STATE GEOLOGICAL SURVEY OF KANSAS

RAYMOND C. MOORE, Ph. D., Sc. D.,
State Geologist and Director

KENNETH K. LANDES, Ph. D.,
State Geologist and Assistant Director

BULLETIN 30

OIL AND GAS IN LINN COUNTY, KANSAS

By JOHN M. JEWETT
with chapters by WALLACE LEE and R. P. KEROHER

PRINTED BY AUTHORITY OF THE STATE OF KANSAS
DISTRIBUTED FROM LAWRENCE

UNIVERSITY OF KANSAS PUBLICATIONS
VOL. 1940, NO. 5, SEPTEMBER 10, 1940
18-5069

STATE OF KANSAS

PAYNE H. RATNER, *Governor*

STATE BOARD OF REGENTS

FRED M. HARRIS, *Chairman*

LESTER MCCOY
DREW MCLAUGHLIN
W. T. MARKHAM
MRS. DONALD MUIR
RALPH T. O'NEIL*
GROVER POOLE
MRS. ELIZABETH REIGART
DR. H. L. SNYDER

MINERAL INDUSTRIES COUNCIL

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

STATE GEOLOGICAL SURVEY OF KANSAS

DEANE W. MALOTT, Chancellor of the University of Kansas, and ex officio Director of the Survey

ADMINISTRATION

R. C. Moore, Director and State Geologist
K. K. Landes, Assistant Director and State Geologist
Lea Dreibing, Secretary
Maribelle McClelland, Stenographer
D. E. Dowers, Draftsman
J. E. Clark, Draftsman
Ralph H. King, Editor

DIVISION OF STRATIGRAPHY, PALEONTOLOGY AND AREAL GEOLOGY

R. C. Moore, Geologist in charge
J. M. Jewett, Stratigraphic Geologist
Ralph H. King, Paleontologist
Ruth Mary Dudley, Research Assistant
Russell Jeffords, Assistant

DIVISION OF GROUND WATER (coöperative project with U. S. Geological Survey)

S. W. Lohman, Geologist in charge
Herbert Waite, Assistant Geologist
John Frye, Assistant Geologist
Thad McLaughlin, Junior Geologist
Bruce Latta, Junior Geologist
Ruth A. Wilson, Stenographer
Ellis Gordon, Driller
Perry McNally, Sampler

SPECIALISTS ON PART-TIME BASIS

Walter A. Ver Wiebe, Petroleum Geologist
Walter H. Schoewe, Pleistocene Geologist
H. T. U. Smith, Physiographic Geologist
Robert Dreyer, Economic Geologist
E. D. Kinney, Metallurgist

DIVISION OF ECONOMIC GEOLOGY

K. K. Landes, Geologist in charge

DEPARTMENT OF SUBSURFACE GEOLOGY

Raymond P. Keroher, Geologist in charge
Wallace Lee, Coöperative Geologist
Jacob Lemmons, Assistant
Louellen Montgomery, Clerk
Homer French, Curator of well samples

DEPARTMENT OF MINERAL RESOURCES

G. E. Abernathy, Petroleum Geologist
John Moore, Petroleum Technologist
Norman Plummer, Ceramic Geologist
Ray Whitla, Assistant Geologist
John Romary, Assistant Geologist

DIVISION OF TOPOGRAPHIC SURVEYS (coöperative project with U. S. Geological Survey)

C. L. Sadler, Section Chief, Central Division, in charge

* Deceased.

CONTENTS

ILLUSTRATIONS

OIL AND GAS IN LINN COUNTY, KANSAS

By JOHN M. JEWETT

INTRODUCTION

Location.—Linn county is in the eastern tier of counties next to the Kansas-Missouri boundary. It is the fourth county southward from Kansas City, and the fourth northward from the southeast corner of Kansas. It is approximately 25 miles square and it is bounded on the north by Miami county, on the east by Bates county, Missouri, on the south by Bourbon county, and on the west by Anderson county. The county seat is Mound City.

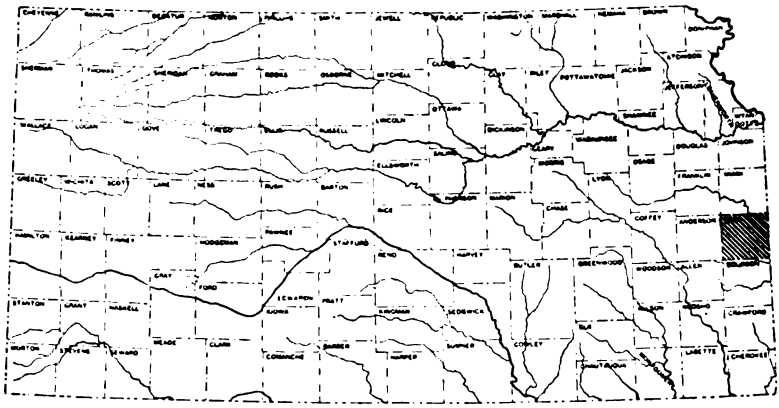

FIG. 1.—Index map of Kansas, showing location of Linn county.

There are three railroads in the county. The Missouri, Kansas and Texas railway passes through Centerville, Goodrich, and Parker in the western part of the county. The St. Louis and San Francisco railway is in the eastern part, passing through Prescott, Pleasanton, and La Cygne. Mound City is the western terminus of a branch line of the Missouri Pacific railway, which passes through Pleasanton. U. S. highway 69 and state highway 7 traverse the county from north to south, the former near the eastern edge and the latter through the central part. State highways 31 and 3 traverse the southwestern part of the county, state highway 52 connects 69 and

7, by way of Mound City, and state highway 35 connects the same roads by way of La Cygne. There is a good system of county roads along almost all of the section lines.

Purpose of the report.—The compilation of data relative to the oil and gas industry in Linn county is made for the purpose of assisting in the development of the mineral industry of the county. The investigation leading to this report and accompanying map has been a part of general geologic studies of the Survey in eastern Kansas. A map showing the detailed areal geology of the county, and descriptions of the outcropping rocks are planned for later publication. This map and report are a part of a series being published on southeastern Kansas counties. A similar report for Labette county by G. E. Abernathy has recently been published and one on Montgomery county has been completed.

Field work.—I have studied Linn county during parts of several field seasons. In the summers of 1937 and 1938 I obtained many logs of wells drilled in the county. Additional logs, especially of more recent wells, were obtained in 1939. Some records have been in the files of the State Geological Survey for many years and have been obtained by different persons. The map was compiled from a study of all available well logs.

Acknowledgments.—I am deeply indebted to my many friends who are engaged in various phases of the oil and gas industry in Linn and neighboring counties. Space permits only a very incomplete list, but acknowledgment of assistance is made particularly to the following: H. D. Evans, Roy Cook, and Roe Henderson of Pleasanton; T. S. Salathiel of Fort Scott; A. L. Woodrum and D. D. Richards of Garnett; John A. Edwards and Chas. Willis of Paola; J. S. Cyr of Prescott; C. E. Morris of Ottawa; and George Shrier of Nowata, Okla. I am especially indebted to Dean McGee and Robert Garrett of the Kerlyn Oil Company, Oklahoma City, Okla., for well records and other information. The Linn county engineer, Charles Kinney, and his staff have been especially helpful in many phases of my studies. They supplied data from which the profile of the county across T. 21 S. was constructed. Many other citizens have been helpful, and all with whom I have had contact have been extremely courteous. Thanks are expressed to Elsie Lowell, a student in the University of Kansas, who skillfully helped in assembling the data.

SURFACE FORMATIONS

DISTRIBUTION AND AREAL EXTENT

The layers of bedrock in Linn county dip gently to the north of west. Hence the older and lower rocks occur at the surface in the eastern and southeastern part and the younger layers in the western and northwestern part of the county. Strata that are exposed at the surface in the eastern part are present in the subsurface in the western part. This condition is shown in plate 1. With the exception of a few feet of unconsolidated deposits of Tertiary (?), Pleistocene, and Recent age, the surface rocks are entirely of Pennsylvanian (Upper Carboniferous) age. They include most of the Marmaton group, all of the Bourbon, Bronson, and Kansas City groups, and the lower 50 feet of the Lansing group. The Marmaton group belongs to the Des Moines series and the other groups belong to the Missouri series. The surface formations are shown in some detail on the accompanying stratigraphic section of outcropping rocks (pl. 2A).

DES MOINES SERIES

The Marmaton group includes the following formations, named in upward order: Fort Scott limestone, Labette shale, Pawnee limestone, Bandera shale, Altamont limestone, Nowata shale, Lenapah limestone, and Memorial shale. All the Marmaton strata, except the Fort Scott limestone (Oswego lime of drillers), are exposed in Linn county. It should be noted from the stratigraphic sections that the limestone formations consist of various limestone members that are separated by shale members. The thickness and other details of rock formations of the county are indicated in the stratigraphic section (pl. 2). The Mulberry coal, near the base of the Bandera shale, is being mined in eastern Linn county and at Mound City. This coal bed has been traced by me to a point a very short distance north of the southern boundary of Bourbon county, about 45 miles south of Linn county. It is commercially important in northern Bourbon county. The base of the upper member of the Altamont formation is an excellent key horizon for surface structural mapping in eastern Linn county. This upper (Worland limestone) member is persistent and can be identified in the field by lithologic and paleontologic features, by its position in the sequence of beds, and especially by the occurrence of numerous small phosphatic con-

cretions in the shale directly below it. The lower limestone member of the Altamont formation is not persistent, but is recognized in widely separated places.

MISSOURI SERIES

Definition of the Hepler sandstone.—Above the Marmaton group is the Bourbon group, containing about 150 feet of shale and sandstone and locally 40 feet or more of alternating very hard dark-blue and dark shale beds in the upper part. At the base is a very persistent sandstone, which is generally not more than 3 or 4 feet thick, but which is about 20 feet thick north of Pleasanton, where it is asphalt-bearing. This sandstone is a good marker, and its upper surface can be used as a key horizon for surface mapping. It is equivalent to the lower part of the Seminole formation in Oklahoma and probably to the Warrensburg sandstone in Missouri. It is here named the Hepler sandstone and classed as a formation of the Bourbon group. Field studies show that the Bourbon strata are lithologically varied and are divisible into several formations. The Checkerboard limestone of Oklahoma is tentatively identified in Kansas as a part of the Bourbon beds. From Kansas City southward to Linn county a sandy zone called the Knobtown sandstone (Greene, 1933, pp. 13, 19) occurs in the upper part of the Bourbon. This sandstone, which is very lenticular, is recognized in central Linn county, but alternating beds of dark-blue flaggy limestone and shale are found at this stratigraphic position in southern Linn county and northern Bourbon county. Subdivisions of the Bourbon group above the Hepler sandstone are to be discussed in a later paper.

The thickness of the Hepler sandstone in Kansas ranges from 3 feet or less to about 20 feet. The sandstone is thickest in an area north of Pleasanton in Linn county. It is easily traceable along its outcrop from northeastern Linn county to southwestern Labette county. The location of the outcrop belt is indicated by the line representing the base of the Bourbon beds on the state geologic map (Moore and Landes, 1937). The sandstone is a fine-grained micaceous quartzose rock, in which the grains are bound by calcareous cement. The sand grains are mostly angular in shape. Weathered exposures are brown, but fresh exposures are light gray. The bedding is thin and only locally irregular. In central Labette county the sandstone is believed to grade laterally into a sandy limestone containing marine fossils, principally brachiopods and crinoid fragments. Farther south in Labette county the ordinary sandstone

cretions in the shale directly below it. The lower limestone member of the Altamont formation is not persistent, but is recognized in widely separated places.

MISSOURI SERIES

Definition of the Hepler sandstone.—Above the Marmaton group is the Bourbon group, containing about 150 feet of shale and sandstone and locally 40 feet or more of alternating very hard dark-blue and dark shale beds in the upper part. At the base is a very persistent sandstone, which is generally not more than 3 or 4 feet thick, but which is about 20 feet thick north of Pleasanton, where it is asphalt-bearing. This sandstone is a good marker, and its upper surface can be used as a key horizon for surface mapping. It is equivalent to the lower part of the Seminole formation in Oklahoma and probably to the Warrensburg sandstone in Missouri. It is here named the Hepler sandstone and classed as a formation of the Bourbon group. Field studies show that the Bourbon strata are lithologically varied and are divisible into several formations. The Checkerboard limestone of Oklahoma is tentatively identified in Kansas as a part of the Bourbon beds. From Kansas City southward to Linn county a sandy zone called the Knobtown sandstone (Greene, 1933, pp. 13, 19) occurs in the upper part of the Bourbon. This sandstone, which is very lenticular, is recognized in central Linn county, but alternating beds of dark-blue flaggy limestone and shale are found at this stratigraphic position in southern Linn county and northern Bourbon county. Subdivisions of the Bourbon group above the Hepler sandstone are to be discussed in a later paper.

The thickness of the Hepler sandstone in Kansas ranges from 3 feet or less to about 20 feet. The sandstone is thickest in an area north of Pleasanton in Linn county. It is easily traceable along its outcrop from northeastern Linn county to southwestern Labette county. The location of the outcrop belt is indicated by the line representing the base of the Bourbon beds on the state geologic map (Moore and Landes, 1937). The sandstone is a fine-grained micaceous quartzose rock, in which the grains are bound by calcareous cement. The sand grains are mostly angular in shape. Weathered exposures are brown, but fresh exposures are light gray. The bedding is thin and only locally irregular. In central Labette county the sandstone is believed to grade laterally into a sandy limestone containing marine fossils, principally brachiopods and crinoid fragments. Farther south in Labette county the ordinary sandstone

facies reappears, and sandstone of this facies extends into Oklahoma. The Hepler sandstone lies disconformably on upper layers of the Marmaton group. It seems to be overlain conformably by gray, yellow, and black shale.

The name is taken from the town Hepler, in southwestern Crawford county, Kansas, and the type exposure is in the center of sec. 14, T. 27 S., R. 22 E., 1.5 miles north of Hepler in Bourbon county on state highway 39. A section measured at this locality is as follows:

Section of the Hepler sandstone and underlying beds in sec. 14, T. 27 S., R. 22 E., Bourbon county

	Thickness, in feet
Missouri series, Bourbon group	
Hepler sandstone formation:	
7. Sandstone, brown, thin-bedded; micaceous; fine angular quartz grains; calcareous cement. Disconformable base	6
Des Moines series, Marmaton group	
Memorial shale	
6. Shale, gray, distinctly bedded, upper few feet not well exposed	16.2
Lenapah limestone	
5. Limestone, gray, sandy-appearing; crinoid stems, brachiopod fragments	3.2
4. Limestone and shale interbedded, blue to gray; the limestone nodular and the shale calcareous	1
3. Limestone, blue to gray, nodular	0.5
2. Shale, gray in upper part, black in lower part, well bedded	11
1. Limestone, dark blue to gray, crystalline, slabby	0.5

Missouri strata above the Bourbon group.—Above the Bourbon shale and sandstone beds there is almost 100 feet of beds belonging to the Bronson group. In Linn county approximately 75 feet of this group consists of limestone. The Bronson limestone and shale beds crop out along the hills in all parts of the county except the extreme eastern and western parts. At the base is the Hertha limestone, of which the lowest member (Critzer limestone) is the most prominent part, except in the northernmost part of the county. Above the Hertha formation is the Ladore shale, about 10 feet thick, ranging from clayey to sandy and calcareous in nature. Next higher is the Swope limestone, which includes 2 to 8 feet of dark bluish-gray limestone at the base (Middle Creek limestone member), a few feet of shale, mostly black and fissile (Hushpuckney shale member), and at the top, the Bethany Falls limestone, about 15 to 25 feet thick. The upper part of the Bethany Falls limestone is oölitic and cross-bedded. Above the Swope formation is the Galesburg shale, which is 3 to 12 feet thick. It is clayey and, especially in the southern part of the county, sandy. The uppermost Bronson formation is called the Dennis limestone. At the base of this formation

is the Canville limestone member, which ranges from a few inches of calcareous shale in the northern part of the county to about 2 feet of dark bluish-gray crystalline limestone in the southern part. Above the Canville limestone is a few feet of shale, most of which is black and platy, called the Stark shale. The uppermost member of the Dennis formation is the Winterset limestone, which is about 40 feet thick and contains much flint and oölitic limestone. The

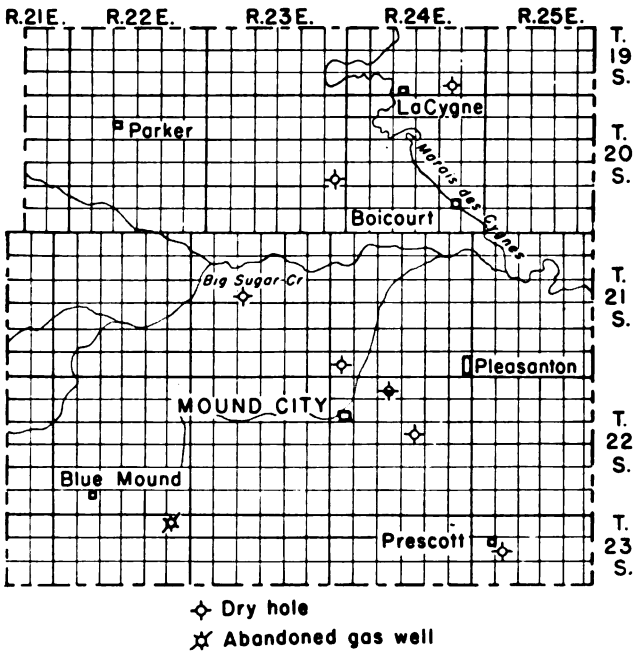

FIG. 2.—Pre-Mississippian wells in Linn county.

base of the Hertha formation is an excellent key horizon for surface or subsurface structural mapping. The black Hushpuckney and Stark shales can be identified easily in well cuttings (see pl. 2).

The Kansas City group overlies the Bronson group. At the base is 12 or 15 feet of clay shale, the Fontana shale, and next above is the thin Block limestone. Above the Block occurs about 20 feet of clay shale, which is locally black and fissile in the upper part. This is the Quivira-Wea shale. Next above comes the Drum limestone, which ranges in thicknes from about 3.5 to 9 feet. The lower member is about 2 feet thick and is fine grained and gray. At the top, overlying about 1 foot of shale, is a cross-bedded member, which

ranges from a few inches to 6 feet in thickness. The Chanute shale lies above the Drum formation. It contains some limestone in the lower part and a coal bed near the middle. Above the coal is several feet of brown sandstone, which caps small hills in the western part of the county. The coal in the Chanute shale has been mined in the vicinity of Blue Mound. The Iola limestone, above the Chanute shale, is about 10 feet thick. It is wavy-bedded, gray and brown, and crystalline. Above the Iola is the Lane shale, which is about 45 feet thick and consists principally of yellow and gray clay shale. Overlying it is the Wyandotte limestone formation, which consists of two limestones separated by a shale member. The total thickness is about 18 feet, of which 10 feet comprises the shale member. The Bonner Springs shale, next above the Wyandotte, is about 40 feet thick, and is somewhat sandy. The highest well-exposed bedrock formation is the Plattsburg limestone, which occurs in the northwest part of the county. It consists of about 10 feet of gray, brown-weathering limestone. The Vilas shale and the lower few feet of the Stanton limestone are present, mostly under soil cover, in the extreme northwestern part of the county. The base of the Drum formation is a good key horizon for surface mapping in the western part of the county.

SUBSURFACE FORMATIONS

PRE-CARBONIFEROUS ROCKS

By R. P. Keroher

General discussion.—The name Arbuckle is used in Kansas to include rocks ranging in age from Late Cambrian to Early Ordovician. These rocks correlate approximately with part of those at the type locality of the Arbuckle group in Oklahoma and have been traced northward across both Oklahoma and Kansas; in southern Oklahoma rocks of Cambrian age are excluded from the Arbuckle, however.

Because of nearness to excellent exposures of Arbuckle rocks in Missouri and the advanced state of classification of these rocks in the Ozark region, it is desirable to correlate subdivisions of the Arbuckle in Kansas with corresponding units that have been named in Missouri. Accordingly, the classification developed in the Ozark area will be used here.

The thickness of the entire section of Arbuckle rocks in Linn county is not known. Only one well, the Holeman and Edwards No. 9 Pollman, in the SE¼ sec. 35, T. 19 S., R. 24 E., penetrated Arbuckle strata far enough to reach the lower formations. The location of this well and of the six other Arbuckle wells that have been drilled in the county is shown in figure 2. The first samples available from the Pollman well were obtained at a depth of 882 feet. The well was drilling in the Arbuckle at this depth, but other information indicates that the top is at approximately that depth.

The Arbuckle rocks that were penetrated in this well are dominantly dolomite and include a few thin sandstone beds. Both Ordovician and Cambrian rocks are present. These will be discussed in ascending order. The pre-Cambrian rocks are not described.

Cambrian rocks.—The Cambrian formations in Linn county are the Lamotte, Bonneterre, Eminence, and Proctor formations, named in upward order. The total thickness is probably about 300 feet.

The Lamotte sandstone is composed mostly of fine subangular quartz grains that are commonly cemented somewhat loosely by calcareous material. The thickness ranges from a featheredge to several hundred feet at places in Missouri. This formation has not been reached by drilling in Linn county. Samples from the nearest well reaching granite, the I. I. Arnold No. 1 Stevenson in sec. 16, T. 26 S., R. 24 E., in Bourbon county, show 125 feet of Eminence dolomite

directly overlying 42 feet of Lamotte sandstone. It is probable that the thickness of these formations in Bourbon county is comparable to that in Linn county.

The Bonneterre formation was penetrated to a depth of 90 feet in the Pollman well. This formation consists of dark-gray, coarsely crystalline dolomite, which is readily distinguishable from the much lighter Eminence formation immediately overlying it. This formation is characterized by the presence of sand, samples from the Pollman well showing a range in amount from less than 5 percent of sand at the top to approximately 60 percent in the lowest samples. The sand grains at the top are fine and somewhat gray in color and range downward into a somewhat coarse angular sand. A considerable amount of pale amethyst-colored quartzose chert is present in the deepest samples. The thickness of the Bonneterre and older formations cannot be determined from wells in Linn county.

The Eminence formation lies next above the Bonneterre dolomite and has a total thickness of 150 feet. A 30-foot zone at the top that is almost free of chert is probably equivalent to the Proctor formation in Missouri, but no attempt is made here to distinguish it from the Eminence formation. The Eminence formation consists dominantly of fine to coarse light-gray fine-grained dolomite.

Ordovician rocks.—Ordovician rocks present in Linn county are correlated with the Van Buren, Gasconade, Roubidoux, Jefferson City, and Cotter formations of Missouri. The total thickness of these beds is approximately 448 feet.

The oldest Ordovician rocks in Linn county, as indicated by the samples from the Pollman well, are correlated with undifferentiated Gasconade and Van Buren formations and with the thin Gunter sandstone below the Van Buren. The combined thickness of these formations is 135 feet. The higher two beds consist of light-gray to cream-colored crystalline dolomite. The relatively large amount of chert present in these formations serves to distinguish them from the overlying Roubidoux formation. The chert is predominantly white and opaque and commonly breaks with a smooth fracture. The sandy zone, which is correlated with the Gunter sandstone, is about 10 feet thick. It seems to contain a considerable amount of dolomite, but the dolomite occurring with the sand in the well samples may be contamination from beds higher in the Van Buren formation. The sand grains composing the sandstone are fine- to medium-grained quartz and range from subangular to rounded.

The Roubidoux formation is 145 feet thick in the Pollman well.

Although the formation is commonly regarded as a sandstone in Missouri, the samples from this well indicate that it consists predominantly of dolomite with three interbedded sand zones. The upper sandy zone is 55 feet thick. It consists of gray, coarsely granular dolomite containing a relatively large amount of coarse, rounded, frosted sand grains and a considerable amount of almost transparent quartzose chert. Two other sandy zones are present, one at a depth of 1,150 to 1,155 feet and another at 1,170 to 1,175 feet. The siliceous material in the samples in these zones constitutes approximately 80 percent of the sample.

The thickness of the combined Jefferson City and Cotter formations in Linn county is approximately 168 feet. Both formations consist of tan, buff, and gray dolomite. The texture ranges from dense to very coarse-grained. The relatively greater amount of chert present makes these beds readily distinguishable from the underlying Roubidoux formation. By far the greater percentage of chert is white and smooth and ranges from opaque to almost transparent. The smooth, waxy chert, especially in thin fragments, has the appearance of thin shavings of paraffin. Large brown "oölites", which occur in a matrix of lighter translucent chert, are characteristic of these formations. A small percentage of sand is present throughout both the Jefferson City and Cotter beds. Commonly only scattered grains are present except at two zones, one at a depth of 925 to 930 feet in the Pollman well, where sand constitutes more than 75 percent of the sample, and another at 1,015 to 1,020 feet, where the sample is about 25 percent sand. The sand grains are large and somewhat angular. Most of the grains are frosted.

MISSISSIPPIAN ROCKS

By Wallace Lee*

Rocks of Mississippian age are not exposed in Linn county, but much information concerning them is provided by the cuttings and logs of drilled wells, 14 of which are known to have passed through the Mississippian within the county. On the eastern side of the county the Mississippian has been reached at depths less than 450 feet in wells drilled in valleys, but because of the regional westerly dip of the rocks the Mississippian strata lie at a depth of nearly 1,000 feet on the western side of the county. The rocks of this age consist chiefly of limestone, but they include some shale and sandstone in their lower part. Their aggregate thickness is slightly more

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

than 350 feet in the northwestern part of Linn county, 390 feet in sec. 8, T. 23 S., R. 25 E., in the southeastern corner, but less than 300 feet in some areas in the central part of the county.

The lowermost formation that is currently regarded as Mississippian in age, although it may possibly be late Devonian, is the Chattanooga shale. This shale in Linn county unconformably overlies Ordovician rocks that are commonly classed as Arbuckle limestone—the "Siliceous lime" of drillers—which is of Cambrian and Ordovician age. The unconformity between the Chattanooga shale and the Ordovician rocks in Linn county and other parts of eastern Kansas is not evident in closely spaced wells, but a wider view indicates that the pre-Chattanooga rocks were gently folded and then eroded to a nearly flat surface before the deposition of the Chattanooga shale. This period of erosion represents a long time, for many hundreds of feet of Ordovician rocks and in some places younger rocks also were worn away. In Linn county the Chattanooga rests on the beveled surface of the older rocks, which dip toward the northwest, in which direction progressively younger beds underlie the shale.

The Chattanooga formation in Linn county is 15 to 20 feet thick and consists of dark- or medium-gray noncalcareous shale, which, like the typical black Chattanooga shale of southeastern Kansas, contains plant spores. Sand referred to as the Misener sand occurs at the base of the Chattanooga in some wells. This sandstone is at least 5 feet thick in Linn county and adjacent areas, but in places it is absent or is represented only by sandy shale. In some parts of Kansas it has produced oil.

Limestones of unquestioned Mississippian age overlie the Chattanooga shale. The lowest of these is the Chouteau limestone of Kinderhook age. The upper part of the Chouteau in Linn county, although composed chiefly of dolomite and dolomitic limestone, is much more silty and contains more impurities than the typical Chouteau at the surface in north-central Missouri. It grades laterally into the Northview shale, which is widespread in the portion of the state south of Linn county. This part of the Chouteau contains dull gray chert stippled with specks of darker gray or buff chert. In addition some zones contain massive brown opaque chert not present either in the typical Chouteau or in the Northview. The lower part of the formation is equivalent to the Compton limestone, which is present south of Linn county. It is composed chiefly of gray limestone not greatly different from the Compton except that

it includes minor amounts of chert. In the Heidenreich No. 5 Leasure well, sec. 24, T. 20 S., R. 23 E., in the central part of Linn county, from which a good set of samples was saved, the Chouteau is 88 feet thick. In this well there is at the top an additional 13 feet of only slightly cherty buff-gray dolomite that may be a partial equivalent of the Sedalia limestone of the outcrops.

The dolomite of possible Sedalia age is overlain unconformably by undivided Burlington and Keokuk rocks of late Osage age. The Burlington and Keokuk rocks, which are 125 feet thick in the Heidenreich No. 5 Leasure well, consist of gray semigranular limestone and gray sucrose (sugary) dolomites containing considerable but varying amounts of gray to white opaque and semiopaque massive chert. Residues obtained by dissolving the limestones in hydrochloric acid include white pulverent silica resembling tripoli.

Rocks of Meramec age, in which the Warsaw is here included, have a total thickness of 155 feet in the Heidenreich No. 5 Leasure well. They overlie the undifferentiated Burlington and Keokuk limestones, from which they are separated by an unconformity that is obscure in Linn county, but well developed farther south in Kansas. The Meramec rocks consist chiefly of gray semigranular limestone in the lower part and sucrose buff and gray dolomite beds in the upper part. The Warsaw limestone at the base of the Meramec is characterized by the presence of gray chert crowded with sponge spicules and the silicified remains of microörganisms. The upper part of the Warsaw of possible Spergen age is composed of limestone lithologically similar to the lower part, but contains less chert. In the residues the microörganisms are less completely silicified and are shown by a network of cavities in the chert from which the calcareous organisms have been dissolved. This limestone, which is not sharply separated from the lower part of the Warsaw, contains in some localities, as in the Heidenreich No. 5 Leasure well, minor amounts of pink or reddish chert. At the top of the Mississippian section in this well the gray semigranular, and fine-textured to lithographic limestones after acid treatment yield residues including glassy chert enclosing microörganisms. These limestones, which are not set off sharply from the underlying rocks, may be of St. Louis age.

After the deposition of the Mississippian rocks the region was again uplifted and gently folded. In eastern Kansas there was a revival in some areas of the northwesterly trending folds that were dominant before the deposition of the Chattanooga shale. In addition, folds trending in a northerly or northeasterly direction were

initiated. These movements do not seem to have been as pronounced in Linn county as in the parts of Kansas farther west, but, inasmuch as few wells have been drilled through the Mississippian rocks in Linn county, the evidence on this point is inconclusive. Erosion accompanied the uplift and folding, and the land surface was finally again reduced to a nearly featureless plain approximately at sea level. Rocks that had been raised above sea level were worn away and those that were folded downward below it were preserved so that anticlines are generally marked by thin sections of Mississippian rocks. On account of the beveling of the deformed Mississippian rocks their thickness over wide areas varies according to the structure.

Logs of wells drilled in the southern part of T. 21 S., Rs. 23 and 24 E., show the Mississippian limestones to be less than 300 feet thick, and in sec. 4, T. 22 S., R. 24 E., a thickness of only 250 feet is reported. A similar thinning occurs in the northern half of T. 23 S., R. 22 E., where the limestones are reported to be slightly less than 300 feet thick. The local thinning of the Mississippian in these two localities as reported in logs suggests the possible presence of pre-Pennsylvanian anticlinal folds in the general areas cited, but the exact position is not indicated from the few well logs available.

PENNSYLVANIAN ROCKS

By John M. Jewett

Cherokee Shale

General description. — The Cherokee shale lies unconformably upon the weathered surface of the Mississippian rocks and is the oldest rock of Pennsylvanian age in eastern Kansas. From all available records of wells that have passed entirely through this unit a thickness ranging from 295 feet to 400 feet is indicated. These extremes may be due to faulty logging, but the range certainly extends from 310 feet to 380 feet. Wells reaching the base of the Cherokee shale are not distributed in such a way that one may obtain a clear picture of the trends of changes in thickness. The greatest thickness, 400 feet, is recorded for sec. 27, T. 21 S., R. 24 E.; and the least thickness, 295 feet, for sec. 12, T. 23 S., R. 24 E. This thickness is probably erroneous, as in the adjacent section to the east, sec. 7, T. 23 S., R. 25 E., a thickness of about 325 feet has been recorded. In numerous wells the thickness is approximately 350 feet. There is indication of local thinning to 310 feet in T. 21 S., R. 24 E.

Dark shale and sandy shale are the predominant kinds of rocks in the Cherokee. The prominent coal beds are shown on the subsurface section (pl. 2B). There are four somewhat persistent zones of fine quartz sandstone. The sandstones are the principal oil- and gas-producing beds, and because of their position within the Cherokee shale they are commonly known by names that have been applied to their possible correlatives in other oil- and gas-producing areas.

"Burgess" and "Tucker" sands.—Near the base of the Cherokee shale is a zone of sandstone ranging from a few inches to about 40 feet in thickness. It is commonly known as the "Burgess sand", a name widely applied to the lowermost sandstone in the Cherokee shale. The term "Tucker sand" is also used for sandstone in this zone and is very probably more nearly correctly applied, because in Oklahoma the "Tucker sand" lies higher than the "Burgess sand" and lower than the "Bartlesville sand". The true Burgess sand of Oklahoma is very probably of Mississippian age. Here it should be noted that locally in Linn county, especially in the western part of T. 22 S., R. 22 E., there is a few feet of flinty limestone, seemingly weathered, at the top of the Mississippian rocks. This deposit is probably Mississippian in age, and some drillers call it "Burgess sand". The last-mentioned rock is oil-bearing in sec. 19, T. 22 S., R. 22 E., and has a "good show of oil" in sec. 4, T. 22 S., R. 24 E. The higher sand, here called "Tucker", is gas-producing in T. 22 S., R. 24 E.; in the northern and northeastern parts of T. 20 S., R. 24 E.; in the eastern part of T. 22 S., R. 22 E.; and in the western and eastern parts of T. 22 S., R. 23 E. (fig. 3). Neither of these zones has been sufficiently tested in most parts of the county. In general, they have not been reached in areas in which there are no wells indicated as entering the Mississippian rocks (yellow color on map, pl. 3). Attention is called to the occurrence of oil at the top of the Mississippian rocks in Woodson county, in rock similar to the deposit at the top of the Mississippian rocks described above.

"Bartlesville sand".—Zones of sandstones and sandy shale lying generally between 150 feet and 300 feet below the top of the Cherokee shale are commonly referred to as "Bartlesville sand". Locally there are two sandstones within this interval and they are called "upper and lower Bartlesville sands". Both are present and yield gas in T. 20 S., R. 23 E.; in T. 20 S., R. 24 E.; in southeastern parts of T. 21 S., R. 24 E.; and the northern and east-central parts of T. 22 S., R. 24 E. Oil occurs in the upper Bartlesville sand in T.

19 S., R. 23 E., and in the northeast part of T. 22 S., R. 23 E. Figure 4 indicates the main known productive areas of the "Bartlesville sands".

Ardmore limestone.—About 100 feet below the top of the Cherokee shale is a persistent 5-foot bed of limestone. It is called Ardmore limestone and is generally logged by drillers. Locally it seems to be no more than 85 feet below the top, but this seeming variation in

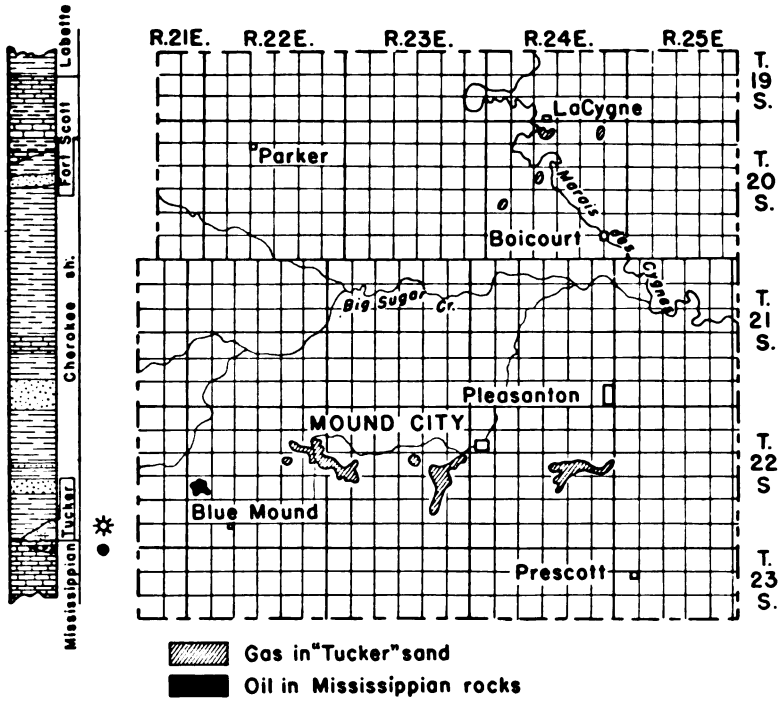

FIG. 3.—Principal known productive areas of "Tucker sand", and area of oil production from Mississippian rocks in Linn county.

thickness of beds between the base of the Fort Scott limestone formation and the Ardmore limestone may be due to differences in interpretation of the base of the Fort Scott limestone. This is discussed below. The Ardmore limestone is a good key bed for determining subsurface structural conditions. There is generally a few feet of black platy shale above the Ardmore limestone that yields gas in scattered areas.

"Squirrel sand".—A few feet below the top of the Cherokee shale is a zone that commonly contains sandstone, which is called "Squirrel

sand", a name applied to sandstone between the Ardmore limestone and the top of the Cherokee shale. In some areas nearly the whole interval between the Ardmore and Fort Scott is occupied by sandstone and sandy shale. The sandstone is especially well developed in the southeast part of T. 19 S., R. 22 E.; in the south part of T. 19 S., R. 24 E.; in the southeast part of T. 20 S., R. 21 E.; and diagonally across T. 20 S., R. 22 E., from section 2 to sections 19

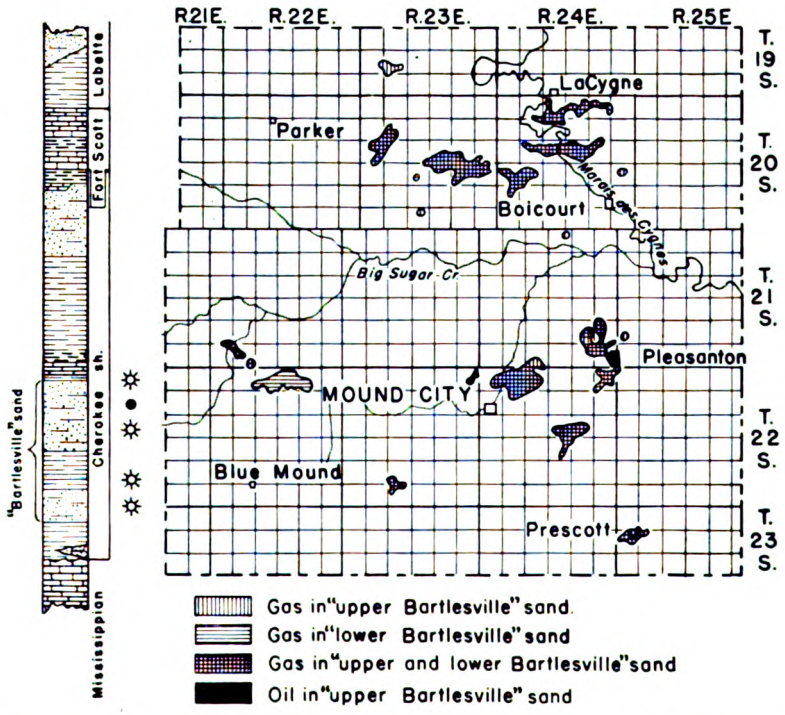

FIG. 4.—Principal known productive areas of "Bartlesville sand" in Linn county.

and 20. In this last-named area much oil has been produced from the "Squirrel sand". Gas is produced from this zone in the east-central part of T. 20 S., R. 23 E.; in T. 20 S., R. 24 E.; in the southern part of T. 21 S., R. 24 E.; in the northern part of T. 22 S., R. 22 E.; in T. 22 S., R. 23 E.; and in the western part of T. 22 S., R. 25 E. Oil is produced from the "Squirrel sand" in T. 21 S., R. 22 E., and in the western part of T. 21 S., R. 23 E. Figure 5 shows the main known productive areas of "Squirrel sand".

Uppermost Cherokee beds.—A few feet of black platy shale at the top of the Cherokee shale seems to be more closely related to the Fort Scott limestone than to underlying beds. The lower boundary of the Fort Scott limestone, which is also the upper boundary of the Cherokee shale, is placed by definition at the base of the lower of the two limestones at the type locality of the Fort Scott

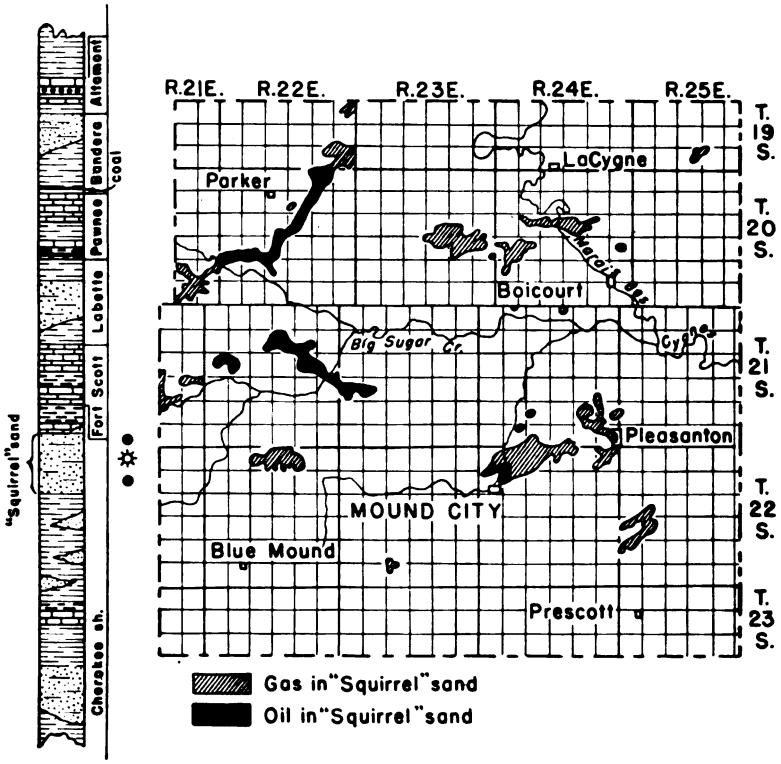

FIG. 5.—Principal known productive areas of "Squirrel sand" in Linn county.

formation. The black shale just below the lower Fort Scott limestone therefore lies in the uppermost part of the Cherokee shale. Locally another limestone lies below this black shale. This third limestone has been named the Breezy Hill limestone (Pierce and Courtier, 1938, p. 33). Because wells that have reached only as low as this black shale zone do not in any sense constitute a test of the Cherokee shale, they are classed on the map (pl. 3) as Marmaton wells.

Marmaton Group

Fort Scott limestone.—The Fort Scott limestone, which is the lowest formation in the Marmaton group, consists of two limestones separated by 5 or 6 feet of shale, which is mostly black and which locally contains a thin bed of coal. Directly below the Fort Scott limestone is a few feet of black platy shale, containing large dark hard limestone concretions, some of which are as much as 3 feet in diameter. The black shale is underlain by a persistent coal bed (Mulky), and below this is locally the somewhat sandy Breezy Hill limestone, about 2 feet thick. Gas is produced in many scattered areas in the northeastern half of the county from the beds between the base of the Fort Scott limestone and the Breezy Hill limestone (fig. 6). Gas from this zone is commonly known as "shale gas", and the zone as the "shale-gas zone". For convenience in this report the gas-producing beds just below the Fort Scott formation are classed with the Marmaton strata and wells that penetrate only this topmost part of the Cherokee shale are designated on the map (pl. 3) as Marmaton-group wells. It is evident that such wells do not constitute a test of the main oil- and gas-producing zones in the Cherokee shale.

Labette shale.—The Labette shale lies between the Fort Scott and Pawnee formations. The thickness ranges from about 20 to 50 feet. The formation consists of shale, sandy shale, and sandstone. Gas is produced from the sandstone of this formation in the southern part of T. 21 S., R. 24 E.; in the southwestern part of T. 21 S., R. 25 E.; in the eastern part of T. 22 S., R. 24 E.; and in the western part of T. 22 S., R. 25 E. In these areas gas is found in other zones, also (fig. 7).

Pawnee limestone.—This limestone formation, which with other exposed rocks is shown in some detail on the section of outcropping rocks (pl. 1A), lies next above the Labette shale. In wells it is generally logged as two limestone beds separated by a shale 5 to 10 feet thick. The lower limestone generally has a thickness of about 5 feet, and the upper limestone a thickness of at least 10 feet. About 2 feet of black platy shale lies below the lower limestone and below this is a very thin limestone that is not recorded in well logs. Shows of gas have been reported from the black shale in scattered areas.

Bandera shale.—Above the Pawnee limestone and below the Altamont limestone is the Bandera shale. The thickness of the Bandera is consistently about 45 feet. The Mulberry coal, which is extensively mined in eastern Linn county, lies near the base. A consider-

able thickness of sandy shale and sandstone occurs in the upper and middle parts of the formation, and where the sandstone is well developed it constitutes one of the important oil- and gas-producing rocks of the county. The Bandera formation produces in the following areas: gas in the eastern part of T. 19 S., R. 22 E.; oil in the southeastern part of T. 19 S., R. 23 E.; oil and gas in the northern part of T. 20 S., R. 23 E.; gas in the northern and eastern parts of T. 20 S., R. 23 E.; in the southeastern part of T. 21 S., R. 22 E.; the northern part of T. 22 S., R. 23 E.; the eastern part of T. 22 S.,

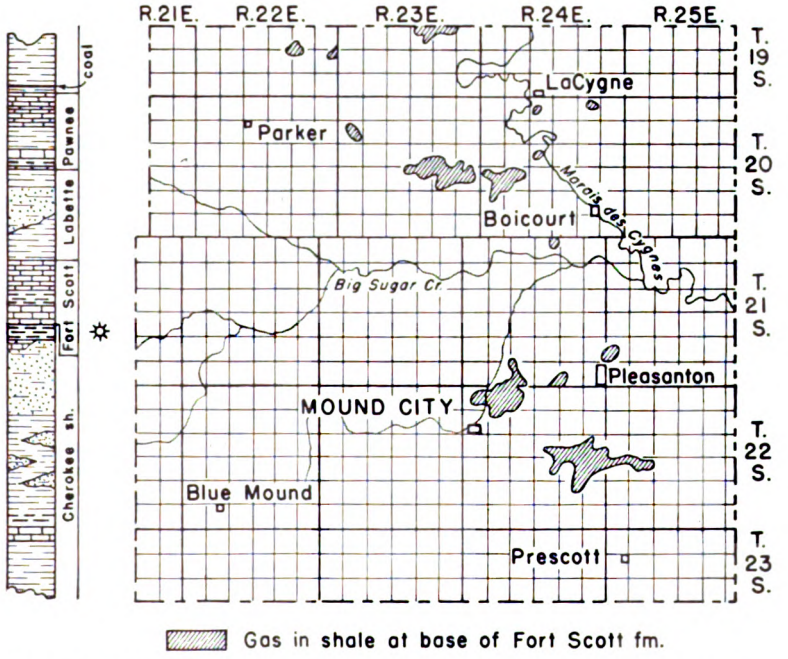

FIG. 6.—Principal known productive areas of shale at base of Fort Scott formation in Linn county.

R. 24 E.; and the western part of T. 22 S., R. 25 E. Figure 7 indicates the main known productive areas of the Bandera formation.

Altamont limestone.—The Altamont limestone lies upon the Bandera shale. It consists of two limestones separated by a shale member. The lower limestone is generally about 1 foot thick and is not present everywhere. The separating shale is about 2 feet thick and is locally dark in color. The upper limestone is generally logged in wells as having a maximum thickness of 10 feet, but this thickness includes thin limestone and shale beds that overlie the more massive part of the member, which is about 3 feet thick.

Upper Marmaton beds.—Between the Altamont and the Lenapah limestone, higher in the section, is about 20 feet of clay shale and locally sandy shale known as the Nowata shale. It is not known to be oil- or gas-bearing in Linn county.

The Lenapah limestone is not as well developed in Linn county as farther south in Kansas, yet it can be readily traced on the surface and is generally logged in wells as a few feet of limestone.

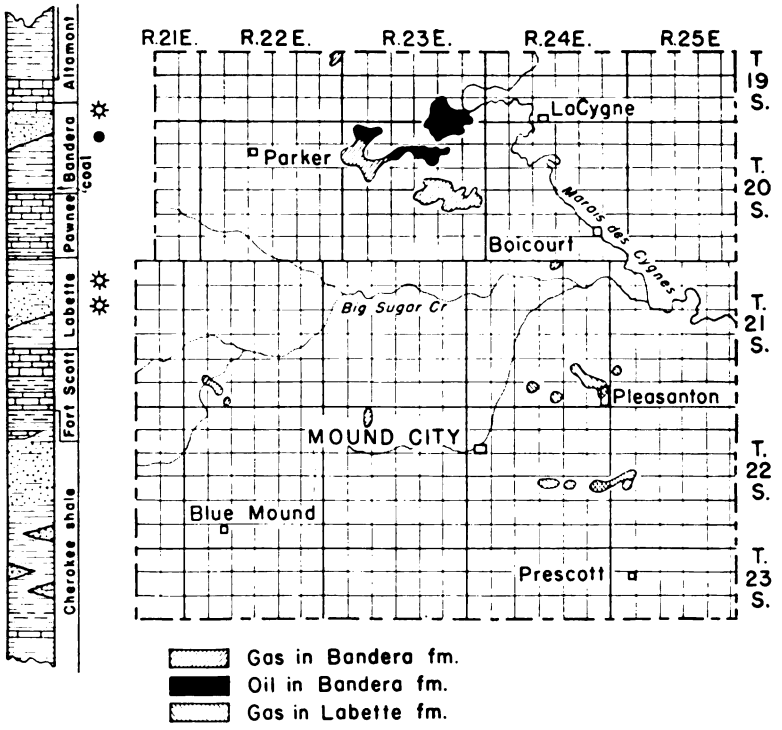

FIG. 7.—Principal known productive areas of the Bandera and Labette formations in Linn county.

Along the outcrop in Linn county it is seen to consist of two thin limestone beds, each having a maximum thickness of 1 foot and separated by about 3 feet of limy, nodular shale.

Above the Lenapah formation and below the persistent thin Hepler sandstone that marks the base of the Bourbon group is a few feet of clay shale, which is believed to be equivalent to the Memorial shale of northeastern Oklahoma. Variation in thickness of this shale in Linn county is governed mainly by the disconformable con-

tact with the overlying sandstone. Because the Hepler sandstone is not generally recorded in well logs, the Memorial shale is not commonly separable from the Bourbon beds.

Bourbon and Bronson Groups

The Bourbon group is about 150 feet thick and is composed principally of shale. Much sandstone occurs locally in the upper part, however, and in southern Linn county there is 20 feet or more of alternating beds of dark-blue limestone and shale in the upper Bourbon section. The Bourbon is known to drillers as the "big shale". It is reported that a small amount of heavy oil was produced from the upper part of this shale several years ago in sec. 20, T. 20 S., R. 24 E.

The Bronson group and higher beds, although buried to some depth in the western part of the county, need not be described in detail here. The section of this paper dealing with surface formations gives a brief description of these beds as they appear along their line of outcrop. They are all easily identified in well logs; and where they are buried their thickness and character are much the same as in the surface exposures. The base of the Hertha formation is an excellent key horizon for subsurface structural mapping in all areas where the surface rocks are younger than the Bourbon formation.

OIL AND GAS PRODUCTION

Definite figures showing total oil and gas production in Linn county or in specific fields of the county are not available. Although no spectacular discoveries of oil or gas have been made, large amounts of each have been produced during many years. The greatest quantity of oil has been obtained from the "Squirrel sand" in the Goodrich and Centerville fields and from the Bandera and Labette formations in the fields near La Cygne. The field north of Mound City was also important for several years. The county is reported to have produced 89,208 barrels of oil in 1926, and 38,969 barrels in 1935. Production is slowly but steadily decreasing at the present time.

Most of the wells are now producing no more than 1 barrel per day, but as late as 1936, 48 wells in the N½ sec. 11, T. 20 S., R. 23 E., averaged 4 barrels per day. These wells generally had a larger production when new. Very many wells in the La Cygne field have been abandoned recently or are being pumped irregularly. One well in the La Cygne city park has now produced an average of 1½ barrels per day for more than four years. Most of the wells in the field east of Parker have been abandoned and the casing has been pulled. Recently water-flooding has been tried in the fields mentioned. The results have been varied. A considerable quantity of oil was produced from the abandoned Mound City pool, but no record of the amount is available. It is reported that the rate of production was 3 to 15 barrels per day for six years. The Mound City field, which is situated on a pronounced structural "high", produced oil principally from the "Squirrel sand". Gas is now being produced in the same area from the "Bartlesville sands" and from the black shale zone directly below the Fort Scott formation. It is worthy of note that a show of oil was discovered in the top of the Mississippian limestone in the southwest part of sec. 4, T. 22 S., R. 24 E., in this area.

The foregoing discussion does not imply that Linn county is necessarily about to become an area of no consequence in oil production. The accompanying map, plate 3, shows that there are large areas in which even the shallower producing zones are as yet untested, and it should be remembered that production from these zones has been profitable, for the wells have in general been long-lived. Oil from wells in the La Cygne field tests 30° A. P. I. gravity. Careful

study is needed in order to determine the conditions under which the Mississippian limestone is productive in the area northwest of Blue Mound and in more important Mississippian pools, such as in those of Woodson county. Watch by drillers for shows of oil in the upper part of the Mississippian rocks is important and it seems quite possible that more Mississippian production will be discovered in Linn county and neighboring counties. The wells near Blue Mound became productive after treatment with a small amount of acid. The oil from these wells tests 22.9° A. P. I. gravity.

The wells shown in figure 2 are the only ones reaching the base of the Mississippian, and penetrating pre-Carboniferous formations. It is obvious that pre-Mississippian rocks have not been sufficiently tested.

The maps accompanying this report show that gas production in Linn county is less localized than oil production. The Blue Mound field in the northeastern part of T. 22 S., R. 22 E., and in the western part of T. 22 S., R. 23 E., was drilled in 1927 and 1928. The field southeast of Goodrich was opened in 1929. Gas that is now being used in Mound City, Pleasanton, La Cygne, and Prescott is produced from the nearby fields. The wells north of Mound City are indicating particularly long life, and so are the wells near Prescott. A great many of the scattered wells are supplying gas for farm homes and are commonly not gauged. Daily production in commercial wells ranges from about 250,000 to 4,000,000 cubic feet. Indications are that Linn county has moderately large shallow gas reserves.

Oil and gas pipelines are shown on plate 3.

EXPLANATION AND PURPOSE OF THE LINN COUNTY OIL AND GAS MAP, PLATE 3

The oil and gas map of Linn county, which accompanies this paper as plate 3, is designed as a guide for future exploration. It shows the location of wells for which there is a record. The shape of the well symbol designates the status of the well, whether it is now producing, is abandoned after having produced, and whether it produced oil, or gas, or was a dry hole. If it was a dry hole, shows of oil and gas are indicated.

The State Geological Survey has logs for the wells shown in colors, and the colors indicate the stratigraphic depth of the wells. Wells shown in red reached the pre-Carboniferous rocks; those in yellow penetrated the Mississippian rocks, but did not reach their base; those in brown were drilled into the Cherokee shale, but not to the "Mississippi lime"; those in green tested Marmaton formations, but not Cherokee shale zones; and those in blue were ended in rocks of the Missouri series. It should be noted that the well color does not indicate the productive zone, but that principal areas of production by zones are shown in figures 3 to 7. Wells shown in black are those for which there is no known log.

It is hardly expectable that the map is complete in every detail. Undoubtedly there are wells for which records exist, but data were not obtained by me. Some wells that are shown as producing may now be abandoned. Nevertheless, this report and the compilation of data shown on the map should have considerable value in showing areas and zones that have been explored and areas and zones that are known to be productive.

BIBLIOGRAPHY

GREENE, FRANK C., *1933,* Oil and gas pools of western Missouri: Missouri Bur. of Geol. and Mines, 57th Bienn. Rept. App. 2, pp. 1-68.

MOORE, R. C., and LANDES, K. K., *1937,* Geologic map of Kansas: Kansas Geol. Survey.

PIERCE, W. G., and COURTIER, W. H., *1938,* Geology and coal resources of the southeastern Kansas coal fields: Kansas Geol. Survey Bull. 24, pp. 1-91.

□

PRINTED BY KANSAS STATE PRINTING PLANT
W. C. AUSTIN, STATE PRINTER
TOPEKA 1940
18-5069