronson group in the county is about 80 feet. Limestone is the dominant rock of this assemblage, which is characterized by

oölitic cross-bedded flinty limestones and thinner black platy shales. These rocks crop out in the southern and southeastern parts of the county.

The thickness of the Bourbon shale in Miami county is approximately 140 feet, but only about the upper 90 feet is exposed. The exposures of these rocks are along Hushpuckney creek, Marais des Cygnes river, Middle creek, and Sugar creek in the southern and southeastern parts of the county.

Subsurface Rocks

Subsurface geologic conditions along the northern boundary of Miami county are shown in plate 2.

Pennsylvanian rocks.—The thickness of Pennsylvanian rocks in Miami county ranges from slightly more than 1,000 feet in the northwestern part to about 600 feet in the southeastern part. All oil and gas production in the county is from Pennsylvanian rocks, and numerous producing zones ranging from the Bourbon shale to the lower part of the Cherokee shale are known. The Bourbon rocks are easily recognized in well logs, and comprise strata that are referred to as the "Big shale." In the subsurface, the Hepler sandstone is locally in contact with the "Big Lake" sandstone in the Bandera shale. Because of this relationship, the "Big Lake" sandstone in some places comprises two sandstones, the Hepler sandstone at the base of the Bourbon shale and the Bandera Quarry sandstone in the upper part of the Marmaton group. A part of the oil and gas produced in the Big Lake area is from the Hepler sandstone. The common thickness of Bourbon rocks in the county is about 200 feet. The Marmaton group is about 150 feet thick, and the Cherokee shale ranges in thickness from about 350 feet to 450 feet.

Mississippian rocks.—The total thickness of Mississippian limestone formations in Miami county ranges from about 350 feet to slightly more than 450 feet. The Chattanooga shale is believed to be less than 50 feet thick in all parts of the county.

Pre-Chattanooga rocks.—Miami county lies on the northern flank of the Chautauqua arch. Ordovician rocks, including Viola dolomite, St. Peter sandstone, and Arbuckle dolomite, are overstepped by the Chattanooga shale. The Viola and St. Peter are believed to be present only in the approximate northwestern half of the county. Elsewhere the Chattanooga shale is in contact with Ar-

buckle dolomite. The thickness of the Viola dolomite ranges from a featheredge to about 200 feet. The maximum thickness of the St. Peter sandstone is probably not much greater than 100 feet. Arbuckle rocks in the county have an average thickness of perhaps 850 feet. The Lamotte sandstone, having a maximum thickness of about 100 feet, probably underlies most or all of the county.

Table 66 gives depths to some stratigraphic horizons in five wells in Miami county.

TABLE 66.—*Depths, in feet, to some stratigraphic horizons encountered in five deep wells in Miami county, Kansas*

Horizon	McDonald No. 1 Lee, SW¼ SW¼ SW¼ sec. 16, T. 16 S., R. 23 E.	Breisch No. 1 Ringer, NW¼ NE¼ NW¼ sec. 3, T. 17 S., R. 23 E.	No. 1 Brown, sec. 12, T. 17 S., R. 21 E.	Clark No. 1 Vaughn, SE¼ SW¼ sec. 28, T. 17 S., R. 12 E.	"Osawatomie", NE¼ NW¼ sec. 12, T. 18 S., R. 22 E.
Base of Hertha limestone	195	195	380	315	95
Base of Fort Scott limestone	445	475	?	615	428
Top of Mississippian limestones	852	888	1,055	981	770
Top of Chattanooga shale	1,278	1,272	1,410	1,385	1,195
Top of Viola limestone	1,435?	1,415?	1,465	1,428	1,255
Top of St. Peter sandstone	?	1,493	1,510	1,460	1,535
Top of Arbuckle limestone	?	1,533	1,538		1,634
Top of pre-Cambrian rocks	2,283				

OIL AND GAS DEVELOPMENTS

In 1884 gas was piped into Paola from wells about 7 miles east of town, and then and perhaps earlier oil was sold locally as lubricating oil. In about 1886 a small refinery was erected in Paola, and oil was shipped from there to Omaha and Kansas City. In 1889 the Paola field is reported to have yielded 500 barrels of oil. Until 15 years ago the leading districts were in the western half of the county where the Paola, Osawatomie, and Rantoul fields are located. Wells in these fields generally had initial productions of less than 100 barrels of oil per day, and their productions soon declined to a few barrels. In the autumn of 1926 the Big Lake pool was discovered. The discovery well in this field was drilled in sec. 20, T. 16 S., R. 22 E. This discovery resulted in an increase in the county's production from 13,153 barrels of oil in 1925 to

752,102 barrels in 1927. Much prospecting in the eastern half of the county followed. The Big Lake field was extended and several smaller fields were opened. In this part of the county producing wells range in depth from about 325 to 400 feet. In the western part, wells are as deep as 750 feet.

Oil and gas wells are distributed so widely in Miami county that it is not deemed practicable to divide the county into small fields. Gas is produced in nearly all parts of the county and wells have been drilled wherever locations are convenient to pipe lines or for domestic use. Many farmers have their own gas wells or one or more wells serve a few farms. The amount of natural gas that enters commercial pipe lines is much less than the total production. Figures listed in this report are of commercial gas only.

The oil and gas fields of Miami county as designated by the Oil Field Nomenclature Committee of the Kansas Geological Society are listed in table 67.

Information about water-flooding projects in this county has been obtained chiefly from United States Bureau of Mines Report of Investigations 3761 (Grandone, 1944, pp. 96-114).

The **Big Lake** oil-producing area is in secs. 14, 15, 16, 20, 21, and 29, T. 16 S., R. 24 E. The discovery well was drilled on the Big Lake lease in sec. 20, T. 16 S., R. 24 E., in November, 1926. The producing formation is a shoestring sandstone having a northeast-southwest trend. The wells range in depth from about 325 to 400 feet. Initial daily productions ranged from about 20 barrels to more than 250 barrels of oil. The producing sandstone is known as the "Big Lake sand"; it is correlated in part with the Bandera Quarry sandstone that lies between the Altamont and Pawnee limestones. In most of the area, however, the Altamont limestone is absent and the Hepler sandstone is seemingly locally in contact with the lower sandstone, the Bandera Quarry. Until more detailed studies are made, it is not deemed possible to determine whether production is chiefly from the Hepler sandstone or from the Bandera Quarry sandstone. The maximum known thickness of the "Big Lake sand" in the area is slightly more than 55 feet. Water flooding is being introduced in the Big Lake area. Repressuring by air has been practiced for many years.

The **Pressonville** shoestring oil-producing area extends westward from sec. 35, T. 17 S., R. 22 E. through the western border of the county in T. 16 S., R. 21 E. into Franklin county. This area in

Miami county is about 12 miles long and ranges from about a quarter of a mile to 2 miles or more in width. Oil production is chiefly from the "Squirrel sand" at depths ranging from about

TABLE 67.—*Oil and gas fields in Miami county, Kansas*

(As designated by the Oil Field Nomenclature Committee of the Kansas Geological Society, November 15, 1944)

Name	Location
Beagle[1]	T 19 S, R 22 E, secs. 10, 11, 14, 15
Black	T 18 S, R 24 E, sec. 33
	T 19 S, R 24 E, secs. 2 to 5, 8 to 17
Block	T 17 S, R 24 E, secs. 31, 32
	T 18 S, R 23 E, secs. 1, 10 to 15, 22 to 25, 36
	T 18 S, R 24 E, secs. 5 to 9, 14 to 23, 29 to 32
Fontana	T 18 S, R 23 E, secs. 26, 27, 34, 35
	T 19 S, R 23 E, secs. 2, 3
Fontana South[1]	T 19 S, R 23 E, secs. 10 to 16
Louisburg	T 16 S, R 24 E, secs. 13, 23 to 26, 35, 36
	T 16 S, R 25 E, secs. 15 to 23, 26 to 35
	T 17 S, R 24 E, secs. 1, 2, 11 to 14, 23 to 27, 34 to 36
	T 17 S, R 25 E, secs. 1 to 36
	T 18 S, R 24 E, secs. 1 to 3, 11 to 14
	T 18 S, R 25 E, secs. 2 to 9, 16 to 20
Louisburg Northeast	T 15 S, R 25 E, secs. 33, 34
	T 16 S, R 25 E, secs. 2, 3, 10, 11
Paola-Rantoul[2]	T 15 S, R 24 E, sec. 35
	T 16 S, R 21 E, secs. 1, 2, 11 to 14, 23 to 26, 35, 36
	T 16 S, R 22 E, secs. 1 to 36
	T 16 S, R 23 E, secs. 5 to 8, 13 to 36
	T 16 S, R 24 E, secs. 1 to 4, 9 to 22, 27 to 34
	T 17 S, R 21 E, secs. 1, 2, 11 to 14, 23 to 26, 35, 36
	T 17 S, R 22 E, secs. 1 to 36
	T 17 S, R 23 E, secs. 1 to 36
	T 17 S, R 24 E, secs. 3 to 10, 15 to 22, 28 to 33
	T 18 S, R 21 E, secs. 1, 2, 11 to 14, 23 to 26, 35, 36
	T 18 S, R 22 E, secs. 1 to 36
	T 18 S, R 23 E, secs. 2 to 9, 16 to 21, 28 to 33
	T 19 S, R 21 E, secs. 1, 2
	T 19 S, R 22 E, secs. 1 to 8, 11 to 14
	T 19 S, R 23 E, secs. 4 to 8, 17, 18
Stillwell[3]	T 15 S, R 24 E, sec. 24
	T 15 S, R 25 E, secs. 19, 20

[1] Also in Linn county (see table 59)

[2] Also in Franklin county (see table 38); includes fields formerly knows as Wellsville, Stanton, Paola, Big Lake, Osawatomie, Rantoul North, and Rantoul South.

[3] Also in Johnson county, T. 14 S., R. 24 E., secs. 25, 36; T. 12 S., R. 25 E., secs. 10, 11, 14, 15, 21 to 23, 26 to 31; T. 15 S., R. 24 E., secs. 1 to 3, 10 to 11; and T. 15 S., R. 25 E., secs. 2 to 11, 15 to 18.

500 feet in the eastern part to about 750 feet in the western part of the area. The thickness of the "Squirrel sand" ranges from a few feet to about 50 feet.

The **Paola** oil-producing area includes pools that lie north, south, and southwest of Paola from secs. 33 and 34, T. 16 S., R. 23 E., or scattered pools farther north and east, to secs. 29 and 30, T. 17 S., R. 23 E. Wells in sec. 13, T. 17 S., R. 23 E., however, loosely connect this area with the Pressonville shoestring area, and other wells east of the north end of the designated area loosely connect the Paola area with the area of the Big Lake pool in T. 16 S., R. 24 E. Oil production in this part of the county is chiefly from the "Wayside sand" (in the Nowata shale), but some production seemingly is from the Hepler sandstone. Disconformable relations at the base of the Hepler cause it to be in contact with various upper Marmaton rocks. The Lenapah limestone is thin and locally absent, and it is difficult to differentiate the Hepler and "Wayside sand" in many logs. Some oil and frequent oil shows have been reported in the Knobtown sandstone in the area. Gas is produced in the Paola area from the Hepler sandstone, "Wayside sand," sandstone in the Bandera shale, "Peru sand," black shale in the upper few feet of the Cherokee shale, and "Bartlesville sand." Gas production is not as completely confined to definite areas as is oil production, and there is almost an unbroken gas field extending from Paola northwestward about 14 miles, eastward about 10 miles, southeastward, southward, and westward to the county boundaries and beyond.

The N. Y. K. Oil Company started a water-flooding project in the SW¼ sec. 4, T. 17 S., R. 23 E. in the northern part of the Paola area in July, 1941. Repressuring by air had preceded water flooding and it is reported that oil production had decreased to 6 barrels per day at the time water drive was initiated. The first increase in production took place 4 months after water was first injected and during 16 months 13,665 barrels of oil was recovered. The top of the producing sandstone is 300 feet below the surface. Another water-flooding project in the Paola area is the Wallace Oil Company project which was started in the SE¼ sec. 29, T. 17 S., R. 23 E. in October, 1941. Oil production from the lease had declined to 1½ barrels per day. By November 1, 1942, 3,754 barrels of oil had been recovered as the result of injecting 21,039 barrels of water.

In Miami county the **Stanton** oil area extends southeastward from secs. 25 and 26, T. 17 S., R. 21 E. to sec. 8, T. 18 S., R. 22 E. The area extends westward into Franklin county. Scattered wells in all directions cause exact delineation of the pool boundary to be uncertain. Production is chiefly from the Hepler sandstone or possibly from both the Hepler sandstone and the "Wayside sand" of the Nowata shale. The producing sand has a thickness of about 15 feet and occurs between 350 and 450 feet below the surface. The "Squirrel sand" also is productive in a part of the area, and gas is produced from several zones.

In July, 1940, F. W. Black began water-flooding operations in sec. 25, T. 17 S., R. 21 E. In 30 months 14,646 barrels of oil was produced from 10 wells and 223,900 barrels of water was injected. The Bernice C. Yount water-flooding project is in sec. 26, T. 17 S., R. 21 E. The "Squirrel sand" is being flooded; it lies at depths ranging from 410 to 430 feet and is about 20 feet thick. Water injection was begun in November, 1939, and an increase of oil production was noted in March, 1940. It is reported that in 36 months 42,063 barrels of oil was recovered as the result of injecting 216,530 barrels of water.

The N. Y. K. Oil Company started a water-flooding project in sec. 36, T. 17 S., R. 21 E. on the McKoon lease in April, 1941. The project was later acquired by the Bradford Producing Company. About 5 barrels of oil was being produced daily when water injection began. During the first 19 months of operation 26,460 barrels of oil was recovered from 12 wells and 175,906 barrels of water was injected. The first notable increase in rate of oil production took place 5 months after water injection began. Repressuring by air had been used for a time preceding water flooding. The Vossler and Ellison water-flooding project was begun in sec. 36, T. 17 S., R 21 E. in March, 1938, and now includes 80 acres. By November 1, 1942, 18 wells were producing oil, and water was being injected through 18 wells. In 36 months 39,985 barrels of oil was recovered as the result of injecting 322,182 barrels of water.

Oil production in the **Osawatomie** area is chiefly in secs. 22, 23, 26, 27, and 34, T. 18 S., R. 22 E. Production is principally from the "Wayside sand." The Seaborn Oil Company began water-flooding operations in secs. 22 and 27, T. 18 S., R. 22 E. in September, 1940. The producing sand lies about 330 feet below the surface. During

the first 20 months of operation, 5,589 barrels of oil was recovered as a result of injecting 84,270 barrels of water.

Oil has been or is being produced in several smaller and more isolated areas in Miami county. North of Louisburg in secs. 29 and 30, T. 16 S., R. 25 E., oil was found in sandstone in the Bourbon shale. Another oil-producing area is in secs. 11, 12, and 13, T. 17 S., R. 24 E. and in secs. 7, 8, 9, 17, 18, and 19, T. 17 S., R. 25 E. F. J. Buist began a water-flooding project in sec. 11, T. 17 S., R. 24 E. in November, 1941. The first important increase in rate of oil production was in March, 1942, and in 13 months 1,161 barrels of oil was recovered from six wells. During that period, 10,772 barrels of water was injected. The formation flooded is the "Peru sand."

The **Starry** lease is in secs. 16 and 21, T. 17 S., R. 25 E. Oil was found here in the "Wayside sand."

The **Sheridan** and **Black** leases are in sec. 33, T. 18 S., R. 24 E. and secs. 2, 3, 4, 9, and 10, T. 19 S., R. 24 E. The producing rock seems to be the Hepler sandstone which lies at shallow depths. At the present time a shaft is being driven into the productive formation and it is planned to drill holes laterally into the sandstone. A part of the area is being water flooded.

Cumulative production figures for Miami county are not available. An average of 694 producing wells was reported in 1943. Reported monthly oil production in Miami county for 1941, 1942, and 1943 is given in table 68. Yearly gas production statistics for 1939 to 1943 are given in table 69.

TABLE 68.—*Reported monthly production of oil in Miami county, Kansas, in barrels*

Month	1941	1942	1943
January	13,262	16,833	15,421
February	14,447	18,267	18,203
March	14,850	21,363	18,406
April	18,519	21,126	21,160
May	18,181	17,411	18,816
June	15,956	21,392	19,950
July	18,656	22,292	20,337
August	17,444	20,881	19,322
September	16,700	19,968	17,920
October	15,229	20,333	17,106
November	18,024	19,108	18,366
December	17,917	16,428	13,897
Totals	199,185	235,402	218,898

TABLE 69.—*Natural gas production in Miami county, Kansas*

Year	Thousands of cubic feet
1939	1,027,123
1940	919,607
1941	949,272
1942	812,749
1943	645,110

MONTGOMERY COUNTY

Gas was discovered in Montgomery county in 1881 and oil was discovered in 1903 in the Bolton pool. The geology and oil and gas resources of Montgomery county were described by Moore and Boughton (1921) and by Abernathy (1940).

SURFACE ROCKS

Pennsylvanian rocks including those of the Douglas, Pedee, Lansing, Kansas City, and Bronson groups, the Bourbon shale, and the Marmaton group (figs. 7, 8) crop out in Montgomery county. Beds in the lower part of the Douglas group are exposed in the western and northwestern parts of the county. The oldest exposed rock in the county is the Altamont limestone of the Marmaton group, which crops out in the southeastern corner.

The Tonganoxie sandstone is the cap rock of prominent hills in the area of Douglas outcrops, and the Weston shale in the Pedee group underlies a broad area south of Elk river in the western part of Montgomery county. The outcrop belt of these rocks north of the river is much narrower. Most of the limestones in the Lansing, Kansas City, and Bronson groups are thin and inconspicuous in this part of the state and several of them pinch out before reaching the Kansas-Oklahoma line. Marmaton limestones, however, are thicker than farther north.

Because of lateral changes in rocks of the Missourian series it is convenient to apply the classification commonly applied to equivalent rocks in northeastern Oklahoma to these rocks south of T. 33 S. In this classification the Ochelata group includes rocks between the base of the disconformity at the base of the Tonganoxie sandstone (Virgilian-Missourian boundary) and the disconformity at the base of the Noxie sandstone. The Ochelata group is about 200 feet thick in Montgomery county. It consists chiefly of shale and sandstone. These rocks crop out in the county

in the west-central and north-central parts. The Skiatook group includes rocks between the disconformity below the Noxie sandstone and the disconformity at the base of the Missourian series, which is overlain by the Hepler (Seminole) sandstone. These rocks are slightly more than 200 feet thick in Montgomery county. The Drum limestone (Kansas City group) is 50 feet or more thick in the vicinity of Independence, but it is not present in the southern part of the county where it is seemingly cut out by the disconformity below the Ochelata rocks. The Dennis (Hogshooter) limestone is persistent across the county. The Swope limestone pinches out in the vicinity of Liberty, or is present southward as a thin zone of limy shale. The Hertha limestone also pinches out before reaching the state line. The Checkerboard limestone, in the lower part of the Skiatook group, crops out in Coffeyville and vicinity. Upper Marmaton rocks are exposed in the southeastern part of Montgomery county. The oldest exposed rock is the Altamont limestone or a few feet of the Bandera shale.

Subsurface Rocks

Subsurface geologic conditions in the northern part of Montgomery county are shown in plate 4.

Pennsylvanian rocks.—The average total thickness of Marmaton rocks in Montgomery county is about 390 feet. A bed of sandstone 20 to 50 feet thick, known as the "Weiser sand," occurs locally in the upper part of the Bandera shale. The thickness of the Bandera ranges from about 60 to 150 feet. The Pawnee limestone ranges in thickness from about 22 to 50 feet. It is chiefly dense, hard, light-gray, fossiliferous limestone, locally consisting of two beds of limestone separated by a few feet of black shale. It is locally designated by drillers as the "Pink lime" or "40-foot limestone." The thickness of the Labette shale ranges from about 40 to 100 feet, and the average is about 70 feet. There is a thin bed of coal in the upper part of the Labette shale in southeastern Montgomery county, and a bed of sandstone, called the "Peru sand," occurs locally. The total thickness of the Fort Scott limestone (including the Breezy Hill? limestone) ranges from about 75 to 100 feet in the county. Three limestone members (locally four or five) are included. The upper limestone, which is very hard and dense, is called "Oswego," "Brown lime," or "First lime" by some drillers and operators. The middle and lower limestones, called

the "Second lime" and "Third lime," commonly are not as hard as the upper limestone and are impure in most places. The black shale beds separating the limestones range in thickness from 2 to 20 feet.

The Cherokee shale in Montgomery county ranges in thickness from about 304 to 495 feet. It consists of gray and black shale, a few lenses of sandstone, several thin beds of coal, and a few thin beds of limestone. A sandstone in the upper part of the Cherokee is known as the "Squirrel sand." The Ardmore limestone is massive, fossiliferous, and dark gray, and ranges from 3 to 5 feet in thickness. It is persistent and commonly lies about 30 to 70 feet below the Fort Scott limestone. A similar bed about 40 feet below the Ardmore occurs locally. Sandstone lenses about 140 to 200 feet above the base of the Cherokee are called "Bartlesville sand." Some of these sandstone bodies are more than 100 feet thick. A conglomerate composed principally of chert and smaller amounts of limestone and pyrite occurs in the basal part of the Cherokee. In some places the "Burgess sand" directly overlies the conglomerate. Black shale, 40 to 90 feet in thickness, commonly lies on the "Burgess sand" in Montgomery county. If the sandstone and conglomerate are not present, the black shale lies on the Mississippian limestone.

Mississippian rocks.—The Mississippian rocks in Montgomery county have an average thickness of about 300 feet. Anticlines are generally marked by thin sections of Mississippian rocks (Lee, 1939, p. 12, pl. 1). The minimum thickness recorded is about 225 feet. The upper part of the Mississippian rocks was weathered and made porous before deposition of the overlying Pennsylvanian rocks, and most of the oil produced from Mississippian rocks is from this porous zone. The Mississippian rocks include the Warsaw limestone, Cowley formation, Keokuk limestone, Burlington limestone, Reeds Spring limestone, St. Joe limestone, Northview shale, and Compton limestone. The Chattanooga shale, which is black or gray and fissile, has an average thickness of about 40 feet in Montgomery county. It lies on Ordovician rocks.

Ordovician rocks.—Ordovician rocks in Montgomery county include the Cotter and Jefferson City dolomites, the Roubidoux formation, and the undifferentiated Gasconade dolomite and Van Buren formation. The total thickness of these rocks in the county is about 725 feet.

Cambrian rocks.—The Cambrian rocks in Montgomery county are the Eminence and Bonneterre dolomites and the Lamotte sandstone. The total thickness of Cambrian rocks in the county is about 350 feet.

Pre-Cambrian rocks.—Well logs indicate that red granite 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 No. 1 Beal well in sec. 12, T. 33 S., R. 14 E.

Oil and Gas Developments

Montgomery was one of the first counties in Kansas to produce large quantities of oil and gas. Gas was found in small quantities at several places in the county as early as 1881. Larger supplies of gas were found near Cherryvale in 1889 and near Coffeyville about a year later. Gas was piped to Coffeyville in 1892; that city was one of the first towns in southeastern Kansas to use natural gas. The largest gas field in the county, the Independence field, reached its peak of production in 1904. At that time it had an open-flow capacity exceeding 700,000,000 cubic feet. Gas wells having initial daily productions of 10,000,000 to 20,000,000 cubic feet were common; the largest well was reported to have had an initial production of 93,000,000 cubic feet per day. During the early history of the gas industry, gas was produced from well-defined areas, such as the Elk City, Independence, Jefferson, Cherryvale, and Coffeyville areas. At the present time gas is produced from widely distributed wells in the county, and development has been so widespread that any one field is almost continuous with other fields. Gas is produced chiefly from the "Bartlesville sand"; the lowest gas-producing rock is the Arbuckle limestone.

Oil was first produced in Montgomery county in 1903, the year in which the Bolton pool southwest of Independence was discovered. Initial productions of wells in that pool ranged from 10 to 1,000 barrels per day. Subsequently oil pools were found in nearly all parts of the county. Oil production in Montgomery county reached its peak in 1925 when 1,136,654 barrels were produced. Water flooding of partly depleted oil-bearing formations was practiced in the county as early as 1920, and modern systematic water flooding started in 1939.

Oil and gas are produced in Montgomery county from the Lane-Vilas shales, the Bandera shale, the Labette shale, the Fort

Scott limestone, the Cherokee shale, the Mississippian limestone, and the Arbuckle limestone.

Gas is produced in the northwestern part of the county from at least three sandstones in the Lane-Vilas shale. The upper sandstone is locally called "Bush-Denton" or "Ferguson"; the middle sandstone is called "Longton," "Webb," or "Heck"; and the lower sandstone is called "Encill." Oil is produced from the "Wayside sand" in the Nowata shale; this sandstone ranges in thickness from 10 to 30 feet. A sandstone in the Bandera shale, known as the "Weiser sand," yields oil and gas; it ranges in thickness from 20 to 60 feet. Of 303 wells in Montgomery county that have been drilled into the Bandera or higher formations, 170 were oil wells, 70 were gas wells, and 63 were dry holes.

There are three important oil and gas producing zones in the Cherokee shale in Montgomery county. The "Squirrel sand," which occurs locally in the upper part of the Cherokee shale, yields small amounts of gas and some oil. It is separated from the Fort Scott limestone by 10 to 80 feet of shale. The "Bartlesville sand," which occurs as lenses 10 to 100 feet in thickness and 40 to 100 feet above the base of the Cherokee, yields both oil and gas. The "Burgess sand," at or near the base of the Cherokee shale, yields much gas.

Gas occurs in the upper part of the Mississippian rocks both in porous limestone and in beds of fragmental chert, called "chat." The "chat" is restricted in its distribution to the flanks of "Mississippi lime" hills.

Seven oil pools and one gas pool have been discovered in Arbuckle rocks of Ordovician age in Montgomery county. The oil occurs in a siliceous limestone zone in the upper part of the Arbuckle. The Arbuckle pools are in small but well-defined anticlinal folds. Arbuckle rocks have been penetrated in 221 wells in Montgomery county. Commercial quantities of oil have been produced from 86 of these wells and gas has been produced from 6 of them.

A list of the oil and gas fields in Montgomery county as designated by the Oil Field Nomenclature Committee of the Kansas Geological Society is given in table 70.

The **Bolton** pool, discovered in 1903, was the first oil pool 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 was en-

countered at a depth of 1,180 feet in the "Bartlesville sand." The initial production of this well was about 40 barrels per day (Haworth, 1908, p. 37). Initial productions of many wells in the pool have exceeded 1,000 barrels. This pool is in secs. 4 to 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 produced. The "Bartlesville sand" in this pool ranges in thickness from 10 to 30 feet and occurs at a depth of 1,150 to 1,200 feet, about 200 feet below the Fort Scott limestone.

TABLE 70.—*Oil and gas fields in Montgomery county, Kansas*
(As designated by the Oil Field Nomenclature Committee of the Kansas Geological Society, November 15, 1944)

Name	Location
Brewster	T 32 S, R 16 E, secs. 16, 17, 20 to 22, 27 to 29, 32 to 36
	T 33 S, R 16 E, secs. 2 to 5, 9, 10
Caney	T 34 S, R 14 E, secs. 27, 32 to 34
	T 35 S, R 14 E, secs. 3 to 5, 7 to 10, 15 to 18
Caney West[1]	T 35 S, R 13 E, secs. 11, 14
Coffeyville-Cherryvale[2]	T 31 S, R 16 E, secs. 23 to 26, 35, 36
	T 31 S, R 17 E, secs. 3 to 10, 15 to 22, 27 to 34
	T 32 S, R 16 E, secs. 1, 2, 11 to 13, 24, 25, 36
	T 32 S, R 17 E, secs. 3 to 10, 15 to 22, 27 to 34
	T 33 S, R 16 E, secs. 1, 11 to 13, 23 to 26, 35, 36
	T 33 S, R 17 E, secs. 3 to 10, 15 to 22, 27 to 34
	T 34 S, R 16 E, secs. 1, 12, 13, 23 to 28, 33 to 36
	T 34 S, R 17 E, secs. 3 to 10, 15 to 22, 27 to 34
	T 35 S, R 16 E, secs. 1, 2, 11 to 14
	T 35 S, R 17 E, secs. 3 to 10, 15 to 18
Coleman	T 32 S, R 14 E, secs. 28, 32, 33
	T 33 S, R 14 E, sec. 5
Elk City[2]	T 31 S, R 13 E, secs. 13, 14, 23 to 26, 35, 36
	T 31 S, R 14 E, secs. 30, 31
Jefferson-Sycamore[1]	T 31 S, R 15 E, secs. 11, 14, 21 to 28, 31 to 36
	T 31 S, R 16 E, secs. 27 to 34
	T 32 S, R 14 E, secs. 13, 23 to 25, 35, 36
	T 32 S, R 15 E, secs. 1 to 5, 7 to 36
	T 32 S, R 16 E, secs. 4 to 6
	T 33 S, R 14 E, secs. 1 to 3, 10 to 14, 23 to 26
	T 33 S, R 15 E, secs. 1 to 36
	T 33 S, R 16 E, secs. 19, 28 to 32
	T 34 S, R 15 E, secs. 1 to 5, 8 to 17, 21 to 26, 36
	T 34 S, R 16 E, secs. 5 to 10, 15 to 22, 28 to 33
	T 35 S, R 15 E, secs. 1, 12, 13
	T 35 S, R 16 E, secs. 5 to 8, 17, 18

Neodesha[5]	T 31 S, R 15 E, sec. 1
	T 31 S, R 16 E, secs. 1 to 18, 23, 24
	T 31 S, R 17 E, secs. 7, 18, 19
Sorghum Hollow	T 32 S, R 13 E, secs. 24, 25, 35, 36
	T 32 S, R 14 E, secs. 16 to 21, 29 to 31
	T 33 S, R 13 E, secs. 1, 2
Tyro	T 34 S, R 15 E, secs. 19, 20, 28 to 34
	T 35 S, R 14 E, secs. 1, 12, 13
	T 35 S, R 15 E, secs. 3 to 11, 15 to 18
Wayside-Havana[1]	T 33 S, R 13 E, secs. 25, 35, 36
	T 33 S, R 14 E, secs. 16 to 22, 26 to 36
	T 34 S, R 13 E, secs. 1, 2, 11 to 14, 23
	T 34 S, R 14 E, secs. 1 to 18, 21 to 24
	T 34 S, R 15 E, secs. 17 to 19

[1] Also in Chautauqua county (see table 20)
[2] Also in Wilson and Labette counties (see tables 52 and 86)
[3] Also in Elk county (see table 35); formerly called Coffeyville, Cherryvale, Uncle Sam, and Fors
[4] Includes fields formerly called Larimer-Sycamore, Bolton, and Jefferson.
[5] Also in Wilson county (see table 86)

The **Wayside-Havana** oil-producing area is in the southwestern part of Montgomery county in secs. 27, 28, 32, 33, and 34, T. 33 S., R. 14 E. and secs. 3 to 10, T. 34 S., R. 14 E. Oil was discovered in this area in 1904 and more than 500 wells have produced oil. A small amount of oil is still produced. The oil is high grade; it has a paraffin base and the specific gravity is 36 to 38° A. P. I. (Moore and Boughton, 1921, p. 25). The "Wayside sand" in the Nowata shale, which occurs at an average depth of about 575 feet, is the uppermost productive rock in this area. The "Weiser sand," about 120 feet below the "Wayside," also yields oil. The third producing zone is the "Bartlesville sand" which lies at an average depth of about 1,200 feet and ranges from about 15 to 50 feet in thickness.

There are now five water-flooding projects in operation in the Wayside-Havana area (Grandone, 1944, pp. 114-125). The Alpine Oil and Gas Company has a project in sec. 7, T. 34 S., R. 14 E. The oil-producing formation being flooded is the "Wayside sand" which has an average thickness of about 18 feet and is about 690 feet below the surface. Water flooding was started in November, 1941; the first increase in oil production was in March, 1942. The cumulative oil production to November 1, 1942, was 310 barrels per acre. The Consolidated Gas, Oil, and Manufacturing Company is water flooding in sec. 10, T. 34 S., R. 14 E. The formation being flooded is the "Wayside sand," which has an average thickness of about

26 feet and lies at a depth of about 637 feet. Water flooding was started in May, 1942, and the first important increase in the rate of oil production was in September, 1942. To November 1, 1942, 673 barrels of oil were recovered as a result of injecting 20,261 barrels of water.

The Forest Producing Corporation has a water-flooding project in sec. 5, T. 34 S., R. 14 E. The "Wayside sand," which has an average thickness of 33 feet and lies at a depth of about 675 feet, is being flooded. Water injection was first started in December, 1939, and the first increase in rate of oil production was in April, 1941. Over a period of 35 months 1,299 barrels of oil per acre were recovered for an injection of 14.4 barrels of water per barrel of oil produced.

The Greysolon Oil Company has a water-flooding project in secs. 15, 16, 21, and 22, T. 34 S., R. 15 E. The "Wayside sand," which has an average thickness of about 20 feet and lies at a depth of about 450 feet, is the oil-producing formation. The first water was injected into the sandstone in July, 1940, and the first increase in the rate of oil production was in October, 1940. To November 1, 1942, 79,458 barrels of oil were recovered as a result of injecting 881,243 barrels of water.

Bert L. Horton has a water-flooding project in sec. 16, T. 34 S., R. 14 E. The producing formation, the "Wayside sand," lies about 660 feet below the surface and has an average thickness of about 25 feet. Water flooding was started in November, 1940, and the first increase in rate of oil production was noted in December, 1940. During the first 24 months of water flooding, the operator recovered 533 barrels of oil per acre for an injection of 12.1 barrels of water per barrel of oil produced.

The **Tyro** pool, discovered in 1904, is southeast of Tyro in secs. 3 to 9 and 15, T. 35 S., R. 15 E. It yields oil and gas from the "Bartlesville sand" which ranges in thickness from 20 to 60 feet and has an average depth of 1,250 feet.

The **Coffeyville** oil and gas-producing area is 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 one of the oldest producing areas in the state and small quantities of both oil and gas are still produced. There are three producing zones: the "Wayside sand" at a depth of about 400 feet; the Fort Scott limestone at a depth of about 600 feet; and the "Bartlesville sand" at a depth of about 1,000 feet.

The **Larimer-Sycamore** oil and gas field, in secs. 5, 8, 9, 16, 21, 22, 27, 31, 32, 33, and 34, T. 31 S., R. 17 E., was opened in 1904. The chief producing zone is the "Bartlesville sand" at a depth of about 800 feet. The field is now practically exhausted.

A small amount of oil is produced in the **Coleman** pool in secs. 28 and 33, T. 32 S., R. 14 E. The discovery well in this pool was the Red Bank Oil Company No. 1 Coleman, completed on July 1, 1921. The initial production of this well 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 **Thompson** pool is 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 0°F. cold test; its gravity is about 28° Bé. A small amount of oil is still produced in this pool.

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

The **Bellairs** pool is in secs. 3 and 4, T. 33 S., R. 17 E. The discovery well, the Bellairs No. 1, was drilled in 1921. Production is from the Arbuckle limestone at a depth of about 1,250 to 1,300 feet. Twenty-five wells have been drilled in this pool, and during the early life of the pool some of the wells flowed initially 220 barrels per day. Seven wells are now producing oil. The pool was extended one-half mile east in 1942. Five producing wells and one dry hole were drilled in the east extension in 1943. The oil has small gasoline content and a -10°F. cold test. The specific gravity is about 24° Bé. The oil is sold as Diesel fuel.

Monthly production of oil in Montgomery county is shown in table 71. Gas production statistics for the years 1939 to 1943 are given in table 72.

MORRIS COUNTY

Oil is produced in two small fields in the southeastern part of Morris county a few miles east of the Lost Springs field in Marion county. Gas discoveries have been more widespread. Oil production is from the "chat," fragmentary flint deposits derived by ero-

TABLE 71.—*Reported monthly production of oil in Montgomery county, Kansas, in barrels*

Month	1941	1942	1943
January	23,191	23,952	28,310
February	20,361	28,350	30,384
March	25,695	36,015	32,875
April	25,452	34,278	31,595
May	26,934	32,271	29,698
June	25,857	34,443	30,525
July	28,083	34,577	33,343
August	25,833	32,535	30,832
September	26,096	32,562	31,764
October	27,123	27,260	30,411
November	27,380	30,014	31,386
December	29,518	31,119	26,209
Totals	311,523	377,376	367,332

TABLE 72.—*Natural gas production in Montgomery county, Kansas*

Year	Thousands of cubic feet
1939	1,548,394
1940	1,538,373
1941	1,496,140
1942	1,803,633
1943	3,422,417

sion from the Mississippian limestones. Like other basal detrital deposits, the "chat" is of different ages in various places. Gas production is from the Indian Cave sandstone and other zones in lower Permian rocks and the Willard shale, the Lawrence shale, and the Lansing group in the Pennsylvanian. Depths to gas production range from about 450 to 1,450 feet.

SURFACE ROCKS

The outcropping bedrocks in Morris county are of Permian age. Approximately the lower 100 feet of the Sumner group (Leonardian), the Chase group (Wolfcampian), and nearly all of the Council Grove group are exposed. The total thickness of exposed Permian rocks is about 700 feet. Alluvium in the valleys of recent streams and upland gravel deposits are similar to surficial deposits in other eastern Kansas counties.

A thickness of 100 feet or more of the Wellington shale in the Sumner group is present at the surface in the western part of Morris county. The Chase formations (fig. 6) occupy an outcrop

belt about 20 miles wide. This group is characterized by massive limestones, several of which are flinty, and by highly colored shales; it is about 350 feet thick in Morris county. Included in these rocks are several excellent key horizons for structural mapping. The Florence limestone lies below the most extensive dip slope in the area. The upper surface of the Florence, however, should be used as a datum plane only in places where it is protected by overlying shale beds. Council Grove rocks crop out along Neosho river in the southeastern part of the county. The lowest well-exposed unit is the Grenola limestone (which includes the Neva limestone member).

Subsurface Rocks

Subsurface geologic conditions in the central part of Morris county are shown diagrammatically in plate 2. The Nemaha anticline extends through the county. In the buried Nemaha fault scarp, rocks as old as the Arbuckle limestone are believed to be in contact with basal Pennsylvanian deposits.

Permian and Pennsylvanian rocks.—The average thickness of Permian and Pennsylvanian rocks in Morris county is about 2,000 feet. The Shawnee group includes much more limestone than shale, and the Lansing and Kansas City groups are chiefly limestone. Higher rocks and those of the Douglas group are similar to equivalent strata farther east in the state.

Mississippian rocks.—On the eastern side of the Nemaha anticline in Morris county the total thickness of Mississippian limestone formations ranges from a featheredge to approximately 350 feet, and on the western side to slightly more than 150 feet. These rocks are absent from a large area (Lee, 1939, pl. 1). The thickness of the Chattanooga shale in the county ranges from a featheredge to about 150 feet (Lee, 1940, pl. 3).

Pre-Chattanooga rocks.—The "Hunton" limestone is believed to have been eroded from a large part of Morris county in the area of the Nemaha anticline. The maximum thickness is probably not more than 200 feet. The Maquoketa shale is believed to be present in the county on both sides of the Nemaha fault; its maximum thickness is probably less than 100 feet. The Viola limestone has a maximum thickness of probably not more than 200 feet. The thickness of the St. Peter sandstone ranges from a featheredge to about 50 feet or more. The greatest thickness of Arbuckle rocks

in the county is believed to be about 400 feet. In the Alta Vista Oil Company No. 1 Helen Taylor well, in the NE¼ SW¼ sec. 5, T. 14 S., R. 8 E., pre-Cambrian granite was reached at 2,480 feet.

Oil and Gas Developments

Oil and gas producing areas in Morris county are shown in figure 19. Oil production is confined to the southwestern part of the county. This area may be regarded as a part of the **Lost Springs** area which is chiefly in Marion county. Oil production is from the Mississippian "chat."

The **Alta Vista** gas producing area is in secs. 3 and 10, T. 14 S., R. 8 E. Gas is produced from several zones in lower Permian rocks at a depth of about 500 feet.

The **Diamond Springs** gas producing area is in secs. 11 to 14, T. 17 S., R. 6 E. The **Wilde** gas producing area is in secs. 14, 15, 21, 22, and 27, T. 17 S., R. 7 E. Gas was discovered in this area in 1929. Producing zones include the Willard shale at about 600 feet, the

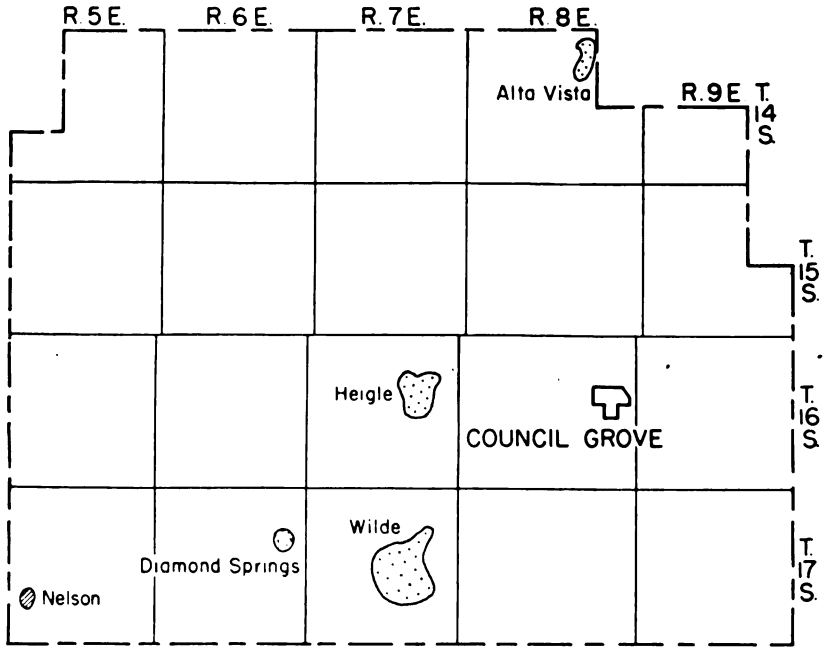

Fig. 19. Map of Morris county showing oil and gas producing areas. (Gas, dots; oil, diagonal lines.)

Lawrence shale at about 1,200 feet, and Lansing rocks at about 1,400 feet.

Gas was discovered in the **Wilsey** (Heigle) area in 1927. This area is in secs. 10, 11, 14, 15, and 22, T. 16 S., R. 7 E. Production is chiefly from rocks in the upper part of the Lansing group, but some production is from basal Permian rocks. The shallower production comes from a depth of about 450 feet, and the deeper production from about 1,450 feet.

Morris county oil production is included with that of Marion county in table 63. Yearly gas production statistics for 1939 to 1943 are given in table 73.

TABLE 73.—*Natural gas production in Morris county, Kansas*

Year	Thousands of cubic feet
1939	177,157
1940	231,510
1941	226,767
1942	193,718
1943	149,485

NEMAHA COUNTY

Neither oil nor gas in commercial amounts has been discovered in Nemaha county. A few test wells have been drilled.

SURFACE ROCKS

Exposed consolidated rocks in Nemaha county are of Permian and Pennsylvanian ages. The oldest outcropping formation is the Topeka limestone, and the youngest consolidated formation is the Wreford limestone. In Nemaha and neighboring counties the Nemaha anticline and the syncline that borders it on the east have brought about structural conditions that are unique in Kansas. In the western part of the county is a band of exposed Pennsylvanian rocks bordered both on the east and the west by Permian beds.

The Wreford limestone underlies an area in the eastern part of T. 1 S., R. 13 E. and the western two-thirds of T. 1 S., R. 14 E. The Topeka limestone is exposed along Nemaha creek in sec. 2, T. 1 S., R. 12 E. Glacial drift occurs in comparatively thick deposits in all parts of Nemaha county and the country rock is concealed in many places.

Subsurface Rocks

Subsurface geologic conditions along the southern border of Nemaha county are shown diagrammatically in plate. 1. Pre-Cambrian rocks are nearer the land surface in Nemaha county than elsewhere in Kansas. Crystalline rocks are about 600 feet deep in the highest part of the buried granite ridge of the Nemaha anticline. About 3,500 feet of sedimentary rocks overlie the pre-Cambrian floor east of the buried fault escarpment of the anticline.

Permian and Pennsylvanian rocks.—The maximum thickness of Permian and Pennsylvanian rocks in Nemaha county is about 2,000 feet. About 600 feet of Pennsylvanian rocks is present over the crest of the buried crystalline core of the anticline.

Mississippian rocks.—Mississippian rocks are absent in Nemaha county in the area west of the buried fault escarpment of the Nemaha anticline, but the Mississippian limestone formations have a total thickness of about 150 feet in the southeastern part of the county. Undifferentiated Burlington-Keokuk limestone is believed to be the uppermost Mississippian limestone in the county. It is probably underlain by the Gilmore City and Chouteau formations.

Pre-Chattanooga rocks.—According to Lee (1943, fig. 12), the thickness of rocks between the base of the Chattanooga shale and the top of the Maquoketa shale in Nemaha county ranges from a featheredge to about 650 feet. The interval between the top of the Maquoketa shale and the top of the St. Peter sandstone ranges from a featheredge to about 400 feet (Lee, 1943, fig. 11). The maximum thickness of the rocks from the top of the St. Peter sandstone to the pre-Cambrian floor is about 200 feet (Lee, 1943, fig. 9).

Oil and Gas Exploration

Several test wells have been drilled in Nemaha county. Data on 12 wells in the county are given in table 74.

NEOSHO COUNTY

Oil and gas have been produced in Neosho county for many years. The first active prospecting in the county was in the vicinity of Humboldt in 1894 when both oil and gas were discovered. The geology and oil and gas resources of Neosho county have been described by Moore and Elledge (1920).

TABLE 74.—*Data on wells in Nemaha county, Kansas*

Name of well	Location	Remarks	Total depth, in feet
Partman and McKenna No. 1 Sudbeck	SW¼ NW¼ NW¼ NW¼ sec. 20, T. 1 S., R. 12 E.		490?
Rock Island R.R. Co. ———	Sec. 25, T. 1 S., R. 12 E.	Stopped in Douglas-Pedee rocks	550
——— No. 1 Whittmer	Sec. 20, T. 1 S., R. 13 E.	Pre-Cambrian rocks at 1,295 (?) feet	1,880
Clifton Galle and Towle No. 1 Mills	Cen. SE¼ NE¼ sec. 24, T. 1 S., R. 14 E.	Stopped in "Hunton" limestone	2,946
——— No. 1 Williams	SE cor. SE¼ sec. 27, T. 2 S., R. 12 E.		1,100
——— No. 1 Seneca	SW¼ NE¼ NE¼ sec. 33, T. 2 S., R. 12 E.		746?
——— Seneca	NE¼ SW¼ NW¼ sec. 34, T. 2 S., R. 12 E.	Pre-Cambrian at 575 feet	732
Shelly No. 1 Sabetha	SW¼ NE¼ SW¼ SW¼ sec. 1, T. 2 S., R. 14 E.	Drilled in 1876	521
Nemaha Oil & Gas Co. No. 1 Seneca	NW cor. NW¼ sec. 19, T. 3 S., R. 11 E.		3,256
——— No. 1 Noll	SE¼ SE¼ NE¼ sec. 23, T. 3 S., R. 12 E.	Very poor log; pre-Cambrian at 1,510 (?) feet	2,190
McAlphine et al. No. 1 Tylor	NE¼ SW¼ SW¼ sec. 4, T. 3 S., R. 15 E.		1,250
Ladd et al. No. 1 Achlen	Cen. S½ SE¼ NW¼ sec. 12, T. 4 S., R. 14 E.	Stopped in "Hunton" limestone	3,130

SURFACE ROCKS

The surface rocks of Neosho county consist of alternating beds of limestone and shale and locally some beds of sandstone. With the exception of sand and gravel deposits of Recent age, the exposed rocks of Neosho county belong to the Kansas City and Bronson groups, the Bourbon shale, and the Marmaton group of Pennsylvanian age.

Rocks of the Kansas City group (fig. 8) crop out in the western part of Neosho county. The Lane-Bonner Springs shale is the

youngest consolidated rock and is exposed in the area west and north of Chanute. The lower part of the Kansas City group and the upper part of the Bronson section are modified by a local disconformity in the area east of Chanute. Sandstone in the Chanute shale, which lies next above the disconformity, rests on strata ranging in age from the Drum limestone to the basal part of the Dennis limestone. The Bronson rocks consist of thick beds of limestone separated by thin beds of shale. Where the entire Bronson section is present, its thickness is about 150 feet. The Bourbon shale in Neosho county is about 100 feet thick and consists chiefly of shale. It contains a persistent sandstone a few feet thick in the basal part and a few thin beds of limestone. Rocks of the Marmaton group (fig. 8), which are the oldest exposed Pennsylvanian rocks in the county, crop out in the southeastern part and are about 250 feet thick.

Subsurface Rocks

Pennsylvanian rocks.—The Cherokee shale is about 420 feet thick in Neosho county. It consists of light and dark shale, sandstone lenses, and thin beds of limestone and coal. Sandstone lenses about 50 feet below the top of the Cherokee shale are called "Squirrel sand." The Ardmore limestone, an excellent key bed, lies about 80 feet below the top of the Cherokee. The "Bartlesville sand," which occurs about 100 feet below the top of the Cherokee, is the most productive oil sand in the Cherokee shale. The Cherokee lies unconformably upon the eroded surface of Mississippian limestone.

Mississippian rocks.—Mississippian rocks in Neosho county consist dominantly of limestone, some of which is cherty or dolomitic. They have a total thickness of about 300 feet. The formations present in the county are the Warsaw, Keokuk, Burlington, Reeds Spring, and St. Joe limestones, the Northview shale, and the Compton limestone. The Chattanooga shale is less than 50 feet thick (Lee, 1940, pl. 3).

Ordovician and Cambrian rocks.—Very little information pertaining to Ordovician and Cambrian rocks in Neosho county is available. The drillers' log of one deep well in Neosho county, the Arnett No. 1 in sec. 34, T. 30 S., R. 18 E., shows 927 feet of limestone, sandstone, and shale between Mississippian and pre-Cambrian rocks.

Pre-Cambrian rocks.—Pre-Cambrian rocks underlie Neosho county at a depth of about 2,000 feet. The drillers' log of a deep well in the southeastern part of the county records these rocks as granite. Samples of the pre-Cambrian rocks from a deep well west of Chanute are red granite composed of red feldspar, quartz, mica, and hornblende.

Oil and Gas Developments

Gas was first discovered in Neosho county near Humboldt in 1894. Guffey and Galey drilled a number of dry holes in the vicinity of Chanute a short time later. Oil was discovered in the Chanute field in 1899. The greatest development of oil and gas has been in the northwestern part of the county where production is from sands in the Cherokee shale. In the Erie pool, in the east-central part of the county, oil is produced from the "Bartlesville sand" at a depth of about 550 feet. This pool has been extended to the southeast, and recent drilling has extended the shoestring trend to a point northeast of St. Paul. In the Island district, a part of the St. Paul-Walnut area, gas is produced from the "chat" at the top of the Mississippian limestone. Some wells in this area reported a daily open flow of 5,000,000 cubic feet of gas. Oil and gas wells are so widespread in the northeastern part of the county that it is difficult to differentiate the pools.

The oil and gas fields in Neosho county as designated by the Oil Field Nomenclature Committee of the Kansas Geological Society are listed in table 75. The locations of the oil and gas fields are shown in figure 20.

The **Chanute-Iola** area is in all of T. 27 S., Rs. 17 and 18 E.; all of T. 27 S., R. 19 E. except secs. 25, 35, and 36; all of T. 28 S., Rs. 17 and 18 E.; and in sec. 6, T. 28 S., R. 19 E. During the early development of the area, the part east of Chanute was known as the "East Trend" and that north of Chanute was known as the "North Trend." Drilling activity was renewed in 1913, and the area was again redrilled in 1937 for water-flooding projects. Production is from the "Bartlesville sand" which has an average thickness of about 40 feet and lies at a depth of about 700 feet.

Six water-flooding projects are in operation in the Chanute-Iola area (Grandone, 1944, pp. 127-141). Kirby Oil Company has 44 acres flooded in secs. 10 and 15, T. 27 S., R. 18 E. There are 17 producing wells which had a cumulative production of 1,904 barrels of oil per acre from January 1, 1940, to November 1, 1942.

TABLE 75.—*Oil and gas fields in Neosho county, Kansas*

(As designated by the Oil Field Nomenclature Committee of the Kansas Geological Society, November 15, 1944)

Name	Location
Altoona East[1]	T 28 S, R 17 E, secs. 35, 36
	T 29 S, R 17 E, sec. 2
Canville Creek	T 27 S, R 20 E, secs. 20 to 22, 27 to 32
Dennis[2]	T 30 S, R 18 E, secs. 21, 22, 26 to 28, 33, 34
Erie	T 28 S, R 19 E, secs. 4, 9 to 11, 13 to 15, 21 to 28, 33, 34
	T 28 S, R 20 E, secs. 18 to 21, 28 to 36
	T 28 S, R 21 E, sec. 31
	T 29 S, R 20 E, secs. 1, 2
	T 29 S, R 21 E, sec. 6
Galesburg	T 30 S, R 19 E, secs. 5 to 8
Hertha	T 29 S, R 19 E, sec. 36
	T 29 S, R 20 E, secs. 29 to 32
Humboldt-Chanute[3]	T 27 S, R 17 E, secs. 1, 2, 11 to 14, 23 to 26, 35, 36
	T 27 S, R 18 E, secs. 1 to 36
	T 27 S, R 19 E, secs. 1 to 24, 26 to 34
	T 27 S, R 20 E, secs. 3 to 8, 18
	T 28 S, R 17 E, secs. 1, 2, 11 to 14, 23 to 25
	T 28 S, R 18 E, secs. 1 to 24, 29, 30
	T 28 S, R 19 E, secs. 4, 6, 7
Kimball	T 27 S, R 20 E, secs. 24, 25
	T 27 S, R 21 E, secs. 19, 29 to 32
	T 28 S, R 21 E, secs. 3 to 10
Ladore	T 30 S, R 19 E, secs. 32 to 34
Ladore North	T 30 S, R 19 E, secs. 19, 20, 29, 30
Morehead	T 30 S, R 18 E, sec. 30
St. Paul-Walnut[4]	T 28 S, R 21 E, secs. 15 to 17, 20 to 22, 27 to 29, 32 to 34
	T 29 S, R 20 E, secs. 13, 23 to 26, 35, 36
	T 29 S, R 21 E, secs. 3 to 5, 8 to 10, 15 to 22, 27 to 33
	T 30 S, R 20 E, secs. 1, 2, 12, 13, 24
	T 30 S, R 21 E, secs. 4 to 9, 17 to 20, 29, 30
Thayer (Abandoned)	T 29 S, R 17 E, secs. 23 to 26, 35, 36
Thayer East (Aband'd)	T 29 S, R 18 E, secs. 20, 29
Trent	T 28 S, R 20 E, secs. 13, 14, 23, 24
	T 28 S, R 21 E, secs. 18, 19
Urbana	T 28 S, R 18 E, secs. 25 to 28, 33 to 36
	T 28 S, R 19 E, secs. 30 to 32
	T 29 S, R 18 E, secs. 1, 2, 11, 12
	T 29 S, R 19 E, secs. 5 to 8, 16 to 22, 27 to 30

[1] Also in Wilson county (see table 86)

[2] Also in Labette county (see table 52)

[3] Also in Allen, Woodson, and Wilson counties (see tables 3, 86, and 89); includes fields formerly known as Humboldt, Chanute, Diamond, Earlton, and Nyman.

[4] Also in Crawford county (see table 30); includes fields formerly known as St. Paul, Walnut, and Island.

Lynde, Walter and Darby have a water-flooding project in secs. 15 and 22, T. 27 S., R. 18 E.; 234 acres are being flooded. Injection of water into the "Bartlesville sand," which is at a depth of about 725 feet and about 35 feet thick, started in December, 1937. There are 96 oil wells in this project which yielded 3,118 barrels of oil per acre from January 1, 1938, to November 1, 1942. Riverside Oil Company has 60 acres flooded in sec. 34, T. 27 S., R. 18 E. The 18 oil wells had a cumulative production of 112 barrels per acre from June, 1941, to November 1, 1942. The Fred Stipp project includes 20 acres in sec. 21, T. 28 S., R. 18 E., and was started in October, 1941. The first increase in the oil-producing rate was in January,

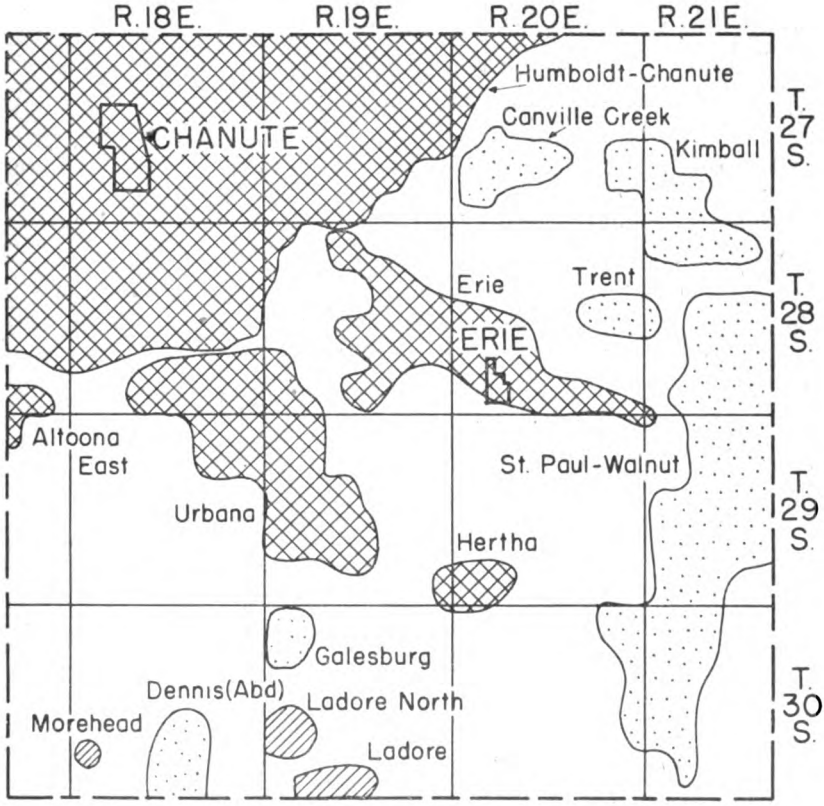

FIG. 20. Map of Neosho county showing oil and gas producing areas. (Gas, dots; oil, diagonal lines; oil and gas, crossed diagonal lines.)

1942. There are six oil wells and three injection wells in this project. The cumulative production from January 1, 1942, to November 1, 1942, was 151 barrels of oil per acre. The Sutcliffe and Blake project, in secs. 33 and 34, T. 27 S., R. 19 E., has 40 acres flooded and 25 producing wells. From March, 1939, to November, 1942, 35,923 barrels of oil were recovered and 525,358 barrels of water were injected, a recovery of 898 barrels of oil per acre. The T. B. Wilson No. 1 project, in secs. 20, 29, 31, and 32, T. 27 S., R. 19 E. and sec. 6, T. 28 S., R. 19 E., has 60 acres flooded. There were 35 injection wells and 32 oil wells in this project on November 1, 1942. Between February, 1938, and November 1, 1942, 2,125,516 barrels of water were injected and 188,018 barrels of oil were recovered; this is a recovery of 3,134 barrels per acre.

The **Erie** oil and gas-producing area is in secs. 18 to 21 and 28 to 36, T. 28 S., R. 20 E.; secs. 3, 4, 9, 10, 11, 13, 14, 15, 21 to 27, 33, and 34, T. 28 S., R. 19 E.; sec. 1, T. 29 S., R. 20 E.; and sec. 6, T. 29 S., R. 21 E. Oil was discovered in this area in 1903. Oil and gas are produced from the "Bartlesville sand" at a depth of about 650 feet. The field is now largely abandoned, with the exception of some areas that are being water flooded. The wells are small producers and yield low-gravity oil (much of it below 25° Bé.). The average initial production was about 20 barrels of oil per day and after a few months production decreased to 4 to 8 barrels per day. A water-flooding project was started by Andrus, Lent, and Daggett in secs. 19 and 30, T. 28 S., R. 20 E. on June 10, 1942. About 10 acres are being flooded and there are seven producing oil wells. During the first five months of operation the total cumulative production of oil was 48 barrels per acre (Grandone, 1944, pp. 126, 127).

The **Urbana** oil-producing area is in secs. 25 to 28 and 33 to 36, T. 28 S., R. 18 E.; secs. 30 to 32, T. 28 S., R. 19 E.; secs. 1, 2, 11, and 12, T. 29 S., R. 18 E.; and secs. 5 to 8, 16 to 22, and 27 to 30, T. 29 S., R. 19 E. Production is from the "Bartlesville sand" which has an average thickness of about 20 feet and lies at a depth of about 750 feet. The area has had several gas wells, but all are now abandoned. There were 14 producing oil wells in December, 1944.

The **St. Paul-Walnut** oil and gas-producing area is in secs. 15, 16, E½ 17, E½ 20, 21, 22, 27 to 29, and 32 to 34, T. 28 S., R. 21 E.; secs. 13, 23 to 26, 35, and 36, T. 29 S., R. 20 E.; secs. 3 to 10, 15 to 22, 27 to 32, and W½ 33, T. 29 S., R. 21 E.; secs. 1, E½ 2, 12, 13, and

24, T. 30 S., R. 20 E.; and secs. W½ 4, 5 to 8, W½ 9, 17 to 19, W½ 20, NW¼ 29, and N½ 30, T. 30 S., R. 21 E. Oil production is from the "Bartlesville sand" which occurs as a "shoestring" in the northwestern part of the area. Gas production is from the "Bartlesville sand" and the Fort Scott limestone. The "Bartlesville sand" has an average thickness of about 30 feet and lies at a depth of about 550 feet.

Reported monthly production of oil in Neosho county for 1941, 1942, and 1943 is given in table 76. Yearly gas production figures for the years 1939 to 1943 are given in table 77.

TABLE 76.—*Reported monthly production of oil in Neosho county, Kansas, in barrels*

Month	1941	1942	1943
January	61,563	54,388	57,812
February	58,967	51,088	56,395
March	59,270	61,649	55,057
April	61,624	62,434	62,360
May	64,865	60,770	53,359
June	56,700	59,832	58,287
July	63,208	65,119	57,461
August	63,729	64,008	58,437
September	57,557	60,530	54,083
October	55,240	60,184	55,669
November	58,231	52,434	54,761
December	61,905	50,972	50,356
Totals	722,859	703,408	674,037

TABLE 77.—*Natural gas production in Neosho county, Kansas*

Year	Thousands of cubic feet
1939	492,304
1940	826,550
1941	411,793
1942	439,721
1943	507,000

OSAGE COUNTY

Oil and gas in commercial quantities have not been reported from Osage county. The Pomona gas pool in Franklin county, however, is a short distance east of the Osage-Franklin county line. Gas production in that area is from the upper part of the Cherokee shale. About 35 to 40 wells have been drilled in Osage

county. Most of the wells did not test rocks lower than the Cherokee shale or the upper part of the Mississippian limestone.

Surface Rocks

Like other eastern Kansas counties, scattered surficial deposits of alluvial material are widespread in Osage county. Flint gravel beds a few feet thick are present on the uplands, especially in the southern part of the county. Outcropping consolidated rocks include the lower few feet of the Admire group (Permian), the Wabaunsee and Shawnee groups, and the upper part of the Douglas group (Pennsylvanian). The thickness of the exposed Pennsylvanian rocks is about 850 feet.

Permian rocks.—The lower few feet of the Towle shale (fig. 6), lowermost Permian formation in Kansas, crops out in the extreme northwestern part of Osage county.

Pennsylvanian rocks.—Wabaunsee rocks (fig. 7) are well exposed in western and especially northwestern Osage county. The Church limestone member of the Howard formation lies below an extensive dip slope in the west-central part of the county. The thickness of Wabaunsee sediments in the county is about 500 feet. Thin fusuline-bearing limestones and drab clayey and sandy shales are characteristic of the group. The formations of the Shawnee group are well exposed and their total thickness is about 350 feet. The belt of outcrop of these rocks covers the approximate eastern half of the county. Rocks of the Shawnee group are characterized by clayey and sandy shales ranging from a few feet to 25 feet or more in thickness and by limestones generally less than 20 feet thick. Many of the limestones contain abundant fusulines.

Subsurface Rocks

Subsurface geological conditions in the north-central part of Osage county are shown diagrammatically in plate 2.

Pennsylvanian rocks.—The maximum thickness of Pennsylvanian rocks in Osage county is about 2,250 feet.

Mississippian rocks.—Mississippian limestone formations in Osage county range from less than 300 feet to more than 400 feet in total thickness (Lee, 1939, pl. 1). The Chattanooga shale ranges in thickness from about 50 feet to nearly 150 feet (Lee, 1943, fig. 14). The greatest thickness is in the northwestern part of the county.

Pre-Chattanooga rocks.—The Chattanooga shale oversteps the upper part of the "Hunton" limestone, the Maquoketa shale, and beveled beds of the Viola limestone in the northwestern part of Osage county. The Viola limestone immediately underlies the Chattanooga in most of the county. Devonian rocks are present only in the northwestern part. Their thickness ranges from a featheredge to less than 100 feet. Silurian rocks are believed to be absent in Osage county (Lee, 1943, fig. 13). A small thickness of Maquoketa (uppermost Ordovician) shale is present in the northwestern part. The average thickness of the Viola limestone is about 175 feet. The interval between the top of the St. Peter sandstone and pre-Cambrian rocks ranges from about 450 feet in the northwestern corner of the county to nearly 800 feet in the southeastern corner.

Depths at which some stratigraphic horizons were reached in the Elmhurst Investment Company No. 1 Badger well, in sec. 4, T. 15 S., R. 16 E., are given in table 78.

TABLE 78.—*Depths at which some stratigraphic horizons were reached in the Elmhurst Investment Company No. 1 Badger well, NW¼ sec. 4, T. 15 S., R. 16 E., Osage county, Kansas*

Horizon	Depth, in feet
Base of Oread limestone	230
Top of Lansing limestone	628
Base of Hertha limestone	1,010
Top of Mississippian limestone	1,700
Top of Chattanooga shale	1,978
Top of Viola limestone	2,070
Top of St. Peter sandstone	2,240
Top of Arbuckle limestone	2,290
Top of pre-Cambrian rocks	2,838

POTTAWATOMIE COUNTY

Oil and gas in commercial quantities have not been found in Pottawatomie county. This county is in the northern part of the Nemaha anticlinal area.

SURFACE ROCKS

Outcropping consolidated rocks in Pottawatomie county include strata from the Barneston limestone of Permian age (fig. 6) to about the horizon of the Reading limestone of Pennsylvanian age (fig. 7). Glacial drift conceals the bedrock in some areas.

Permian rocks.—Permian rocks of Wolfcampian age crop out in most of Pottawatomie county. The exposed Permian section is about 650 feet thick.

Pennsylvanian rocks.—Exposed Pennsylvanian rocks in Pottawatomie county include the Brownville limestone (uppermost Pennsylvanian formation in Kansas) and about 250 feet of older rocks. The oldest rock exposed is the Reading limestone or the upper part of the Auburn shale.

Subsurface Rocks

Plate 1 shows diagrammatically the subsurface geological conditions along the western border of Pottawatomie county.

Permian and Pennsylvanian rocks.—About 1,000 feet of Pennsylvanian rock is present in the Nemaha anticline area in Pottawatomie county. In the western part of the county, where there are both Permian and Pennsylvanian rocks, the combined thickness is about 2,250 feet.

Mississippian rocks.—Mississippian limestone formations are absent in Pottawatomie county west of the buried fault escarpment of the Nemaha anticline (Lee, 1943, fig. 16). The total thickness of limestones of Mississippian age in the eastern part of the county ranges from a featheredge to more than 200 feet. The western edge of Mississippian limestones crosses the northern boundary of the county near the northwest corner of T. 6 S., R. 12 E., and it crosses the southern boundary near the center of the south line of T. 10 S., R. 10 E. The Chattanooga shale also is absent in Pottawatomie county west of the fault escarpment of the Nemaha anticline. The thickness of the Chattanooga shale in the eastern part of the county ranges from a featheredge to about 250 feet (Lee, 1940, pl. 3; 1943, fig. 14).

Pre-Chattanooga rocks.—"Hunton" limestone (Devonian-Silurian) is present in Pottawatomie county east of the Nemaha fault escarpment; there is a thin wedge of Silurian limestone between Pennsylvanian rocks and the Sylvan (Maquoketa) shale in the extreme western part of the county (pl. 1) (Ockerman, 1935, fig. 2). According to Lee (1943, fig. 12), the thickness of rocks between the base of the Chattanooga shale and the top of the Maquoketa shale in eastern Pottawatomie county ranges from about 225 feet in the southeastern corner to about 450 feet in the northeastern part. The thickness of rocks between the top of the

Maquoketa shale and the top of the St. Peter sandstone (interval including the Maquoketa shale and Viola limestone) in both eastern and western Pottawatomie county ranges from about 200 to 300 feet (Lee, 1943, fig. 11); these rocks are absent in the Nemaha anticline. The St. Peter sandstone is believed to be present in all of Pottawatomie county except in the northern part of the Nemaha anticline area (Lee, 1943, fig. 9). The thickness of the St. Peter sandstone probably does not exceed 100 feet except in the southeastern part of the county; it is more than 200 feet in the extreme southeastern part. In the Turner No. 1 Umschied well, in sec. 32, T. 8 S., R. 9 E., the St. Peter sandstone is 20 feet thick and is separated from pre-Cambrian rocks by 20 feet of Bonneterre dolomite and 5 feet of Lamotte sandstone (Lee, 1943, fig. 5). The St. Peter sandstone is believed to lie on pre-Cambrian rocks in much of western Pottawatomie county. About 200 feet is the greatest vertical distance between the top of the St. Peter sandstone and the pre-Cambrian rocks in the eastern part of the county (Lee, 1943, fig. 9).

Oil and Gas Exploration

Several wells have been drilled in Pottawatomie county. Data on 11 tests in the county are given in table 79.

RILEY COUNTY

Neither oil nor gas has been discovered in Riley county, but there has not been sufficient drilling to prove the county barren of petroliferous materials. Because of favorable structural conditions, it is expected that oil or gas or both may be discovered there. Twelve wells have been drilled in the county which has an area of about 600 square miles. The geology of Riley county was described by Jewett (1941).

Surface Rocks

With the exception of glacial drift, loess (?), and alluvium, the outcropping sedimentary rocks in Riley county are chiefly early Permian to late Pennsylvanian in age. A few feet of Cretaceous sandstone is present on the uplands in the extreme northwestern part of the county. There are three outcrops of basic igneous rock of probable Cretaceous age. The oldest exposed rock is the Auburn shale of the Wabaunsee group.

Cretaceous and younger rocks.—A few feet of Dakota sandstone caps the uplands in a small area in northwestern Riley county. This rock is coarse-grained ferruginous quartz sandstone. Unconsolidated deposits of doubtful classification, commonly called loess, cover much of the upland area of the county. Some

TABLE 79.—*Data on wells in Pottawatomie county, Kansas*

Name of well	Location	Remarks	Total depth, in feet
Tri-State No. 1 Pierce	Cen. NW¼ NW¼ sec. 23, T. 6 S., R. 9 E.	Pennsylvanian on Maquoketa shale at 1,425? feet; pre-Cambrian at 1,770? feet	1,773
Empire Oil & Refining Co. No. 1 Rokes	Cen. SW¼ NW¼ sec. 34, T. 6 S., R. 11 E.	Pre-Cambrian at 975? feet	1,735
Olson and McCale No. 1 Anderson	NW¼ SW¼ NW¼ sec. 1, T. 8 S., R. 7 E.	Incomplete log	1,095
Turner et al. No. 1 Umschied	Cen. NE¼ SW¼ sec. 32, T. 8 S., R. 9 E.	Pre-Cambrian at 1,975 feet	1,985
————	Sec. 3, T. 8 S., R 11 E.	Incomplete log	1,734
Lashelie Oil Co. No. 1 Umschied	Cen. NW¼ NW¼ sec. 16, T. 9 S., R. 9 E.	Top of "Hunton" limestone at 1,292 feet; top of Simpson sandstone at 1,944 feet; top of Plattin limestone at 1,984 feet; top of St. Peter sandstone at 2,002 feet; top of "basal sand" at 2,065 feet	2,075
Crawford No. 1 Hoofer	NE¼ SE¼ NW¼ sec. 34, T. 9 S., R. 9 E.	Pre-Cambrian rocks at 1,850 feet	2,225
————	Sec. 2, T. 10 S., R. 9 E.	Drilled in 1905, no log	895
Wamego Coal Hole	Cen. NW¼ sec. 12, T. 10 S., R. 10 E.	Drilled in 1887	930
Crawford No. 1 Doyle	Cen. S. line SE¼ SE¼ SW¼ sec. 4, T. 10 S., R. 12 E.		2,635
Crawford No. 1 St. Marys	Cen. W. line SW¼ NE¼ sec. 11, T. 10 S., R. 12 E.	Incomplete log	2,190

easily identified glacial drift is present, and probably some of the material that has been called loess is deeply weathered drift.

Permian rocks.—Permian strata, about 800 feet thick, are exposed in Riley county. The youngest of these is the lower part of the Wellington shale, which consists of about 5 feet of silty limestone underlain by about 45 feet of highly colored shale. The combined thickness of rocks of the Chase group (fig. 6) in Riley county is about 350 feet. Massive limestones, some of which are flinty, and bright-colored shales are characteristic rocks. Flint is abundant in the lower member of the Winfield limestone, in the Florence limestone, and in the Wreford limestone.

Rocks assigned to the Council Grove group (fig. 6) have a total thickness of slightly more than 300 feet in Riley county. The Cottonwood limestone member of the Beattie formation and the Neva limestone member of the Grenola formation are easily recognized and traced along their lines of outcrop. The Americus limestone member of the Foraker formation at the base of the group is a conspicuous marker bed. Highly colored shales are the characteristic rocks.

With the exception of rocks in the three upper formations, the Admire group (fig. 6) is fairly well exposed in eastern Riley county. The combined thickness of rocks in this group is about 170 feet. The group is characterized by yellow and gray shales and thin limestones. The Falls City limestone, locally the thickest limestone, has a maximum thickness of about 3 feet. The Indian Cave sandstone member of the Towle shale, the lowermost Permian rock known in Kansas, ranges in thickness from a featheredge to about 75 feet. This sandstone lies disconformably on beds of the Wabaunsee group ranging from the Brownville limestone to the lower part of the Langdon shale (Jewett, 1941, pl. 5).

Pennsylvanian rocks.—Pennsylvanian rocks assigned to the Wabaunsee group (fig. 7) crop out in the valley of Deep creek in the eastern part of Riley county. Rocks older than the Auburn shale are not exposed in the county, and rocks between the upper part of the Pony Creek shale and the lower part of the French Creek shale are concealed by mantle deposits or removed by intraformational erosion. The Tarkio limestone is the most easily recognized exposed stratum in the Wabaunsee group. It is about 12 feet thick, massive, weathers to a deep brown color, and con-

tains myriads of large fusulines which resemble large wheat grains. Individual fusulines are smaller and less numerous in other Wabaunsee limestones. Other limestones in the group are much thinner and generally are light gray where weathered. The Wabaunsee rocks in Riley county have a total thickness of about 575 feet. Approximately the upper 175 feet is exposed.

Surface Rocks

Subsurface geologic conditions along the northern boundary of Riley county are shown in plate 1.

Permian rocks.—Logs of wells in the western part of Riley county indicate much lateral variation in the shallow subsurface, and detailed study of cuttings is necessary before definite statements can be made about these shallow Permian rocks. The same is true of the upper part of the Pennsylvanian section.

Pennsylvanian rocks.—Pennsylvanian rocks which are probably no older than late Desmoinesian (Marmaton) overstep older Paleozoic rocks and overlap pre-Paleozoic rocks (pl. 1). Pennsylvanian rocks in this area are about 1,500 feet thick. They consist chiefly of limestone and gray shale and include a small thickness of sandstone and red shale or siltstone. Although the Permian-Pennsylvanian contact can be readily recognized at the surface, it is not so easily identified in the subsurface. However, studies of drill cuttings should allow such identifications.

Mississippian rocks.—Limestone of Mississippian age ranging in thickness from a featheredge to about 100 feet is present in the western part of Riley county. Shale about 150 feet thick believed to be of Kinderhookian age and probably correlative with the Chattanooga shale is the oldest rock assigned to the Mississippian system. This rock has been identified in the western part of the county.

Pre-Chattanooga rocks.—The "Hunton" limestone lies next below Mississippian and younger rocks in most of Riley county (McClellan, 1930, fig. 2; Lee, 1939, pl. 1). The "Hunton" has a maximum thickness in this area of about 400 feet and lies unconformably between the Chattanooga and Maquoketa shales. It consists of limestone and dolomite.

The Maquoketa shale, the Viola limestone, and the Simpson sandstone are present in Riley county. The Maquoketa, which consists chiefly of shale but contains some sandstone, has a maxi-

mum thickness of about 100 feet; the Viola has an average thickness of perhaps 150 feet; and the Simpson is probably not more than 40 or 50 feet thick. These rocks are separated by unconformities. The Simpson sandstone is believed to overstep older rocks, including pre-Cambrian, in Riley county. The overstep is toward the east; that is, the Simpson extends across the Arbuckle limestone and the Lamotte (?) sandstone and lies on granite in the eastern part of the county. Paleozoic rocks older than those of some part of the Missourian series are not continuous over the buried Nemaha fault escarpment, the crest of which lies below the extreme eastern part of Riley county. Very little definite information about older Paleozoic rocks in this county is available. It is believed, however, that in the western part the Lamotte (?) sandstone and the Arbuckle limestone range in thickness from a featheredge to 150 feet or more. The Lamotte (?) sandstone is not known to be more than 85 feet thick in this area.

Because of the presence of the Nemaha uplift, the surface of the pre-Cambrian floor in this part of Kansas is very irregular, having a relief in Riley county of 2,000 feet or more. The pre-Cambrian rocks are igneous and metamorphic and are believed to be chiefly granite and schist. Younger rocks ranging in age from Middle Pennsylvanian to Late Cambrian lie on the surface of the crystalline rocks. According to available records, the Cain Bloom No. 1 Zeandale well, in the NW cor. SW¼ sec. 28, T. 10 S., R. 9 E., reached granite at a depth of 928 feet. The Parker Oil Company No. 1 Bardwell well, in the SW¼ NE¼ sec. 28, T. 10 S., R. 9 E., is reported to have reached granite at 950 feet. The oldest Paleozoic rock encountered in this well is probably of Bronson age. The Empire Gas and Fuel Company No. 1 Woodbury well, in the SW¼ NE¼ sec. 14, T. 9 S., R. 4 E., reached granite at 2,760 feet. In this well, the Simpson sandstone lies next above the pre-Cambrian granite. The Arkansas Fuel Company No. 1 Martin well, in the SE¼ NE¼ SW¼ sec. 24, T. 8 S., R. 4 E., reached granite at about 2,938 feet. About 168 feet of limestone next above the granite is believed to be of Arbuckle age.

Oil and Gas Exploration

According to records in the files of the State Geological Survey of Kansas, 12 wells have been drilled in Riley county. Seven of these are reported to have reached pre-Cambrian rocks. How-

ever, Pennsylvanian rocks lie on the granite in two of these; hence only Pennsylvanian rocks were tested. Table 80 lists the wells that have been drilled in Riley county and shows the lowest formation reached in each well. All wells were dry holes.

TABLE 80.—*Test wells drilled for oil and gas in Riley county, Kansas*[1]

Company and farm	Location Sec., T., R.	Completion date, total depth, feet	Lowest formation tested
General Utilities et al. No. 1 Hay	NE cor. SW 30-6-6E	11/23/29 2,535	Arbuckle
C. Gentler et al. No. 1 Doyle	SE cor. SE 36-7-4E	8/1/24 2,601	Maquoketa
Gypsy Oil Co. No. 1 Droll	SE SW NW 2-7-5E	6/30/17 3,520	Pre-Cambrian
Derby Oil Co. No. 1 Lindstrom	NE cor. NE 32-7-5E	10/9/29 2,226	"Hunton" ?
Arkansas Fuel Oil No. 1 Martin	SE NE SW 24-8-4E	1/11/30 2,942	Pre-Cambrian
Empire Oil & Refg. No. 1 Woodbury	SW cor. NE 14-9-4E	4/29/25 2,804	Pre-Cambrian
Pawnee Oil & Gas No. 1 Marks	NE SW NW 26-10-6E	12/22/23 1,853	Mississippian?
F. J. Heeley et al. No. 1 Thier	NW NE NW 20-10-7E	5/23/29 2,965	Pre-Cambrian
Coronado Oil No. 1 Parks	Cen. SE SE 16-10-8E	7/28/38 1,989½	Pre-Cambrian
Cain Bloom No. 1 Zeandale	NW cor. SW 28-10-9E	--/--/14 1,020	Pre-Cambrian
Parker Oil Co. No. 1 Bardwell	SW NE 28-10-9E	1,093	Pre-Cambrian
W. R. Wilson et al. No. 1 Rannels	SE SW NW 4-11-8E	9/12/28 2,310	"Hunton"

[1] Compiled by R. P. Keroher.

SHAWNEE COUNTY

Neither oil nor gas is produced in Shawnee county. A few test wells have been drilled, but the county is very inadequately explored for oil and gas.

Surface Rocks

Rocks of Permian age are exposed in two small areas in the southwestern part of Shawnee county. The exposed bedrocks elsewhere in the county are Pennsylvanian in age. Thin deposits of glacial till and outwash material are found in all the county except the southwestern part.

Pennsylvanian rocks.—Outcropping Pennsylvanian rocks in Shawnee county extend from uppermost Pennsylvanian strata to beds in the upper part of the Douglas group (fig. 7). Several limestones cap conspicuous escarpments that cross the county in a general north-south direction. The most prominent are those of the Topeka, Deer Creek, Lecompton, and Oread limestones of the Shawnee group.

Subsurface Rocks

Pennsylvanian rocks.—In southwestern Shawnee county where the uppermost Pennsylvanian rocks are present the total thickness of these rocks is about 2,000 feet.

Mississippian rocks.—According to Lee (1943, fig. 16), the total thickness of the Mississippian limestones in Shawnee county ranges from slightly less than 200 feet to slightly more than 350 feet. The youngest Mississippian formation that has been identified in the county is the Warsaw limestone, which is believed to lie next below the Pennsylvanian deposits in all parts of the county (Lee and Payne, 1944, fig. 17). In the McBride and Goens No. 1 Shirley well, in sec. 21, T. 12 S., R. 14 E., Lee (1940, pl. 6) identified 50 feet of Warsaw limestone. In the same well 25 feet of Keokuk limestone was found overlying 47 feet of Burlington limestone. This is underlain by 29 feet of limestone of Fern Glen age. The Sedalia limestone, which is 13 feet thick, occurs next below. In the basal part of the Mississippian section, 60 feet of Gilmore City limestone was identified. The thickness of the Chattanooga shale ranges from less than 100 feet in the southeastern part of the county to slightly less than 250 feet in the southwestern part (Lee, 1943, fig. 14).

Pre-Chattanooga rocks.—Table 81 shows the depths at which some key pre-Chattanooga horizons were reached in three Shawnee county wells. Data are from studies made by Lee (1943, figs. 5, 7). Lee's studies indicate that the Silurian limestone and the Maquoketa shale have been removed from southeastern Shawnee

TABLE 81.—*Depths at which some key stratigraphic horizons were reached in three wells in Shawnee county, Kansas*

Horizon	Forrester et al. No. 1 Hummer, sec. 14, T. 11 S., R. 16 E.	McKnab No. 1 Fritz, sec. 4, T. 12 S., R. 14 E.	Green et al. No. 1 Ripley, sec. 12, T. 12 S., R. 16 E.
Top of Mississippian limestone	1,785	1,893	1,930
Top of Chattanooga shale	2,040	2,139	2,052
Top of Devonian ("Hunton") limestone	2,160	2,292	2,140
Top of Silurian limestone	2,245	2,348	
Top of Maquoketa shale	2,260	2,430	2,255
Top of Kimmswick limestone (Viola)	2,330	2,492	2,275
Top of Decorah shale	2,450	2,599	
Top of St. Peter sandstone	2,465	2,631	2,405
Top of Arbuckle rocks	2,535	2,680	2,475
Top of Gasconade dolomite	2,710		
Top of Eminence dolomite	2,800		
Top of Bonneterre dolomite	2,890		
Top of Lamotte sandstone	2,980		
Top of pre-Cambrian rocks	3,102		
Total depth	3,023	2,722	3,320

county. The maximum thickness of rocks between the base of the Chattanooga shale and the top of the Maquoketa shale is about 250 feet (Lee, 1943, fig. 12). The interval from the top of the Maquoketa shale to the top of the St. Peter sandstone is not more than 200 feet (Lee, 1943, fig. 11) and the interval from the top of the St. Peter sandstone to pre-Cambrian rocks ranges from about 200 to 600 feet (Lee, 1943, fig. 9).

OIL AND GAS EXPLORATION

Much of Shawnee county is untested or inadequately tested for oil and gas. Data on 22 wells in the county are given in table 82.

WABAUNSEE COUNTY

Oil and gas in commercial quantities have not been found in Wabaunsee county. Several test wells have been drilled. It is reported that 44,000 cubic feet of helium gas was produced from a sandstone between 266 and 276 feet in a well in sec. 9, T. 12 S., R. 10 E. (Ockerman, 1935, p. 71). Subsurface structural conditions are favorable for the accumulation of oil in stratigraphic traps in pre-Pennsylvanian rocks.

Surface Rocks

Both Permian and Pennsylvanian rocks crop out in Wabaunsee county. The exposed Permian section is about 750 feet thick, and the exposed Pennsylvanian section is about 200 feet thick. Surficial deposits of unconsolidated sediments include alluvium in the valleys of Kansas river and other streams, attenuated glacial drift, and scattered gravel beds. The youngest bedrock in the county is the Doyle shale near the top of the Wolfcampian series. The Willard shale (Wabaunsee group) is the oldest surface rock of the county. That shale and the overlying Tarkio limestone are exposed along Kansas river in the northwestern part of the county.

Permian rocks.—Outcrops of rocks of the Chase group (fig. 6) occupy most of the western part of Wabaunsee county. The Fort Riley and Florence limestone members of the Barneston formation, the Wreford limestone, and several highly colored shales are easily identified. Rocks of the Council Grove group crop out in a belt extending in a general northeast direction from the southwest corner of the county. The outcrop belt ranges from about 6 to 20 miles in width. As in other eastern Kansas counties, the thickness of the Council Grove rocks is about 300 feet. Rocks of the Admire group crop out in the eastern half of the county. Exposures along Mill Creek are especially well adapted to study. The basal Admire deposit in Wabaunsee and neighboring counties is a sandstone (Indian Cave member of the Towle formation) that lies above a disconformity. This disconformity locally reaches 135 feet or more below the youngest Pennsylvanian rocks of the region. The Indian Cave sandstone is especially well exposed in the SW¼ NW¼ sec. 3, T. 13 S., R. 13 E. Its base in this area is a few feet above the Maple Hill limestone (Wabaunsee) (Moore and others, 1936, fig. 30). The Admire rocks are chiefly clastic and the limestones are only a few feet thick.

Pennsylvanian rocks.—The thickness of the Wabaunsee group (fig. 7) along the outcrop in Kansas shows little variation, although the thicknesses of the formations are quite variable. In Wabaunsee county and elsewhere in the state, the thickness of the group is about 500 feet. Clayey and sandy shales, light-colored limestones, and minor amounts of sandstone characterize this rock division. Only the upper part of the group, the Willard shale and higher formations, is exposed in the county. These rocks crop out in the northwestern part of the county.

TABLE 82.—*Data on wells in Shawnee county, Kansas*

Name of well	Location	Remarks	Total depth, in feet
Adanac Oil and Refining Company No. 1 Adanac	SW¼ NW¼ sec. 13, T. 10 S., R. 13 E.	Top of Mississippian rocks at 2,115 feet; top of Chattanooga shale at 2,316 ft.; top "Hunton" limestone at 2,563 ft.	2,700
Skelly Oil Company No. 1 Wallace	NW¼ SE¼ SW¼ sec. 13, T. 10 S., R. 13 E.	Top of Mississippian rocks at 2,094 feet; top of "Hunton" limestone at 2,523 ft.; top of Arbuckle rocks at 3,069 ft.	3,147
Jenkins and Scott No. 1 Asherman	NW¼ NE¼ sec. 28, T. 10 S., R. 15 E.	Stopped in Lansing - Kansas City rocks	862
Hall et al. Staley	SW¼ sec. 23, T. 11 S., R. 13 E.	Stopped in Cherokee rocks	1,951
Hall et al. Werner	SE cor. NW¼ sec. 36, T. 11 S., R. 13 E.	Top of Mississippian rocks at 1,990 feet?; stopped in upper part of Mississippian	2,006
Davidson No. 1 Aller	SE¼ NE¼ NW¼ sec. 2, T. 11 S., R. 14 E.	Top of Mississippian rocks at 2,080 feet; top of Chattanooga shale at 2,305 ft.; top of "Hunton" limestone at 2,450 feet; stopped in "Hunton"	2,471
Corbett et al. No. 1 Security Benefit Association	SW cor. SE¼ NW¼ sec. 28, T. 11 S., R. 15 E.	Top of Mississippian rocks at 1,776 feet; top of Chattanooga shale at 1,955 (?) ft.; top of "Hunton" limestone at 2,119 ft.; stopped in "Hunton"	2,170
Forrester et al. No. 1 Hummer	SW¼ SE¼ NE¼ sec. 14, T. 11 S., R. 16 E.	(See table 81)	3,023
————	NW¼ NE¼ SE¼ sec. 32, T. 16 S., R. 16 E.	Drilled in 1886; stopped in Cherokee shale	1,638
————	SW¼ SW¼ NE¼? sec. 34 T. 11 S., R. 17 E.	Stopped in Cherokee shale	1,435

McKnab No. 1 Fritz	SW¼ SE¼ NW¼ sec. 4, T. 12 S., R. 14 E.	(See table 81)	2,720
Jenkins and Scott No. 1 Hayden	NE cor. SE¼ sec. 8, T. 12 S., R. 14 E.	Drillers log is similar to that of McKnab No. 1 Fritz; stopped in St. Peter sandstone	2,693
Rinker No. 1 Flickinger	SW cor. SE¼ sec. 17, T. 12 S., R. 14 E.	Stopped in Cherokee shale	1,880
McBride & Givens No. 1 Shirley	NE¼ SW¼ sec. 21, T. 12 S., R. 14 E.	Top of Mississippian limestone at 2,050 ft.; top of Chattanooga shale at 2,306 ft; stopped in Chattanooga shale	2,469
Green et al. No. 1 Ripley	NW cor. NE¼ sec. 12, T. 12 S., R. 16 E.	(See table 81)	3,320
————	NE¼ sec. 13, T. 12 S., R. 14 E.	Incomplete log	552
———— Bahnmeier	NE¼ sec. 15, T. 12 S., R. 16 E.	Drilled in 1905; incomplete log; stopped in Cherokee shale?	1,310
Goodwin et al. No. 1 Decker	NW¼ SE¼ NE¼ NE¼ sec. 13, T. 12 S., R. 16 E.	No log	1,435
Sterling Drilling Co. No. 1 Milliken	Cen. W. line NW¼ SE¼ sec. 10, T. 12 S., R. 17 E.	Top of Mississippian at 1,714 feet; top of Arbuckle limestone at 2,409 ft.	2,511
Jenkins & Scott No. 1 Milliken	SE cor. NW¼ sec. 10, T. 12 S., R. 17 E.	No log	550
———— No. 1 Marshall	Sec. 23, T. 13 S., R. 13 E.	Top of Mississippian rocks reported at 1,765 ft.	1,812
Wapeka Oil Company No. 1 Neal	Cen. SW¼ NE¼ sec. 26, T. 13 S., R. 15 E.		2,430

Subsurface Rocks

Subsurface geological conditions along the southern border of Wabaunsee county are shown diagrammatically in plate 2. The crest of the buried crystalline core of the Nemaha anticline underlies the western part of the county. Rocks of Marmaton age are believed to lie on pre-Cambrian crystalline rocks in this area, and a little farther east the Cherokee shale oversteps the upturned and beveled edges of Mississippian limestone formations, the Chattanooga shale, and older rocks.

Depths to some key horizons in three wells in Wabaunsee county are given in table 83.

Table 83.—*Depths in feet to some stratigraphic horizons in three wells in Wabaunsee county, Kansas*

Horizon	Ramsey Petroleum Company No. 1 Kaul, sec. 2, T 11 S., R. 11 E.	Empire Oil and Gas Company No. 1 Schwalm, sec. 19, T. 12 S., R. 11 E.	Williams et al. No. 1 Henderson, sec. 15, T. 13 S., R. 12 E.
Top of Shawnee group	560	900	525
Top of Douglas group	970	1,255	915
Top of Lansing group	1,170	1,495	1,305
Top of Bronson group	1,525	1,850	1,505
Base of Marmaton group	1,748	2,070	1,705
Top of Mississippian rocks	2,240	2,485	2,230?
Top of Chattanooga shale	2,375	2,805	2,453
Top of "Hunton" limestone	2,585	2,990	2,727
Top of Maquoketa shale	.....	3,215	2,822
Top of Viola limestone	.....	3,285	2,895
Top of St. Peter sandstone	.....	3,400	3,040
Top of Arbuckle limestone	.....	.....	3,130
Top of pre-Cambrian rocks	.....	.....	3,428?
Total depth	2,830	3,431	3,652

Pennsylvanian rocks.—The average thickness of Pennsylvanian rocks in Wabaunsee county is about 2,000 feet. The section is thinner in the western part of the county in the area of the Nemaha anticline.

Mississippian rocks.—According to Lee (1939, pl. 1; 1943, fig. 16), Mississippian limestone formations in Wabaunsee county have a total thickness ranging from a featheredge to slightly more

than 350 feet. The greatest thickness is in the southeast corner of the county. These rocks are absent in the extreme western part. The Chattanooga shale ranges in thickness from a fraction of a foot to more than 150 feet (Lee, 1943, fig. 14). It was removed by post-Mississippian erosion west of a line from the northern boundary of Wabaunsee county at about the middle of R. 10 E. to the southern boundary at about the middle of R. 9 E.

Pre-Chattanooga rocks.—Lee's studies (1943, fig. 7) indicate that a well in sec. 19, T. 12 S., R. 11 E. was drilled through 41 feet of Devonian limestone, and that 179 feet of Silurian limestone was penetrated. Lee also identified 72 feet of Maquoketa shale, 103 feet of Fernvale (?) and Kimmswick limestone, 23 feet of Decorah shale and Plattin limestone, and 19 feet of St. Peter sandstone. Arbuckle rocks lie below the St. Peter sandstone. Pre-Cambrian rocks are 958 feet below the surface in sec. 26, T. 10 S., R. 9 E., and 3,625 feet below the surface in sec. 15, T. 13 S., R. 12 E. The difference in elevation of the pre-Cambrian floor between these two places is approximately 2,400 feet. The well in which granite was found at the shallow depth is near the crest of the Nemaha anticline, where Pennsylvanian rocks are in contact with the pre-Cambrian.

Oil and Gas Exploration

Wabaunsee county has been very inadequately tested for oil and gas. Table 84 gives data on 20 wells in the county.

WASHINGTON COUNTY

Oil and gas have not been found in Washington county. The county is on the eastern margin of the Salina basin and in the northern part of the Kansas portion of the North Kansas basin.

Surface Rocks

Cretaceous rocks.—The youngest exposed rock in Washington county is a part of the Carlile shale which caps hills in the northwestern part of the county. Older Cretaceous rocks exposed include the Greenhorn limestone, the Graneros shale, the Dakota formation, and probably the Kiowa shale. Sandstones of the Dakota formation crop out in a large part of the area.

Permian rocks.—Outcropping Permian rocks in Washington county extend from the lower part of the Wellington shale to the upper part of the Matfield shale (fig. 6).

TABLE 84.—*Data on wells in Wabaunsee county, Kansas*

Name of well	Location	Remarks	Total depth, in feet
Parker Oil Company No. 2 Bardwell	Sec. 26, T. 10 S., R. 9 E.	Pennsylvanian rocks on pre-Cambrian rocks at 958 ft.	1,093
Empire Oil & Gas Company No. 1 Root	SW¼ NE¼ sec. 1, T. 11 S., R. 9 E.	Pennsylvanian rocks on pre-Cambrian rocks at 1,180 ft.	2,000
Ramsey Petroleum Co. No. 1 Kaul	NE¼ NE¼ sec. 2, T. 11 S., R. 11 E.	(See table 83)	2,830
Kansas Oil Association No. 1 Wille	SW¼ NE¼ sec. 5, T. 11 S., R. 11 E.	Top of Mississippian rocks at 2,295 ft.; top of Chattanooga shale at 2,480 ft.	2,700
———— No. 1 Newbury	NW¼ NE¼ sec. 22, T. 11 S., R. 11 E.		500
Bullock No. 1 McFarland (City)	SW¼ sec. 31, T. 11 S., R. 11 E.	Stopped in upper Cherokee rocks	2,006
American Petroleum Co. No. 1 Smidt	SE¼ SE¼ sec. 9, T. 12 S., R. 10 E.	Top of Mississippian rocks at 2,270 ft.	2,339
Coleman-Edgerton No. 1-B Smith	NE¼ SE¼ SE¼ sec. 9, T. 12 S., R. 10 E.	Produced 44,000 cubic feet of helium-bearing gas between 266 and 276 ft.	
Cosden No. 1 Renker	SW¼ SE¼ sec. 17, T. 12 S., R. 11 E.	Stopped in Cherokee rocks	1,880
Empire Oil & Gas Co. No. 1 Schwalm	SE cor. SE¼ sec. 19, T. 12 S., R. 11 E.	(See table 83)	3,431
Manhattan Oil Co. No. 1 Steinmeyer	NE cor. NW¼ SW¼ sec. 11, T. 13 S., R. 10 E.	Top of Mississippian rocks at 2,340 ft.	2,405
Williams et al. No. 1 Henderson	NE¼ sec. 15, T. 13 S., R. 12 E.	(See table 83)	3,652

Pinnacle Oil Co. No. 1 Martin	Cen. S. line SE¼ NW¼ sec. 35, T. 13 S., R. 12 E.	Drillers log similar to Williams et al. No. 1 Henderson	3,640?
Zinn No.1 Langvardt	NE¼ SW¼ SE¼ sec. 1,T. 14 S., R. 8 E.	Stopped in lower Permian rocks	625
Rose No. 1 Hartraft	Cen. NE¼ sec. 2, T. 14 S., R. 8 E.	Stopped in lower Permian rocks	618
Rose No. 2 Stice	SW cor. SW¼ sec. 2, T. 14 S., R. 8 E.	Slight show of gas in lower Permian rocks at 431 ft.	700
Rose No. 1 Stice	SW¼ NW¼ sec. 11, T. 14 S., R. 8 E.	Show of gas in lower Permian rocks at 485 ft.	604
Benedum No. 1 Lockhart	SW cor. SW¼ sec. 17, T. 14 S., R. 11 E.	Stopped in Cherokee rocks	2,665
Holborne Oil Co. No. 1 Stevenson	SW cor. NE¼ sec. 29, T. 14 S., R. 12 E.	Top of Mississippian rocks at 2,405 ft.	2,510
———— No. 1 Wilson	NE¼ SW¼ NE¼ sec. 5, T. 15 S., R. 11 E.		1,052

Subsurface Rocks

The average thickness of Permian and Pennsylvanian rocks in Washington county is about 2,000 feet (Moore and Jewett, 1942, fig. 2). Geologic conditions along the southern boundary of Washington county are shown diagrammatically in plate 1. Data pertaining to rocks older than Pennsylvanian were furnished chiefly by Wallace Lee.

The Chattanooga shale is believed to underlie Pennsylvanian rocks in the southwestern part of the county (Lee, 1943, fig. 14). A thin wedge of Mississippian limestone is believed to separate Pennsylvanian and Chattanooga rocks in the western part of the county. The maximum thickness of the Chattanooga shale is slightly more than 200 feet.

Pre-Chattanooga rocks.—The "Hunton" limestone, which has an average thickness of about 400 feet, is believed to be present in all parts of Washington county. The Sylvan (Maquoketa) shale

probably underlies all the county. Its thickness probably does not exceed 75 feet. The Viola limestone probably is present in all parts of the county; its average thickness is believed to be about 400 feet. A small thickness of Simpson (St. Peter) sandstone probably lies between the Viola limestone and pre-Cambrian rocks in most of the county. There is a thin wedge of Arbuckle (or Bonneterre) dolomite below the Simpson sandstone in the western part.

Depths at which some stratigraphic horizons were reached in a well in sec. 1, T. 1 S., R. 2 E. are given in table 85. Data were supplied by Constance Leatherock of the United States Geological Survey.

TABLE 85.—*Depths to some stratigraphic horizons in the Gulf Oil Company No. 1 Baker well, NW¼ SE¼ SE¼ sec. 1, T. 1 S., R. 2 E., Washington county, Kansas*

Horizon	Depth, in feet
Base of Pennsylvanian rocks and top of Devonian ("Hunton") rocks	2,185
Top of Silurian rocks	2,340
Top of Maquoketa shale	2,600
Top of Kimmswick (Viola) limestone	2,655
Top of Simpson formation	2,770
Top of Bonneterre dolomite	3,105

WILSON COUNTY

Oil and gas have been produced in every township in Wilson county. Oil was first discovered in the county near Neodesha in 1890 (Haworth, 1908, p. 24). Neodesha was supplied with gas on July 4, 1894. More than 40 wells were producing gas in this area by the close of 1894. Oil and gas were produced near the towns of Fredonia, Benedict, and Buffalo in 1900. Neodesha, Altoona, Fredonia, Buffalo, and Vilas are nearly surrounded by producing areas. The oil and gas resources of Wilson county were described by Moore and Boughton (1921).

SURFACE ROCKS

The surface rocks in Wilson county consist of alternating beds of shale, limestone, and sandstone. The Oread limestone of the Shawnee group (fig. 7) is the youngest consolidated rock exposed in the county. It crops out in the extreme northwestern part. The

Douglas group, which consists of thick massive or cross-bedded sandstones, shaly sandstones, and sandy shales, is about 230 feet thick in the county. Pedee rocks (fig. 8) have a thickness of about 60 feet, Lansing rocks are about 165 feet thick, and Kansas City rocks are about 150 feet thick.

Surface Rocks

Pennsylvanian rocks.—Bronson rocks are about 100 feet thick in Wilson county. The Bourbon rocks are mostly silty to sandy shale; their thickness in the county is probably about 100 feet. The Marmaton group of rocks consists of about 250 feet of shale, sandstone, and limestone and a minor amount of coal. The Cherokee shale ranges in thickness from about 200 feet in the central part of Wilson county to about 425 feet in the east-central part (Bass, 1936, pl. 1). It is composed principally of light and dark shale containing sandstone lenses and thin beds of limestone and coal. The "Bartlesville sand" is separated from the underlying Mississippian limestone by about 100 feet of shale. A sandstone occurs locally in the basal part of the Cherokee shale.

Mississippian rocks.—The total thickness of the Mississippian rocks in Wilson county ranges from 150 to 300 feet (Lee, 1939, pl. 1). The identified Mississippian rocks and their thicknesses in a well in sec. 22, T. 30 S., R. 15 E., are: Warsaw limestone, 97 feet; Keokuk limestone, 44 feet; Burlington limestone, 54 feet; Reeds Spring limestone, 121 feet; St. Joe limestone, 5 feet; Northview shale, 7 feet; Compton limestone, 5 feet; and Chattanooga shale (Mississippian or Devonian), 17 feet. The Chattanooga shale lies unconformably on the Ordovician rocks.

Ordovician and Cambrian rocks.—The driller's log of a well in sec. 10, T. 29 S., R. 15 E. records 979 feet of rocks that are probably Arbuckle. According to this log, granite was penetrated at a depth of 2,214 feet.

Oil and Gas Developments

Wilson county has been thoroughly tested for oil and gas by extensive drilling which has extended for a period of many years. The county is more important as a gas producer than as an oil producer. In 1935 more than 8,000 gas wells were reported in the county. Most of the productive sands are lenticular bodies in the Cherokee shale. Some production is from the top of the Mississip-

pian limestone and from the top of the Ordovician ("Siliceous lime").

Figure 21 shows the distribution of the oil and gas producing areas in Wilson county. Table 86 lists the oil and gas fields in Wilson county as designated by the Oil Field Nomenclature Committee of the Kansas Geological Society.

The largest gas field in the county is in the **Vilas** area. Some of the wells in this area had initial productions of 40 million cubic feet of gas per day. Production is from the "Bartlesville sand" which has an average thickness of about 140 feet.

The largest oil and gas producing area, the **Neodesha-Altoona,** is in the southeastern part of Wilson county and covers about 75

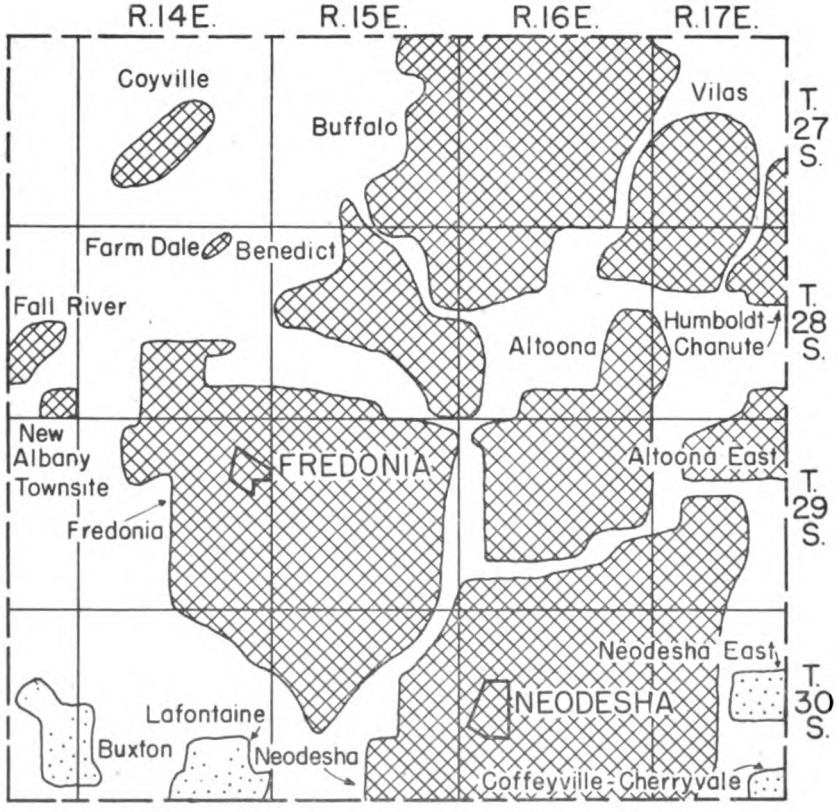

FIG. 21. Map of Wilson county showing oil and gas producing areas. (Gas, dots; oil, diagonal lines; oil and gas, crossed diagonal lines.)

TABLE 86.—*Oil and gas fields in Wilson county, Kansas*

(As designated by the Oil Field Nomenclature Committee of the Kansas Geological Society, November 15, 1944)

Name	Location
Altoona	T 28 S, R 16 E, secs. 13, 23 to 26, 33 to 36
	T 28 S, R 17 E, secs. 19, 30
	T 29 S, R 16 E, secs. 1 to 6, 8 to 17, 20 to 24, 27 to 29
Altoona East[1]	T 28 S, R 17 E, sec. 34
	T 29 S, R 17 E, secs. 3 to 5, 8 to 10
Benedict	T 27 S, R 16 E, sec. 33
	T 28 S, R 15 E, secs. 2 to 4, 8 to 11, 13 to 18, 21 to 26, 36
	T 28 S, R 16 E, secs. 18, 19, 30, 31
Buffalo[2]	T 27 S, R 15 E, secs. 1, 2, 12 to 14, 23 to 27, 34 to 36
	T 27 S, R 16 E, secs. 1 to 24, 26 to 35
	T 27 S, R 17 E, secs. 6, 7
	T 28 S, R 15 E, secs. 1, 12, 13
	T 28 S, R 16 E, secs. 4 to 9, 17, 18
Buxton	T 30 S, R 13 E, secs. 14, 24, 25, 36
	T 30 S, R 14 E, secs. 19, 30, 31
Coffeyville-Cherryvale[3]	T 30 S, R 17 E, sec. 34
Coyville	T 27 S, R 14 E, secs. 15, 20, 21, 28, 29
Fall River	T 28 S, R 13 E, secs. 23, 24, 26
Farm Dale	T 28 S, R 14 E, sec. 2
Fredonia	T 28 S, R 14 E, secs. 21 to 23, 27, 28, 33 to 36
	T 28 S, R 15 E, secs. 31 to 34
	T 29 S, R 14 E, secs. 1 to 5, 8 to 15, 22 to 27, 34 to 36
	T 29 S, R 15 E, secs. 1 to 36
	T 30 S, R 14 E, secs. 1, 2, 12
	T 30 S, R 15 E, secs. 2 to 10, 16 to 18, 20
Humboldt-Chanute[4]	T 27 S, R 17 E, secs. 15, 22, 27, 34
	T 28 S, R 17 E, secs. 3, 9, 10, 15
Lafontaine	T 30 S, R 14 E, secs. 25 to 27, 34 to 36
Neodesha[5]	T 29 S, R 16 E, secs. 24 to 27, 31 to 36
	T 29 S, R 17 E, secs. 16, 17, 19 to 21, 28 to 32
	T 30 S, R 15 E, secs. 1, 11 to 14, 23 to 27, 34 to 36
	T 30 S, R 16 E, secs. 1 to 36
	T 30 S, R 17 E, secs. 5 to 8, 17 to 20, 29 to 32
Neodesha East	T 30 S, R 17 E, secs. 15, 16, 21, 22
New Albany Townsite	T 28 S, R 13 E, sec. 36
Vilas	T 27 S, R 16 E, secs. 24, 25, 36
	T 27 S, R 17 E, secs. 16, 17, 19 to 21, 27 to 34
	T 28 S, R 16 E, secs. 1, 11, 12
	T 28 S, R 17 E, secs. 4 to 9

[1] Also in Neosho county (see table 75)
[2] Also in Woodson county (see table 89)
[3] Also in Montgomery and Labette counties (see tables 52 and 70)
[4] Also in Allen, Woodson, and Neosho counties (see tables 3, 75, and 89)
[5] Also in Montgomery county (see table 70)

square miles. Production is from a sandstone in Pennsylvanian rocks and from the Arbuckle dolomite. One water-flooding project is in operation in Wilson county (Grandone, 1944, pp. 142-144). This is the Gillilan and Carr project in secs. 9 and 16, T. 29 S., R. 17 E., in the Neodesha-Altoona area. Forty acres are being flooded; there are four injection wells and fourteen oil-recovery wells. The producing rock is the "Bartlesville sand" which is 25 feet thick and lies at a depth of about 825 feet. Water injection was started in November, 1939, and the first increase in the rate of oil production was in June, 1940. Cumulative production to November 1, 1942, was 507 barrels per acre.

In the **Fredonia** area, which covers about 40 square miles, oil is produced from Pennsylvanian sandstones.

Reported monthly production of oil in Wilson county during 1941, 1942, and 1943 is given in table 87 and yearly gas production statistics for the years 1939 to 1943 are given in table 88.

TABLE 87.—*Reported monthly production of oil in Wilson county, Kansas, in barrels*

Month	1941	1942	1943
January	9,708	7,210	5,008
February	8,013	7,424	4,329
March	9,159	9,192	5,548
April	9,336	7,418	4,571
May	7,875	6,943	5,097
June	9,488	8,490	3,773
July	8,889	7,405	5,578
August	9,021	7,628	6,265
September	10,091	6,532	4,493
October	7,672	5,734	3,356
November	7,601	6,884	4,572
December	9,394	5,297	3,124
Totals	106,247	86,157	55,714

TABLE 88.—*Natural gas production in Wilson county, Kansas*

Year	Thousands of cubic feet
1939	734,880
1940	687,886
1941	517,605
1942	463,954
1943	417,748

WOODSON COUNTY

There are many scattered oil and gas producing areas in Woodson county. The largest oil production comes from the west-central part. Most of the oil and gas is produced from the "Bartlesville sand" and the upper part of the Mississippian limestone.

Surface Rocks

Granite is exposed at the surface in sec. 13, T. 26 S., R. 15 E. in a small anticline known as Rose dome. Quartzite that has been formed by hydrothermal action occurs at the surface in sec. 32, T. 26 S., R. 15 E. in another small anticline, the Silver City dome.

Pennsylvanian rocks.—Surface rocks of Woodson county include the Shawnee, Douglas, Pedee, and Lansing groups. The Topeka limestone of the Shawnee group is the surface rock in the northwestern part of the county. The oldest exposed rock is the Plattsburg limestone of the Lansing group which is the surface rock in the southeastern part.

The thickness of the Shawnee group (fig. 7) in Woodson county is about 300 feet. The Douglas group consists chiefly of shale, sandy shale, and sandstone and some thin beds of limestone and coal. These rocks are about 300 feet thick and occupy a broad band of prominent sandstone hills about 6 miles wide which trends in a northeast-southwest direction across the middle of the county. Pedee rocks crop out in eastern Woodson county in a narrow band immediately east of the broad outcrop of Douglas rocks. The total thickness of the Lansing group is about 90 feet.

Subsurface Rocks

Rose dome, a small anticline in sec. 13, T. 26 S., R. 15 E., is one of the few places in the state where igneous rocks are known to be intruded into sedimentary rocks. A well drilled on the east flank of Rose dome penetrated igneous rocks, which were reported by Knight and Landes (1932) as "apparently an altered dike rock." Samples of a well south of Rose dome in section 19 were studied by Twenhofel and Bremer (1928, p. 758). They reported peridotite between 1,151 and 1,253 feet. The driller's log of the McGinnis No. 1 Hill well, in the SW¼ SE¼ sec. 32, T. 26 S., R. 15 E. on the flank of the Silver City dome, records "red rock and mica," "shale and mica," and "mica" between depths of 775 and 840 feet.

Subsurface geologic conditions along the northern boundary of Woodson county are shown in plate 4.

Pennsylvanian rocks.—The Kansas City group has an average thickness of about 210 feet in Woodson county and consists chiefly of limestone and shale. The Bronson group, which consists of alternating beds of limestone and shale and some sandstone, is about 210 feet thick. Gas is produced near Neosho Falls from a porous zone in the Dennis limestone in the Bronson group at a depth of about 325 feet. The Bourbon shale consists chiefly of clayey and sandy shale and is about 120 feet thick in the county. The Marmaton rocks consist of alternating beds of shale, limestone, and sandstone; they are about 210 feet thick.

The Cherokee rocks in Woodson county have an average thickness of about 330 feet. They are composed chiefly of clayey and sandy shale, sandstone, and thin beds of limestone and coal. The "Bartlesville sand" lies in the upper middle part of the Cherokee, and thick lenses of sandstone occur near the base. The "Bartlesville" yields both gas and oil in the Iola-Humboldt area which extends into southeastern Woodson county from Allen county.

Mississippian rocks.—The total thickness of Mississippian limestones in Woodson county ranges from 250 to 350 feet (Lee, 1939, pl. 1). Formations present are the Warsaw limestone; the Keokuk limestone which is absent in the northeastern one-third of the county; the Burlington limestone; the Reeds Spring limestone; the St. Joe limestone which is absent in the northeastern corner of the county; the Sedalia limestone which is absent in the western and southwestern parts; the Northview shale; the Compton limestone; and the Chattanooga shale (Mississippian or Devonian). Oil is produced from a porous zone in the upper part of the Mississippian limestones in the Neosho Falls and Yates Center area.

Ordovician and Cambrian rocks.—The thickness of Ordovician and Cambrian rocks in Woodson county is about 700 feet. These rocks are chiefly limestone and dolomite.

Oil and Gas Developments

Much drilling was done in Woodson county in 1919. In April of that year a well in the SW¼ sec. 22, T. 25 S., R. 15 E., which had come in at more than 5,000,000 cubic feet of gas, started flowing oil at a rate estimated at 200 barrels per day. At about that time 23 drilling rigs were in operation and several fairly large producers were completed.

The oil and gas fields of Woodson county as listed by the Oil Field Nomenclature Committee of the Kansas Geological Society are given in table 89.

Oil is produced in the **Neosho Falls** area from the "first break" of the "Mississippi lime" at an average depth of about 1,200 feet.

TABLE 89.—*Oil and gas fields in Woodson county, Kansas*

(As designated by the Oil Field Nomenclature Committee of the Kansas Geological Society, November 15, 1944)

Name	Location
Batesville	T 25 S, R 14 E, secs. 22, 26, 27, 35, 36
	T 26 S, R 14 E, sec. 1
Buffalo[1]	T 26 S, R 16 E, secs. 27 to 29, 31 to 35
Halligan	T 26 S, R 16 E, secs. 25, 36
	T 26 S, R 17 E, secs. 30 to 32
Hoagland	T 23 S, R 14 E, secs. 26, 35, 36
	T 24 S, R 14 E, secs. 1, 2
Humboldt-Chanute[2]	T 25 S, R 17 E, secs. 9, 10, 15 to 17, 20 to 22, 27 to 29, 33, 34
	T 26 S, R 17 E, secs. 3 to 5, 8 to 10, 15 to 17, 22, 27, 34
Laidlaw	T 24 S, R 15 E, secs. 31, 32
Neosho Falls[3]	T 23 S, R 16 E, secs. 24, 25
	T 23 S, R 17 E, secs. 27 to 34
	T 24 S, R 17 E, secs. 3 to 10, 17 to 20
Perry	T 26 S, R 16 E, secs. 23 to 26
	T 26 S, R 17 E, secs. 18 to 20, 30
Piqua	T 24 S, R 17 E, secs. 15, 21, 22, 27, 28
Quincy[4]	T 25 S, R 13 E, secs. 13, 14, 23, 24
	T 25 S, R 14 E, secs. 19 to 21, 27 to 30, 34
Rose	T 26 S, R 15 E, sec. 13
	T 26 S, R 16 E, secs. 18, 19
Strange	T 24 S, R 16 E, sec. 20
Toronto[4]	T 26 S, R 13 E, secs. 1, 11 to 14, 23
Vernon	T 23 S, R 16 E, secs. 20, 21, 27 to 29, 31 to 35
Virgil North[4,5]	T 23 S, R 13 E, secs. 23, 24, 26
Weide	T 23 S, R 15 E, secs. 29 to 32
	T 24 S, R 15 E, secs. 5, 6
Winterscheid[6]	T 23 S, R 13 E, sec. 36
	T 23 S, R 14 E, secs. 19 to 24, 26 to 33
	T 24 S, R 13 E, secs. 1, 12 to 14, 23, 24
	T 24 S, R 14 E, secs. 4 to 7, 18
Wissman	T 24 S, R 15 E, secs. 2, 3

[1] Extends into Wilson county (see table 86)
[2] Extends into Allen, Neosho, and Wilson counties (see tables 3, 75, and 86)
[3] Extends into Allen county (see table 3)
[4] Extends into Greenwood county (see table 42)
[5] Also in secs. 11 and 14, T. 23 S., R. 13 E., Coffey county
[6] Also in secs. 13 to 16, T. 23 S., R. 14 E., Coffey county

The discovery well in this area was drilled in sec. 31, T. 23 S., R. 16 E. in 1928. The average initial production of wells has been about 20 barrels of oil per day. Daily production usually declines to about 10 barrels or less within the first year. Gas is produced in this area from a sandy zone in the Winterset limestone at a depth of about 325 feet. The accumulation of oil and gas is controlled by changes in porosity and structure.

The **Quincy** producing area of Greenwood county was extended into Woodson county in 1932. The discovery well, near the center of sec. 14, T. 25 S., R. 13 E., had an initial production of about 100 barrels of oil per day from the "Bartlesville sand" at a depth of about 1,500 feet.

The **Sheedy** oil pool, in sec. 19, T. 25 S., R. 14 E., was discovered in December, 1932. The discovery well had an initial production of about 400 barrels from the "Bartlesville sand" at a depth of 1,420 feet. In the **Winterscheid** pool, in sec. 31, T. 23 S., R. 14 E. and sec. 6, T. 24 S., R. 14 E., oil is produced from the "Bartlesville sand." The average initial production of wells has been about 160 barrels. Large quantities of oil are produced from the "Bartlesville shoestring sands" in the **Toronto** and **Batesville** pools.

Oil and gas production figures for Woodson county are given in tables 90 and 91.

WYANDOTTE COUNTY

Gas was discovered in Wyandotte county soon after the first drilling for oil in Miami county. Comparatively small amounts of gas have been produced in the county for many years and a small amount of oil is reported to have been taken from at least one or two wells.

The geology of Wyandotte county was described by Jewett and Newell (1935). Their report includes a description of outcropping rocks and areal and structural geologic maps. The subsurface geology of Wyandotte and other northeastern Kansas counties was discussed by Ockerman (1935).

Surface Rocks

Deposits of glacial drift in Wyandotte county are fairly thin and are scattered. However, much of the county is covered by deposits of loess—accumulations of clay and silt which are believed to have been deposited by wind. The trenches of Missouri

TABLE 90.—*Reported monthly production of oil in Woodson county, Kansas, in barrels*[1]

Month	1941		1942		1943		1944	
	No. of wells	Production	No. of wells	Production	No. of wells	Production	No. of wells	Production
January	318	23,518	305	21,741	270	19,316	259	18,755
February	318	25,601	294	21,202	266	19,564	259	17,110
March	312	24,444	307	22,573	261	20,601	257	17,391
April	304	24,330	311	24,625	262	19,853	257	17,880
May	301	23,740	304	23,103	261	20,753	257	18,817
June	305	22,661	311	23,319	240	23,264	257	17,640
July	304	23,780	312	23,448	259	20,794	257	15,004
August	310	24,431	305	21,846	258	23,027	257	20,739
September	307	26,797	286	21,407	259	20,340	255	18,120
October	292	22,501	281	21,298	258	22,938	256	18,476
November	295	23,098	286	20,218	259	20,835	257	17,730
December	297	22,180	281	19,050	258	21,978	257	16,895
Totals		287,081		263,830		253,263		214,557

[1] Oil produced in the Toronto pool is included in Greenwood county table.

TABLE 91.—*Natural gas production in Woodson county, Kansas*

Year	Thousands of cubic feet
1939	62,484
1940	52,542
1941	87,984
1942	105,118
1943	106,252

and Kansas rivers are partly filled with gravel, sand, and silt. The maximum thickness of valley-fill deposits is about 100 feet.

The outcropping consolidated rocks in Wyandotte county are of Pennsylvanian age. The youngest of these is the Tonganoxie sandstone member of the Stranger formation and the oldest is the Bethany Falls limestone member of the Swope formation. The Tonganoxie sandstone, which comprises the basal part of the Douglas group (fig. 7), is the surface rock in the upland areas in the western part of Wyandotte county. It consists of sandstone and shale and commonly a limestone conglomerate in the basal part. The maximum thickness is about 30 feet. A regional disconformity separates the Tonganoxie sandstone from underlying rocks. A few feet of the Weston shale of the Pedee group (fig. 8) is locally present in the county between the disconformity and the Stanton limestone, but in most of the area the sandstone or conglomerate lies on the Stanton limestone. Locally in the northwestern part of the county the disconformity cuts well into or through the Stanton formation.

The Lansing group in Wyandotte county is about 75 feet thick. The outcrops of the Stanton limestone in Wyandotte county are near the uplands capped by the Tonganoxie sandstone, but the Plattsburg limestone lies below a dip slope 5 miles or more in width in the north-central part of the county. The thickness of rocks of the Kansas City group in the county ranges from about 160 to 225 feet. The range in thickness is due to abrupt lateral changes, particularly in the shale units. Limestones that show abrupt lateral changes in lithology and to a lesser degree in thickness include especially the Farley limestone member of the Wyandotte formation and the Westerville limestone. The Dennis limestone, Galesburg shale, and most of the Swope limestone of the Bronson group are exposed in a quarry about one-half mile east of Morris in the W½ sec. 27, T. 12 S., R. 24 E. These rocks are less prominent eastward along the valley wall of Kansas river.

Subsurface Rocks

Pennsylvanian rocks.—The base of the Hertha limestone is a convenient datum horizon in Wyandotte county, as elsewhere in eastern Kansas. The average thickness of rocks between the Hertha limestone and the Mississippian rocks in Wyandotte county is about 700 feet.

Mississippian rocks.—The average total thickness of Mississippian limestone formations in Wyandotte county is about 450 feet (Lee, 1939, pl. 1). According to Lee and Payne (1944, figs. 12, 17), the St. Louis limestone is the uppermost Mississippian limestone formation in the county. Lee's studies (1943, fig. 14) of wells in Wyandotte and surrounding counties indicate that the maximum thickness of the Chattanooga shale in the county is slightly more than 50 feet and that the thickness decreases to the east.

Devonian rocks.—Lee (1943, fig. 7, pp. 53, 55) believes that Devonian limestone underlies all parts of Wyandotte county. He identified 36 feet of Cooper and undifferentiated limestone in the McCain No. 1 Doane well, in sec. 34, T. 12 S., R. 22 E., Johnson county, about 11 miles southwest of the southwest corner of Wyandotte county. Lee (1943, p. 53) pointed out that about 200 feet of Devonian limestone is present in Clay and Platte counties, Missouri.

Ordovician and Cambrian rocks.—Silurian and Upper Ordovician rocks (Maquoketa shale and some older beds) are believed to be absent in Wyandotte county (Lee, 1943, figs. 6, 11, 13). The uppermost Ordovician rock in the county is believed to be the Kimmswick (Viola) limestone. Its maximum thickness is probably about 100 feet. A few feet of Decorah and Plattin limestones is probably present in all parts of the county. The St. Peter sandstone probably is less than 100 feet thick in the county. According to Lee (1943, fig. 9), the thickness of rocks between the top of the St. Peter sandstone and the top of pre-Cambrian rocks in Wyandotte county ranges from slightly less than 800 feet to slightly more than 900 feet. The thickness of rocks between the top of the Roubidoux formation and the top of the Lamotte sandstone ranges from slightly more than 600 feet to more than 700 feet (Lee, 1943, fig. 10). Formations older than the St. Peter sandstone in Wyandotte county are believed to include Cotter and Jefferson City dolomites, Roubidoux formation, Gasconade and Van Buren dolomites, Gunter sandstone, Eminence dolomite, Potosi dolomite (?), Bonneterre dolomite, and Lamotte sandstone.

Oil and Gas Developments

It is reported that several years ago small amounts of oil were obtained at shallow depths from a well in the SE¼ sec. 1, T. 11 S.,

R. 23 E. and from a well in the southeastern part of the county near Argentine.

The **Bethel** gas-producing area is in secs. 23 to 26, 35, and 36, T. 10 S., R. 23 E.; secs. 19, 30, and 31, T. 10 S., R. 24 E.; secs. 1, 2, and 12, T. 11 S., R. 23 E.; and sec. 6, T. 11 S., R. 24 E. Formerly there were many producing wells, but nearly all have now been abandoned. A Marmaton sandstone, probably the "Wayside," and the "Squirrel sand" are the producing formations.

The **Roberts-Maywood** area is in the S½ sec. 33, T. 10 S., R. 23 E.; sec. 12, T. 11 S., R. 22 E.; and secs. 3, 4, 7 to 10, 16, and 17, T. 11 S., R. 23 E. It includes the Roberts gas pool which extends into southeastern Leavenworth county. Production in this pool is from a Marmaton sandstone and the "Squirrel sand."

Wells in the **Welborn** gas area are now abandoned excepting a few wells that supply gas for local use. This area is in secs. 23 to 26, 35, and 36, T. 10 S., R. 24 E.; secs. 19, 30, and 31, T. 10 S., R. 25 E.; and secs. 1 and 2, T. 11 S., R. 24 E. Gas was found in a Marmaton sandstone and in the "Squirrel sand."

Gas wells in the **Fairfax** area, chiefly in secs. 26 and 27, T. 10 S., R. 25 E., are now abandoned. Gas was formerly produced there from two Marmaton sandstones.

The **Bonner Springs** area is in secs. 19, 20, 21, 28, 29, and 30, T. 11 S., R. 23 E. A small amount of gas is being produced. The **Edwardsville** area is in secs. 23 to 26, T. 11 S., R. 23 E. No commercial gas is being produced, but a few wells supply gas for local use. In 1889 a well was drilled about one-half mile north of Bonner Springs to a depth of 2,150 feet. The Wood No. 1 Wood well, in sec. 21, T. 11 S., R. 23 E., was drilled in 1904, and is reported to have had a show of oil at 505 feet and to have found 200,000 cubic feet of gas at 440 feet. This well was drilled to a depth of 770 feet.

Several gas wells in the Kansas City industrial district supply fuel for local plants. The Paullin No. 2 Paullin well drilled in 1904 "one-haf mile southeast of Argentine" is reported to have yielded about one barrel of lubricating oil and 25,000 cubic feet of gas in 24 hours from a depth of 139 feet (Fuller and Sanford, 1906, p. 82).

The figures in table 57 include some gas production from Wyandotte county. An unknown quantity of gas not included in the table is produced and used locally in the county.

REFERENCES

ABERNATHY, G. E., *1939*, Oil and gas exploration map, Labette county, Kansas; Kansas Geol. Survey, scale 1 inch to 1¼ miles.

————, *1940*, Oil and gas in Montgomery county, Kansas: Kansas Geol. Survey, Bull. 31, pp. 1-29, figs. 1-6, pls. 1-2.

————, *1943*, Deep water well at the Jayhawk Ordnance Works in Cherokee county, Kansas: Kansas Geol. Survey, Bull. 47, pt. 3, pp. 77-112, figs. 1-4.

BASS, N. W., *1929*, The geology of Cowley county, Kansas: Kansas Geol. Survey, Bull. 12, pp. 1-203, figs. 1-23, pls. 1-12.

————, *1936*, Origin of the shoestring sands of Greenwood and Butler counties, Kansas: Kansas Geol. Survey, Bull. 23, pp. 1-135, figs. 1-10, pls. 1-21.

————, LEATHEROCK, CONSTANCE, DILLARD, W. R., and KENNEDY, L. E., *1937*, Origin and distribution of Bartlesville and Burbank shoestring oil sands in parts of Oklahoma and Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 21, no. 1, pp. 30-66, figs. 1-17.

BEEKLY, A. L., *1929*, Virgil pool, Greenwood county, Kansas: Structure of typical American oil fields, vol. 2, pp. 142-149, figs. 1-4, Am. Assoc. Petroleum Geologists.

BOWSHER, A. L., and JEWETT, J. M., *1943*, Coal resources of the Douglas group in east-central Kansas: Kansas Geol. Survey, Bull. 46, pp. 1-94, figs. 1-12, pls. 1-6.

CADMAN, W. K., *1927*, The Golden Lanes of Greenwood county, Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 11, no. 11, pp. 1151-1172, figs. 1-10, pls. 1, 2.

CHARLES, H. H., *1927*, Oil and gas resources of Kansas; Anderson county: Kansas Geol. Survey, Bull. 6, pt. 7, pp. 1-95, figs. 1-13, pls. 1-10.

FATH, A. E., *1921*, Geology of the Eldorado oil and gas field, Butler county, Kansas: Kansas Geol. Survey, Bull. 7, pp. 1-187, figs. 1-9, pls. 1-19.

FOLGER, ANTHONY, and HALL, R. H., *1933*, Development of the oil and gas resources of Kansas in 1928, 1929, and 1930: Kansas Geol. Survey, Mineral Resources Circ. 2, pp. 1-174.

FORBES, GERALD, *1942*, Flush production: Univ. of Oklahoma Press, Norman, Okla., pp. 1-253, illustrated.

FRYE, J. C., *1941*, Reconnaissance of ground-water resources in Atchison county, Kansas: Kansas Geol. Survey, Bull. 38, pt. 9, pp. 237-260, figs. 1-6, pls. 1-3.

FULLER, M. L., and SANFORD, SAMUEL, *1906*, Record of deep well drilling for 1905: U. S. Geol. Survey, Bull. 298, pp. 1-299.

GOULD, C. N., *1925*, Index to stratigraphy of Oklahoma: Oklahoma Geol. Survey, Bull. 35, pp. 1-115.

GRANDONE, PETER, *1944*, History of water-flooding of oil sands in Kansas: U. S. Bur. Mines, Rept. of Investigations 3761, pp. 1-146, figs. 1-52.

HAWORTH, ERASMUS, *1903*, Mineral resources of Kansas: Kansas Univ. Geol. Survey, Ann. Bull. on Mineral Resources of Kansas for 1902, pp. 1-135.

————, *1908*, Special report on oil and gas: Kansas Univ. Geol. Survey, vol. 9, pp. 1-586.

————, and MCFARLAND, D. F., *1905*, The Dexter, Kansas, nitrogen gas well; Science, n. ser., vol. 21, pp. 191-193.

HOOT, CARL, *1944*, Discovery wells increase 32 per cent: Oil and Gas Jour., Jan. 27, pp. 232-241.

JEWETT, J. M., *1940*, Asphalt rock in eastern Kansas: Kansas Geol. Survey, Bull. 29, pp. 1-23, figs. 1-3, pls. 1, 2.

———, *1940a*, Oil and gas in Linn county, Kansas: Kansas Geol. Survey, Bull. 30, pp. 1-29, figs. 1-7, pls. 1-3.

———, *1941*, The geology of Riley and Geary counties, Kansas: Kansas Geol. Survey, Bull. 39, pp. 1-164, figs. 1, 2, pls. 1-17.

———, *1941a*, Classification of the Marmaton group, Pennsylvanian, in Kansas: Kansas Geol. Survey, Bull. 38, pt. 11, pp. 285-344, pls. 1-9.

JEWETT, J. M., and NEWELL, N. D., *1935*, The geology of Wyandotte county, Kansas: Kansas Geol. Survey, Bull. 21, pt. 2, pp. 151-205, fig. 2, pls. 13-23.

JEWETT, J. M., and SCHOEWE, W. H., *1942*, Kansas mineral resources for wartime industries: Kansas Geol. Survey, Bull. 41, pt. 3, pp. 69-180, figs. 1-13.

KESLER, L. W., *1928*, Oil and gas resources of Kansas in 1927: Kansas Geol. Survey, Mineral Resources Circ. 1, pp. 1-60, figs. 1-6.

KNIGHT, G. L., and LANDES, K. K., *1932*, Kansas laccoliths: Jour. Geology, vol. 40, no. 1, pp. 1-15, figs. 1-3.

KOESTER, E. A., *1934*, Development of the oil and gas resources of Kansas in 1931 and 1932: Kansas Geol. Survey, Mineral Resources Circ. 3, pp. 1-76.

LANDES, K. K., *1927*, A petrographic study of the pre-Cambrian of Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 11, no. 8, pp. 821-824.

———, *1937*, Mineral resources of Kansas counties: Kansas Geol. Survey, Mineral Resources Circ. 6, pp. 1-110.

LEE, WALLACE, *1939*, Relation of thickness of Mississippian limestones in central and eastern Kansas to oil and gas deposits: Kansas Geol. Survey, Bull. 26, pp. 1-42, figs. 1-4, pls. 1-3.

———, *1940*, Subsurface Mississippian rocks of Kansas: Kansas Geol. Survey, Bull. 33, pp. 1-114, figs. 1-4, pls. 1-10.

———, *1941*, Preliminary report on the McLouth gas and oil field, Jefferson and Leavenworth counties, Kansas: Kansas Geol. Survey, Bull. 38, pt. 10, pp. 261-284, figs. 1, 2, pls. 1-3.

———, *1943*, The stratigraphy and structural development of the Forest City basin in Kansas: Kansas Geol. Survey, Bull. 51, pp. 1-142, figs. 1-22.

———, and PAYNE, T. G., *1944*, McLouth gas and oil field, Jefferson and Leavenworth counties, Kansas: Kansas Geol. Survey, Bull. 53, pp. 1-195, figs. 1-20, pls. 1-10.

LOOMIS, HARVE, *1923*, The Burkett-Seeley pool, Greenwood county, Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 7, no. 5, pp. 482-487, figs. 1-3.

MCCLELLAN, H. W., *1930*, Subsurface distribution of pre-Mississippian rocks of Kansas and Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 14, no. 12, pp. 1535-1556, figs. 1-3.

MOORE, R. C., *1918*, Geologic history of crystalline rocks of Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 2, pp. 98-113.

———, *1936*, Stratigraphic classification of the Pennsylvanian rocks of Kansas: Kansas Geol. Survey, Bull. 22, pp. 1-256, figs. 1-12.

MOORE, R. C., and BOUGHTON, C. W., 1921, Oil and gas resources of Kansas; Wilson and Montgomery counties: Kansas Geol. Survey, Bull. 6, pt. 6, pp. 1-32, figs. 1-3, pls. 1-4.

MOORE, R. C., and ELLEDGE, E. R., *1920*, Oil and gas resources of Kansas: Allen and Neosho counties: Kansas Geol. Survey, Bull. 6, pt. 5, pp. 1-22, figs. 1, 2, pls. 1-4.

MOORE, R. C., and FRYE, J. C., *1942*, Map of the mineral resources of Kansas: Kansas Geol. Survey.

MOORE, R. C., FRYE, J. C., and JEWETT, J. M., *1944*, Tabular description of outcropping rocks in Kansas: Kansas Geol. Survey, Bull. 52, pt. 4, pp. 137-212, figs. 1-9.

MOORE, R. C., and HAYNES, W. P., *1917*, Oil and gas resources of Kansas: Kansas Geol. Survey, Bull. 3, pp. 1-391, figs. 1-24, pls. 1-40.

MOORE, R. C., and JEWETT, J. M., *1942*, Oil and gas fields of Kansas: The Mines Mag., vol. 32, no. 10, pp. 481-488, 515-520, 526, 538, 560, figs. 1-12.

MOORE, R. C., and LANDES, K. K., *1937*, Geologic map of Kansas: Kansas Geol. Survey, scale 1:500,000.

MOORE, R. C., and others, *1936*, Kansas Geol. Soc., Guidebook 10th Ann. Field Conference, pp. 1-73, figs. 1-47.

————, *1937*, Kansas Geol. Soc., Guidebook 11th Ann. Field Conference, pp. 1-108, figs. 1-34.

————, *1944*, Correlation of the Pennsylvanian formations of North America: Geol. Soc. America Bull., vol. 55, no. 6, pp. 657-706, pl. 1.

NEWELL, N. D., *1935*, The geology of Johnson and Miami counties, Kansas: Kansas Geol. Survey, Bull. 21, pt. 1, pp. 1-150, fig. 1, pls. 1-12.

OCKERMAN, J. W., *1935*, Subsurface studies in northeastern Kansas: Kansas Geol. Survey, Bull. 20, pp. 1-78, figs. 1-4, pls. 1-13.

PLUMMER, NORMAN, and ROMARY, J. F., *1942*, Stratigraphy of the pre-Greenhorn Cretaceous beds of Kansas: Kansas Geol. Survey, Bull. 41, pt. 9, pp. 313-348, figs. 1-4, pls. 1, 2.

REEVES, J. R., *1929*, El Dorado oil field, Butler county, Kansas: Structure of typical American oil fields, vol. 2, pp. 160-167, 5 figs., Am. Assoc. Petroleum Geologists.

RICH, J. L., *1923*, Shoestring sands of eastern Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 7, no. 2, pp. 103-113, figs. 1-6.

————, *1926*, Further observations on shoestring oil pools of eastern Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 10, no. 6, pp. 568-580, figs. 1-3.

SCHOEWE, W. H., *1943*, Kansas oil field brines and their magnesium content: Kansas Geol. Survey, Bull. 47, pt. 2, pp. 37-76, figs. 1-3.

THOMAS, C. R., *1927*, Flank production of the Nemaha Mountains (granite ridge), Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 11, no. 9, pp. 919-931, figs. 1-5.

TWENHOFEL, W. H., and BREMER, BERNARD, *1928*, An extension of the Rose dome intrusives in Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 12, no. 7, pp. 757-762.

VER WIEBE, W. A., *1938*, Oil and gas resources of western Kansas: Kansas Geol. Survey, Mineral Resources Circ. 10, pp. 1-179, unnumbered figs.

————, *1939*, Western Kansas oil and gas developments during 1938: Kansas Geol. Survey, Mineral Resources Circ. 13, pp. 1-106, unnumbered figs.

————, *1940*, Exploration for oil and gas in western Kansas during 1939: Kansas Geol. Survey, Bull. 28, pp. 1-106, figs. 1-34.

————, *1941*, Exploration for oil and gas in western Kansas during 1940: Kansas Geol. Survey, Bull. 36, pp. 1-109, figs. 1-40.

————, *1942*, Exploration for oil and gas in western Kansas during 1941: Kansas Geol. Survey, Bull. 42, pp. 1-123, figs. 1-42.

————, *1943*, Oil industry in Kansas during 1942: Am. Inst. Min. and Met. Engrs. Trans., vol. 151, pp. 348-360.

————, *1943a*, Exploration for oil and gas in western Kansas during 1942: Kansas Geol. Survey, Bull. 48, pp. 1-88, figs. 1-30.

————, *1944*, Oil and gas fields of Kansas during 1943: Am. Inst. Min. and Met. Engrs. Trans., vol. 155, pp. 340-352.

————, *1944a*, Exploration for oil and gas in western Kansas during 1943: Kansas Geol. Survey, Bull. 54, pp. 1-104, figs. 1-31.

INDEX

WASHINGTON COUNTY				MARSHALL COUNTY							NEMAHA COUNTY					ATCHISON COUNTY			
CLAY COUNTY				RILEY COUNTY			POTTAWATOMIE COUNTY					JACKSON COUNTY							
R.1E.	R.2E.	R.3E.	R.4E.	R.5E.	R.6E.	R.7E.	R.8E.	R.9E.	R.10E.	R.11E.	R.12E.	R.13E.	R.14E.	R.15E.	R.16E.	R.17E.	R.18E.	R.19E.	R.20E.

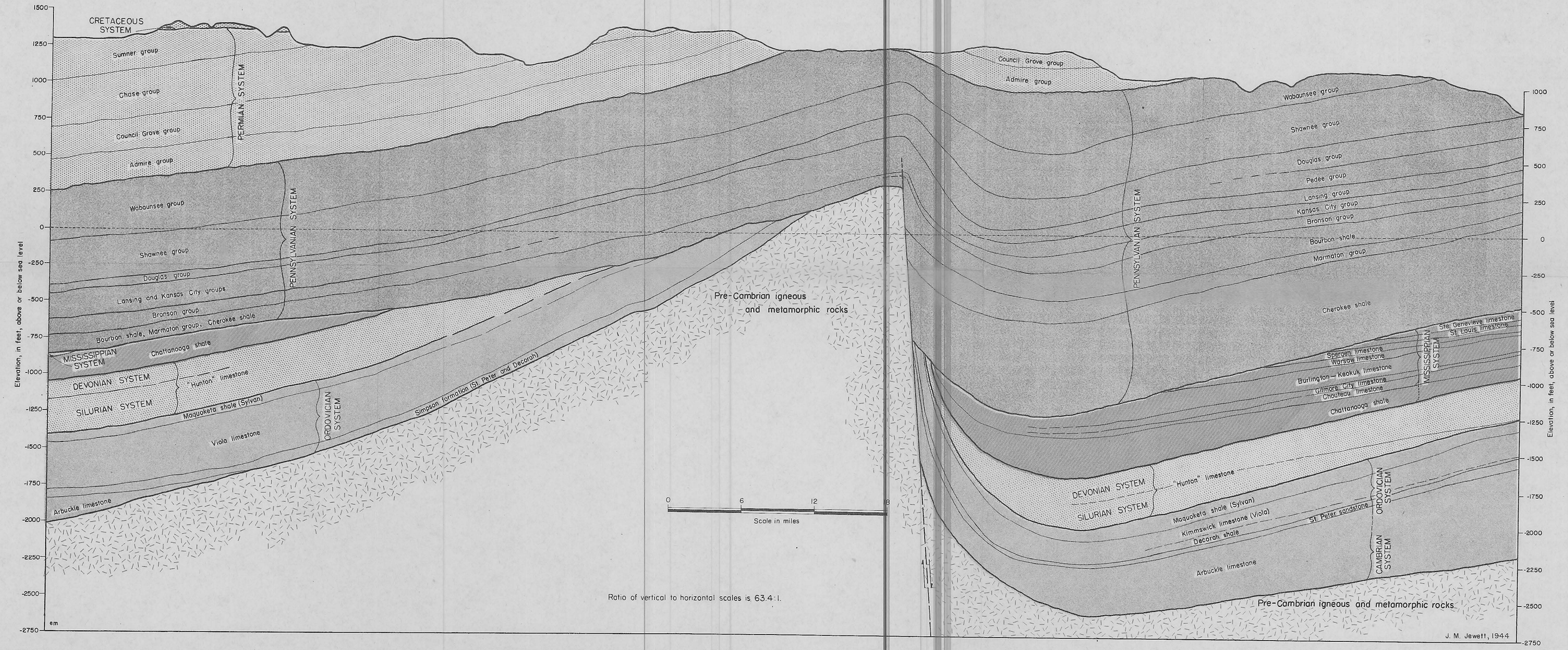

PLATE I. Diagrammatic geologic cross section in eastern Kansas along the south side of Township 5 South.

DICKINSON COUNTY				MORRIS COUNTY					WABAUNSEE COUNTY / LYON COUNTY				OSAGE COUNTY				DOUGLAS COUNTY / FRANKLIN COUNTY				JOHNSON COUNTY / MIAMI COUNTY			
R.1E.	R.2E.	R.3E.	R.4E.	R.5E.	R.6E.	R.7E.	R.8E.	R.9E.	R.10E.	R.11E.	R.12E.	R.13E.	R.14E.	R.15E.	R.16E.	R.17E.	R.18E.	R.19E.	R.20E.	R.21E.	R.22E.	R.23E.	R.24E.	R.25E.

PLATE 2. Diagrammatic geologic cross section in eastern Kansas through the center of Township 15 South.

BUTLER COUNTY						GREENWOOD COUNTY					COFFEY COUNTY / WOODSON COUNTY				ANDERSON COUNTY / ALLEN COUNTY				LINN COUNTY / BOURBON COUNTY			
R. 3E.	R. 4E.	R. 5E.	R. 6E.	R. 7E.	R. 8E.	R. 9E.	R. 10E.	R. 11E.	R. 12E.	R. 13E.	R. 14E.	R. 15E.	R. 16E.	R. 17E.	R. 18E.	R. 19E.	R. 20E.	R. 21E.	R. 22E.	R. 23E.	R. 24E.	R. 25E.

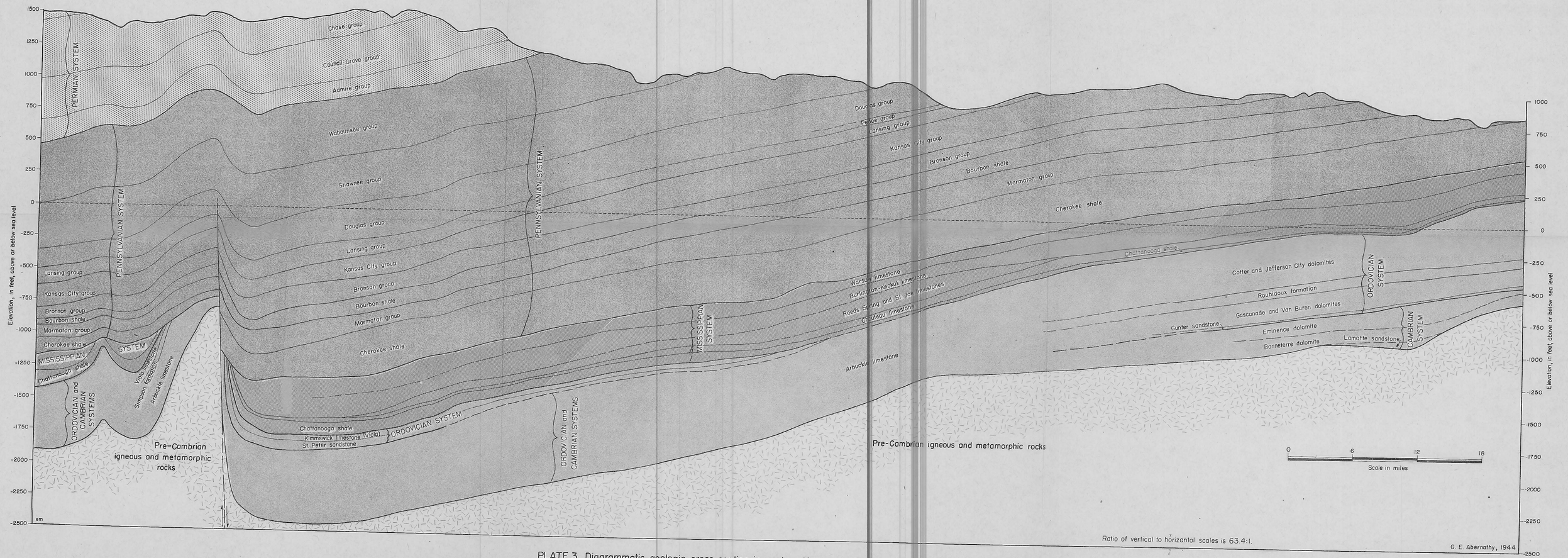

PLATE 3. Diagrammatic geologic cross section in eastern Kansas through the center of Township 23 South.

COWLEY COUNTY						ELK COUNTY						MONTGOMERY COUNTY				LABETTE COUNTY				CRAWFORD COUNTY CHEROKEE COUNTY			
R. 3 E.	R. 4 E.	R. 5 E.	R. 6 E.	R. 7 E.	R. 8 E.	R. 9 E.	R. 10 E.	R. 11 E.	R. 12 E.	R. 13 E.	R. 14 E.	R. 15 E.	R. 16 E.	R. 17 E.	R. 18 E.	R. 19 E.	R. 20 E.	R. 21 E.	R. 22 E.	R. 23 E.	R. 24 E.	R. 25 E.

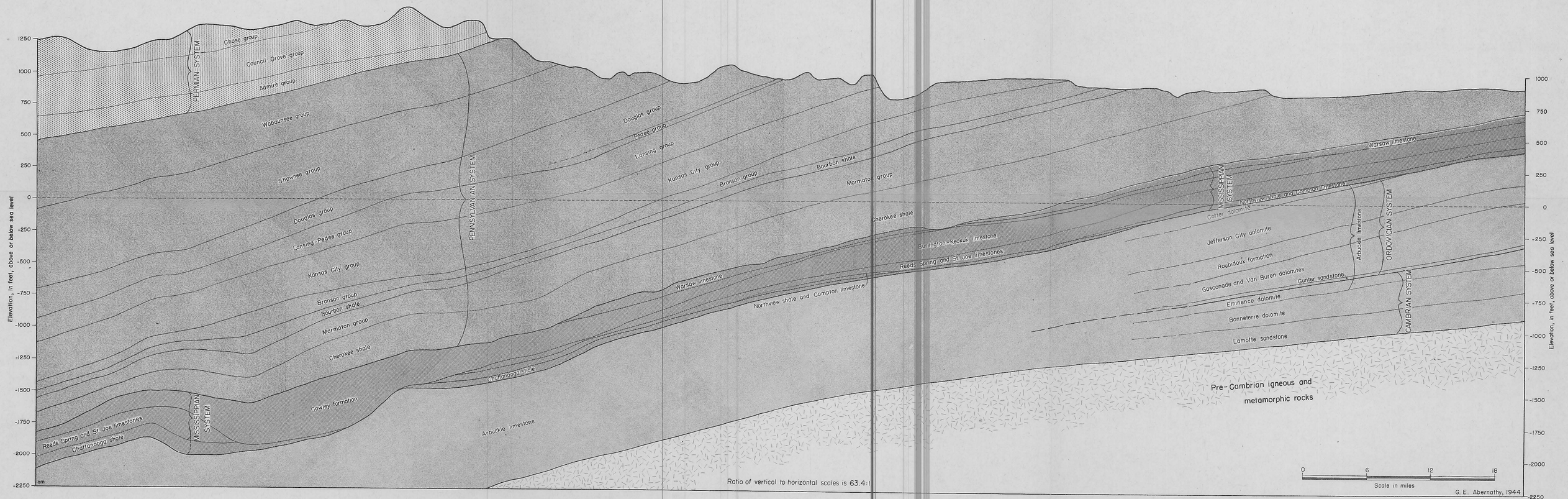

PLATE 4. Diagrammatic geologic cross section in eastern Kansas through the center of Township 31 South.