STATE GEOLOGICAL SURVEY *of* KANSAS

RAYMOND C. MOORE, *State Geologist*

BULLETIN 8

The Economic Geology of the Arkansas City District

By EMMETT R. ELLEDGE

Clay and Shale Resources in the Vicinity of Arkansas City, Kansas

By PAUL TEETOR

In coöperation with the Chamber of Commerce, Arkansas City, Kan.

Printed by authority of the State of Kansas

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The Economic Geology of the Arkansas City District.

By EMMETT L. ELLEDGE.

INTRODUCTION.

"The biggest town of its size in the United States," remarked my friend in the Pullman smoking compartment as we rolled swiftly past the green fields of a part of central Kansas, "is Arkansas City, down near the south line of the state. When you talk about wide-awake business 'go,' progressiveness, and all the other things that make a town worth while—clean, paved streets, fine schools and churches and nice homes—you may put our city right alongside of any of them in the good old U. S. A., and I've been a long way east and west, too."

For the benefit of those who live outside of Kansas and Oklahoma, and those who may never have chanced to meet an Arkansas Citian, it may be mentioned that their headquarters —and there are 11,253 of them reported in the 1920 census—is located just three miles from the Oklahoma state line in southwestern Cowley county, which is about one-third of the state's length east and west from the east Kansas boundary. (See figure 1.) It is thus located in the midst of a prosperous and growingly wealthy part of the great Midcontinent region which has witnessed so rapid a development in the last few decades.

At the request and with the coöperation of the Chamber of Commerce of Arkansas City, the State Geological Survey has made a special examination of the country immediately adjacent to Arkansas City in order to determine in advance, so far as possible, the natural resources which may contribute farther to the development of the city, and to indicate the limitations which may exist in the possibilities of utilization of certain of the local resources. This bulletin records the results of these investigations and represents a type of community study which, it is believed, may advantageously be conducted in many parts of our state. It may be pointed out in this connection that definite scientific information along any line affecting community or state interests is very valuable, even though in some particulars it may be negative; for it is, of course, quite as important to save money which might be uselessly invested and to avoid failures, as it is to call atten-

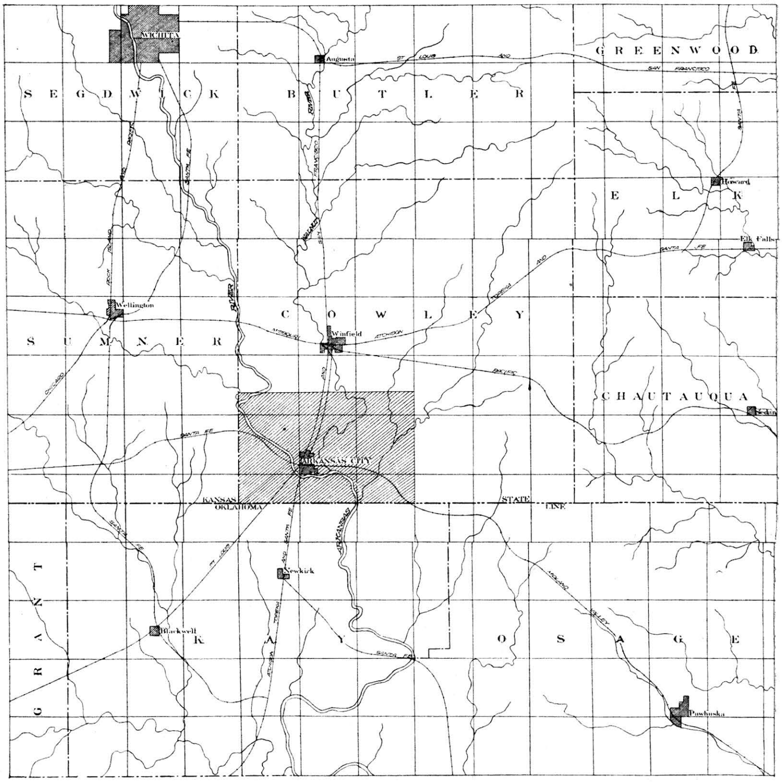


FIGURE 1. Location map of the Arkansas City district.

tion to possible resources, the quality, quantity and exact nature of which has not previously been known.

The area examined especially in the study of the Arkansas City district includes approximately 220 square miles, the location of which is shown on the index map (figure 1.) The field work was done by the writer, assisted by Mr. Lawrence Hay, between June 10 and August 20, 1920. A considerable area was mapped with plane table and telescopic alidade in order to determine somewhat precisely the local structure of the rocks and the possibilities of oil and gas development. All of the area was examined with reference to other resources, such as road materials, sand and gravel deposits, brick clays, and other materials of possible value. Special acknowledgment may be made of the assistance of Mr. O. B. Seyster, secretary of the Chamber of Commerce, for coöperation during the progress of the survey, and for information concerning the development of the Arkansas City area; and to Mr. M. W. Baden, of Winfield, on the stratigraphy and general structural conditions in this part of the state. The Survey is indebted to the Empire Gas and Fuel Company for part of the information used in compiling the geological map of Cowley county.

THE ENVIRONMENT OF ARKANSAS CITY.

The country about Arkansas City has a rolling topography, the chief features of which are the rather abrupt escarpments formed by the outcrop of limestone beds, and the broad, level plains in the valleys of Arkansas and Walnut rivers. The escarpment topography is controlled by moderately hard outcropping limestones, which weather less readily than the interbedded shales. Arkansas City is well located with reference to topography, being situated on a nearly flat river terrace formed at the junction of Arkansas and Walnut rivers.

The largest stream is Arkansas river, which crosses the southwest corner of Cowley county from northwest to southeast. This stream, with Walnut river, which drains the area from the north and empties into the Arkansas just east of Arkansas City, drains practically all the area under discussion.

The southwest part of Cowley county contains many acres of very valuable farm land, especially that in the valleys of the two rivers crossing the area, and Arkansas City is an important industrial center, so that the area is rather thickly populated. Crops which are most important are wheat, corn, alfalfa and cane. Some of the Arkansas river bottom land is considered especially adapted for apple growing, and there are a number of fine apple orchards within this area.

One of the important contributing factors in the development of the agricultural resources of any area is the climate. According to statistics compiled by the United States weather bureau, from observations made at Winfield, the average

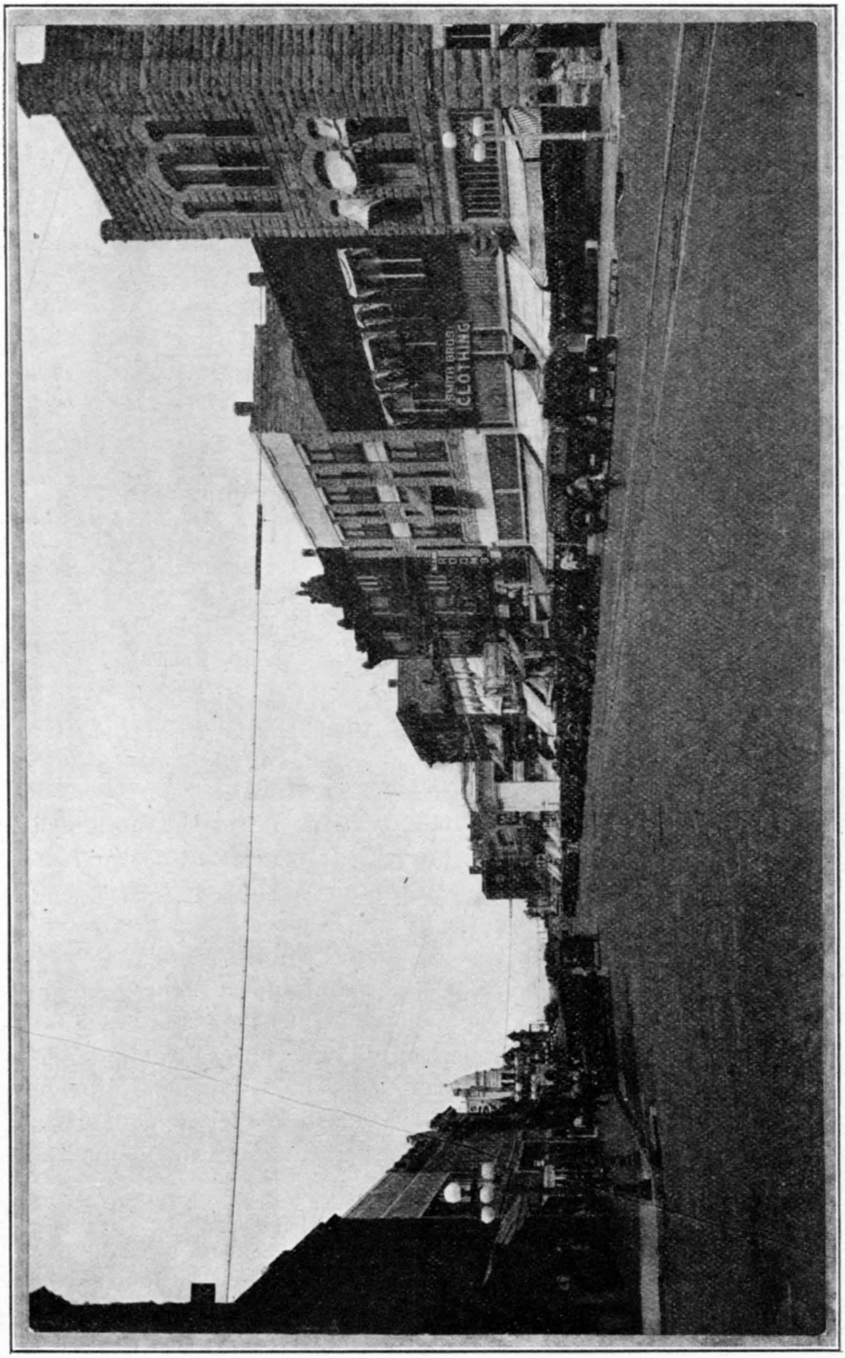


PLATE I. Summit street, Arkansas City, looking north.

annual precipitation in this area from 1894 to 1917, inclusive, was 31.79 inches. The highest average for any month during this period was 5.11 inches, in June, and the lowest 0.99 inch, in January. For the twenty-year period ending with 1917 the average annual temperature was 56.5 degrees Fahrenheit. The lowest average was 33.1 degrees, in January, and the highest 79.9 degrees, in July. For this same period the average date of the earliest killing frost in the fall was October 19, and for the last killing frost in the spring was April 15.

DEVELOPMENT OF THE ARKANSAS CITY DISTRICT.

On April 7, 1870, the town of Cresswell was founded on the present site of Arkansas City, but only a few months later the name was changed to that by which the town is now known. It was located on relatively high land between Arkansas and Walnut rivers, this topographic location affording excellent natural drainage and immunity from danger of possible floods.

During the first fifteen years the greatest problem confronting the town was transportation. All provisions had to be freighted, first from Emporia and later from Wichita. Between the years 1875 and 1879, when the coming of the railroads seemed impossible, the citizens considered the navigation of the Arkansas river as a means of getting products to and from the town, but the shallowness of the channel and the presence of numerous sand bars made this almost an impossibility.

Through the efforts of a few energetic citizens, the Santa Fe railroad became an assured fact in 1885. Lots were given for the site of the station and $10,000 was contributed toward its building. These citizens were also instrumental in locating the Santa Fe shops in Arkansas City a few years later. Later the Missouri Pacific railroad built a line through Arkansas City.

Less than two years after the founding of the town a union church building was erected. To-day the town boasts of some of the finest church buildings in the state. A public school was started in Arkansas City when as yet it was only a few weeks old. Four years later a substantial brick building was erected and named the First Ward school. The city now has four ward schools, a fine high school and a junior high school. The

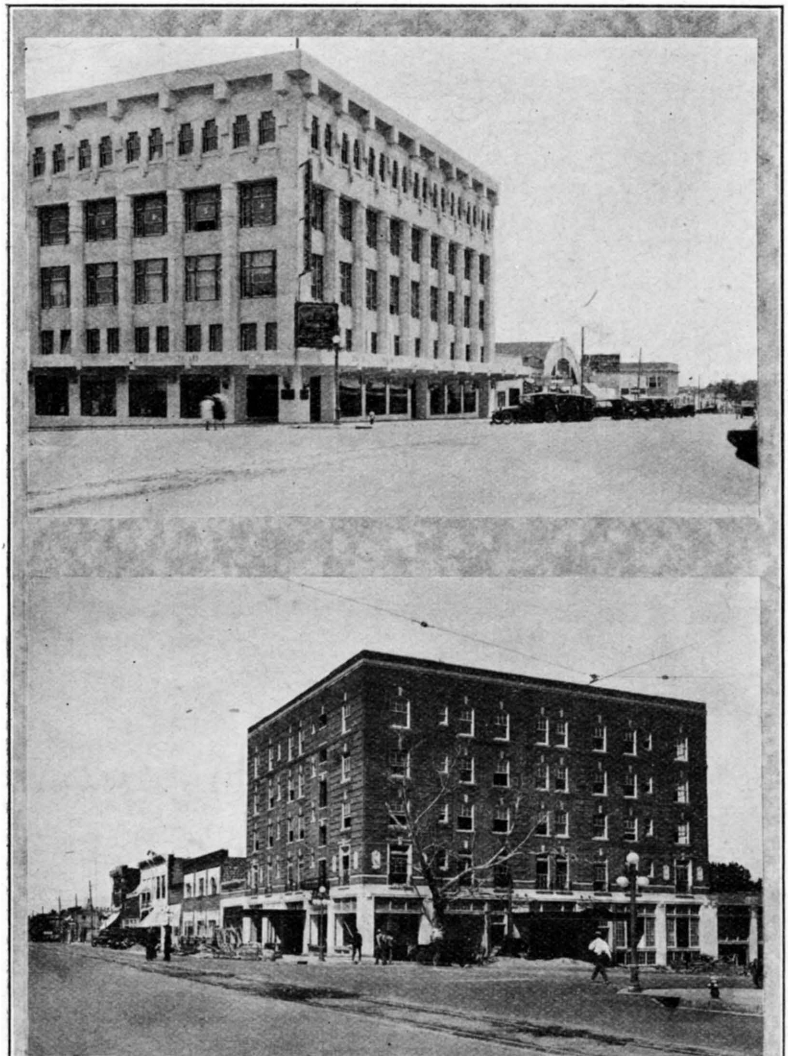


PLATE II. Views in Arkansas City business section.

present school plant is valued at $750,000, and the schools are among the best in the state.

In 1885 the Land Improvement and Water Power Company completed the canal connecting the Arkansas river northwest of town with the Walnut southeast of the city. For years this canal furnished power for a number of manufacturing establishments, and at present is the source of power for the A. C. Milling Company and for the electric-light plant.

The same year saw the beginning of an important building era in Arkansas City, and a number of attractive buildings were erected. The growth of the city was considerably delayed, however, by the opening of the "strip" in Oklahoma, and the panic of 1893 caused a cessation of plans for the town's development; but during the last few years growth has been even more rapid than before. The growth in population since 1910 has been 49 per cent. Since 1912 Arkansas City has been governed by a commission form of city government.

Arkansas City is one of the important industrial centers of the state. Four oil refineries are located here: the Milliken Company, the Kanotex, the National Oil Company, and the Empire natural-gas gasoline plant. The charging capacity of these refineries combined is 12,100 barrels per day. The division headquarters of the Santa Fe for south Kansas and northern Oklahoma, and large shops, are important contributing factors to the growth and prosperity of the city. Two flour mills, with a daily capacity of 2,400 barrels, are also located here. Some of the other industries include a candy factory, a meat-packing plant, and an ice plant.

GEOLOGY.

The rocks of Kansas, as classified on the basis of origin, belong to the sedimentary group. Rocks of igneous origin have been found in some deep wells, but do not outcrop at the surface within the boundaries of the state. Sedimentary rocks are those composed of the transported fragments or particles of older rocks which have undergone disintegration. The chief agencies of transportation are water, wind and glaciers. Materials such as gravel, sand and clay are carried as solid particles, and after deposition may be consolidated to form conglomerate, sandstone or shale. Other materials may be carried in solution and deposited to form limestone, salt or gypsum.

Sedimentary rocks are usually made up of beds or layers, called strata, which can easily be separated.

The rocks which appear at the surface in the state belong to the Mississippian, Pennsylvanian, Permian, Cretaceous and Tertiary geologic divisions, named in order from older to

Geologic section of the Kansas region.

SYSTEM.	Groups.	Formation.	Character of rocks.
Quaternary.	Recent.		Alluvium, dune sands.
Unconformity.	Pleistocene.	Wisconsin stage, Kansas stage.	Glacial deposits.
Tertiary. *Unconformity.*	Pliocene, Miocene.	Ogalalla.	Gravel, sand, clay.
	Montana.	Pierre.	Shale.
Cretaceous.	Colorado.	Niobrara, Benton.	Limestone, chalk, shale.
Unconformity.	Dakota.	Sandstone.	Sandstone, shale.
Comanchean. *Unconformity.*	Washita.	Kiowa, Cheyenne.	Sandstone, shale.
Permian.	Cimarron.	Greer, Woodward, Cave Creek, Enid.	"Red beds," sandstone, shale, dolomite, gypsum, salt.
	Big Blue.	Wellington, Marion, Chase, Council Grove.	Shale limestone.
Pennsylvanian.	Missouri.	Wabaunsee, Shawnee, Douglas, Lansing, Kansas City.	Limestone, shale, sandstone.
Unconformity.	Des Moines.	Marmaton, Cherokee.	Limestone, shale, sandstone.
	Chester. *Unconformity.*		
Mississippian.	Osage.	Warsaw, Keokuk, Burlington, Pierson.	Limestone.
Unconformity.	Kinderhook.		Limestone, shale.
*Ordovician. *Unconformity.*		Joachim, Jefferson City, Roubidoux.	Dolomite, sandstone, shale.
*Cambrian. *Unconformity.*		Gasconade, Proctor, Eminence, Potosi.	
*Pre-Cambrian.			Granite.

*Not exposed in Kansas.

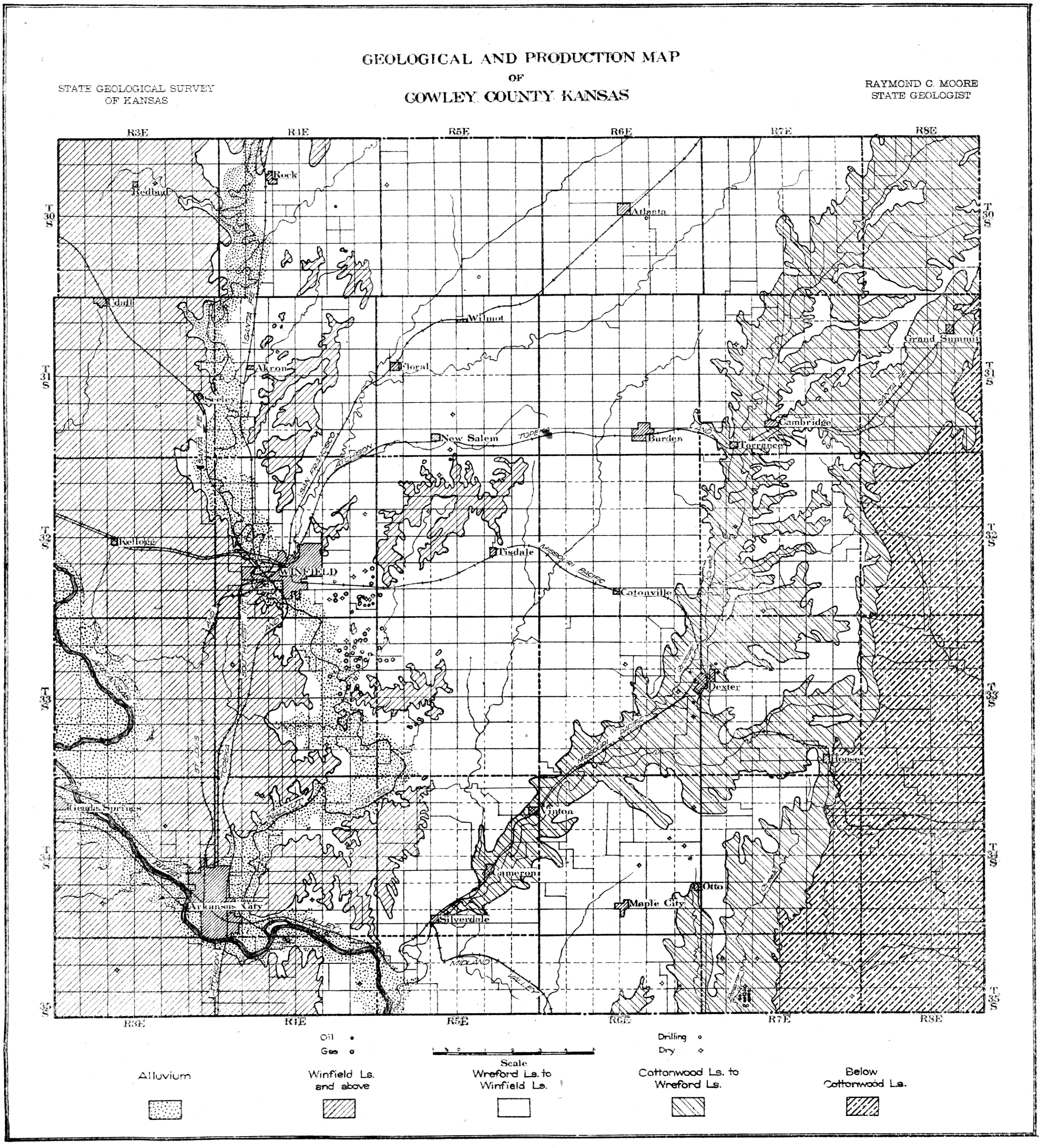


PLATE III. Geological and production map of Cowley county, Kansas.

younger. The older systems, of course, underlie the younger, which were laid down upon them. Sedimentary rocks of systems older than the Mississippian are known to underlie the state from records obtained in drilling deep wells, and wells in central Kansas have encountered igneous rocks of pre-Cambrian age. The accompanying table (page 12) gives the subdivisions of the various systems as recognized in Kansas.

ROCKS EXPOSED IN THE ARKANSAS CITY DISTRICT.

The rocks which are exposed in the Arkansas City district belong to the lower group of the Permian system. Members belonging to the Upper Pennsylvanian system outcrop in the eastern half of Cowley county, but do not appear at the surface in the area included in the Arkansas City district. The distribution of the formations which appear in Cowley county is shown on plate III. The following table gives the divisions of the Pennsylvanian and Permian systems.

- *Permian system.*
  - Cimarron group.
  - Big Blue group
    - Wellington formation (undifferentiated).
    - Marion formation.
      - Pearl shale.
      - Herington limestone.
      - Enterprise shale.
      - Luta limestone.
    - Chase formation.
      - Winfield limestone.
      - Doyle shale.
      - Fort Riley limestone.
      - Florence flint.
      - Matfield shale.
      - Wreford limestone.
    - Council Grove formation.
      - Garrison shale and limestone.
      - Cottonwood limestone.
- *Pennsylvanian system.*
  - Missouri group.
    - Wabaunsee formation.
      - Eskridge shale.
      - Neva limestone.
      - Elmdale shale.
      - Americus limestone.
      - Admire shale.
      - Emporia limestone.
      - Willard shale.
      - Burlingame limestone.
    - Shawnee formation.
    - Douglas formation.
    - Lansing formation.
    - Kansas City formation.
  - Des Moines group.
    - Marmaton formation.
    - Cherokee shale (undifferentiated).

Exposed in Arkansas City district. (Big Blue group through Wreford limestone)

Exposed in Cowley county. (Big Blue group through Burlingame limestone)

As shown in the table, the rocks exposed in the Arkansas City district belong to the Chase, Marion and Wellington formations of the Big Blue group of the Permian. This group, the lower division of the Permian, consists entirely of marine sediments, divided, in the order of their quantitative importance, into shale, limestone, and sandstone. These formations will be discussed in the order of their appearance as the area is crossed from east to west, or from oldest to youngest.

CHASE FORMATION.

Members belonging to the Chase formation are the oldest and lowest rocks, stratigraphically, which appear in the Arkansas City district, and occupy approximately the eastern one-half of the area. (See plate III.) The formation contains a number of massive, cherty limestone members, which, on account of their resistance to erosion, form one of the most prominent topographic features of central Kansas, the Flint Hills. The Chase formation has a total thickness of about 250 feet.

The lowest subdivision of the Chase formation is the Wreford limestone, consisting in its type locality of 35 to 50 feet of massive limestone and chert. The outcrop of the Wreford forms a rather prominent escarpment across eastern Cowley county, and extends westward along Grouse creek to near Silverdale in the eastern part of this area. In parts of southern Kansas the Wreford becomes imperfectly solidified and weathers in places to a reddish-brown, very porous rock. The thickness of the Wreford in parts of Cowley county is not more than 15 to 20 feet.

Overlying the Wreford is the Matfield shale member, which includes from 60 to 70 feet of variously colored shales and thin, interbedded limestones. The outcrop at the surface is not wide.

The Florence flint consists of about 20 feet of very flinty limestone, a number of layers being composed wholly of flint. The member is resistant to erosion, and with the overlying Fort Riley limestone forms a prominent escarpment.

The Fort Riley limestone includes about 40 feet of massive buff limestone with thin, interbedded shaly strata in the upper part. Near the center of the member are one or two very massive beds, which form a conspicuous bench at the outcrop.

The Fort Riley limestone and the Florence flint outcrop in the Arkansas City district, the nearest exposure being in a large quarry about five miles east of town in sec. 1, T. 35 S., R 4 E., where the Fort Riley measures 40 feet in thickness and consists of massive buff limestone, with a little shale in the upper portion. (See plate IV.) The Florence flint is not so well exposed, but is recognizable immediately below the Fort Riley.

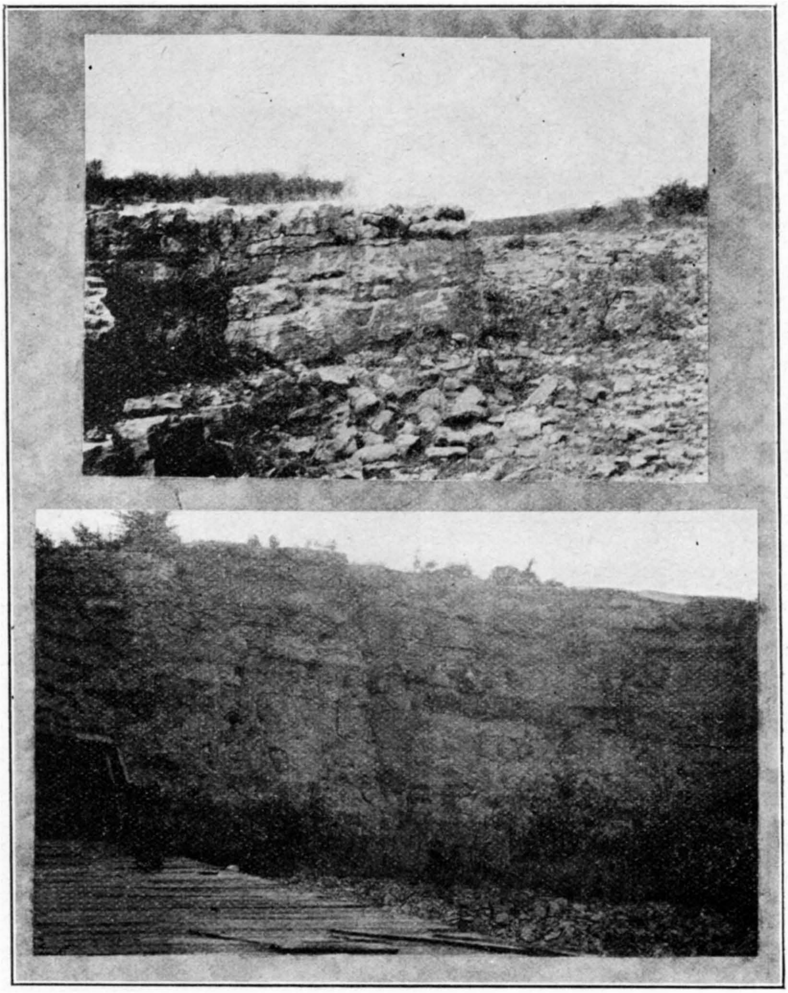


PLATE IV. *Above:* Outcrop of Herington limestone north of Arkansas City. *Below:* Exposure of Fort Riley limestone in quarry in sec. 1, T. 35 S., R. 4 E.

Another good exposure of the Fort Riley is found in the quarry about two miles north of Silverdale.

The Doyle shale member overlies the Fort Riley limestone, and consists of variously colored shales, with thin, interbedded shaly limestone beds. In its type area the Doyle shale is about 60 feet thick, but is thinner in the Arkansas City district, the thickness in some localities being less than 30 feet. It is thicker in the northern part of the area, and contains one rather persistent limestone bed near the center, which is about a foot thick.

The Winfield limestone is the top member of the Chase formation. In areas farther north the Winfield is a very cherty limestone, but in the vicinity of Arkansas City this characteristic is not so prominent. In this area the member is about 15 feet thick. It has a very porous texture near the top, and the upper portion is also fossiliferous, containing numerous crinoid stems and brachipods. The Winfield ranges in color from gray to yellow. It forms an easily traceable escarpment throughout this area, and was used very largely in determining the rock structure of the area. The Winfield is typically exposed near Winfield, 15 miles north of Arkansas City, and its outcrop extends entirely across Cowley county from north to south. (See plate III.) An excellent exposure may be seen about five miles east of Arkansas City at the top of what is locally known as Horseshoe Hill. (See plate V.)

MARION FORMATION.

The Marion formation is clearly defined from the beds above and below it. It lacks the cherty character of the Chase formation below, and is distinguished from the overlying Wellington formation by its limestone content, which is practically absent in the higher formation. The outcrop of the Marion is characterized by broad, rather gentle slopes, in direct contrast to that of the Chase formation. The Marion formation has a total thickness of about 150 feet and has been divided into four stratigraphic subdivisions.

Over a considerable portion of central Kansas the Luta limestone forms the basal member of the Marion formation. It is well exposed in the vicinity of Marion and near Herington, where it is a cellular, soft, gray limestone about 15 feet thick. The member becomes much thinner to the south and is

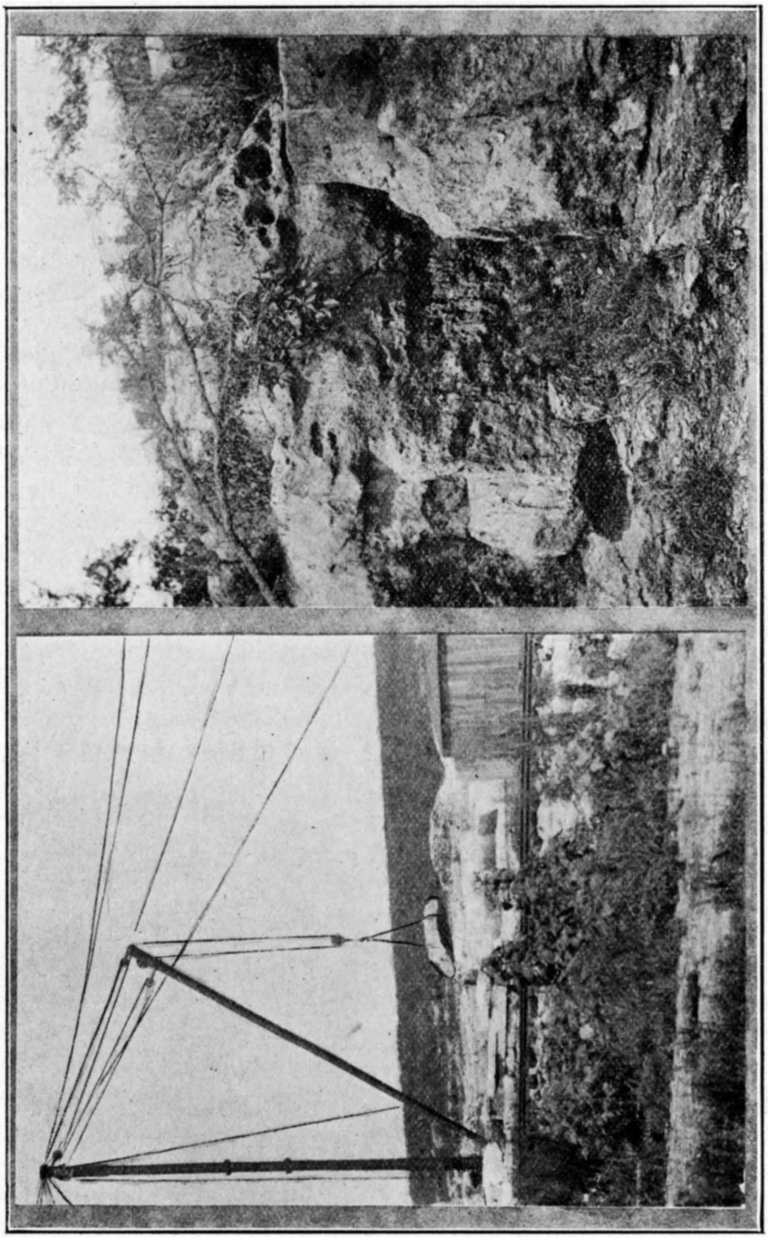


PLATE V. *Left:* Quarry in Fort Riley limestone north of Silverdale. *Right:* Exposure of Winfield limestone at Horseshoe Hill.

barely recognizable in the area about Arkansas City. In some places it is represented by two or three feet of soft, fossiliferous, gray limestone lying immediately above the Winfield, but it is not present over most of southern Cowley county.

The Enterprise shale member consists of variegated shale, green, yellow and maroon in color. It has a thickness in the Arkansas City district of from 45 to 65 feet.

Succeeding the Enterprise shale is a buff to gray, massive limestone, which is rather well exposed in the vicinity of Arkansas City. From typical exposures in the vicinity of Herington, this member has been named the Herington limestone. As exposed about one mile north of Arkansas City, the Herington is about 8 to 10 feet thick, is rather massive, and in places is very sandy. (See plate IV.) A few miles south of Arkansas City, south of Arkansas river, the Herington consists of two limestone beds, separated by 12 to 15 feet of limy shale. The lower limestone is about 3 feet thick, light gray in color, rather hard, and contains a few chert nodules. The upper ledge is about 8 feet thick, buff to light gray in color, thin bedded, and is a good deal softer than the lower ledge.

A succession of green, blue and red shale, termed the Pearl shale member, overlies the Herington limestone. On account of the lack of resistance of the overlying members, outcrops of the Pearl shale are very uncommon. The thickness of the member is estimated to be 70 feet. There are a few more or less persistent limestone members in the upper portion of the Pearl shale, which mark the line of division between the Marion and Wellington formations. These beds have a rather porous texture and are not resistant to weathering, and consequently do not form prominent escarpments.

WELLINGTON FORMATION.

The Wellington formation is the highest formation which is exposed in the Arkansas City district, the lower part of this formation outcropping in the western part of the area near the Sumner county line. The Wellington consists of a thick succession of blue, gray and yellow shales, with a very few nonpersistent limestone beds. The total thickness of the Wellington is estimated to be over 500 feet, but the thickness of the portion exposed in this area is much less. Owing to the lack of any distinct stratigraphic marker between the Wellington and Marion formations, the exact eastern boundary of the Wellington has not been determined.

QUATERNARY DEPOSITS.

In addition to the stratified rocks discussed, there are in this area unconsolidated sediments belonging to the Quaternary system. These deposits are the river alluvium in the valleys of the Arkansas and Walnut rivers and at least one gravel deposit of Pleistocene age. This deposit is located 3 miles north of Silverdale and is a Pleistocene river deposit. It consists largely of a chert gravel, probably having its origin in the cherty members of the Chase formation. The deposit covers several acres of ground and is about 8 feet thick. (See plate VI.)

CONCEALED ROCKS IN THE ARKANSAS CITY DISTRICT.[1]

Information concerning the rocks which underlie the Arkansas City district, but which do not appear at the surface anywhere in the area examined in this survey, may be obtained from two sources, one from well records, and the other from observations made at the outcrops outside the area. From a study of well logs it is known that the lower formations of the Permian system and the Pennsylvanian system of Kansas underlie all of southwest Cowley county. A number of wells have been drilled into the Mississippian, so that at least a part of this system is present. On account of the general west dip of the rock strata in eastern Kansas, these formations which are present beneath the surface in the Arkansas City district outcrop farther east where the overlying rocks have been eroded.

If a well were drilled near Arkansas City, starting in the Winfield limestone member, it would pass through about 200 feet of limestone and shale belonging to the Chase formation, which outcrops in the area east of Arkansas City. The next lower formation which would be encountered is the Council Grove formation, the basal division of the Permian. The average total thickness of the Council Grove is about 150 feet. It consists of an upper member of shale and thin, interbedded limestones, and a lower, resistant limestone member at the base. After passing through the Council Grove formation the

1. For detailed discussion of the geology of Kansas, see Moore, Raymond C.; Oil and gas resources of Kansas; Geology of Kansas: Geol. Survey of Kansas, Bull. 6, pt. 2; 1920.

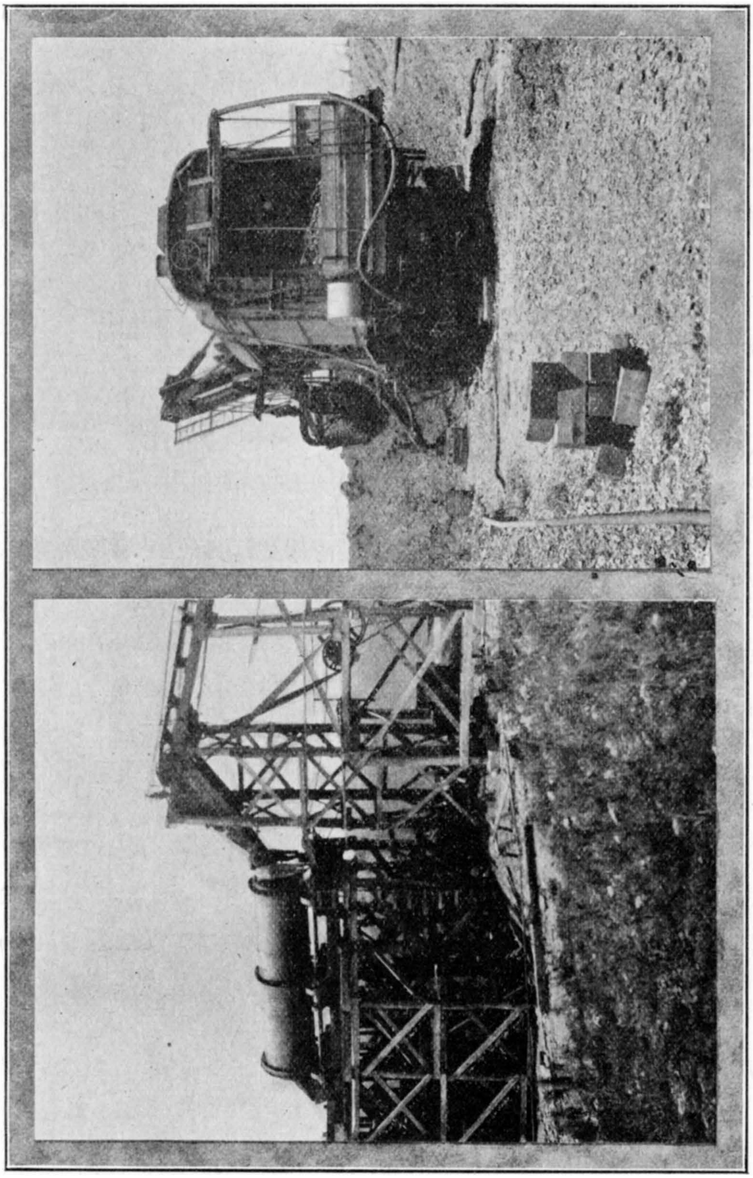


PLATE VI. *Left:* Gravel washer, north of Silverdale. *Right:* Pleistocene gravel deposit, north of Silverdale.

bit would enter the upper members of the Pennsylvanian system. The total thickness of the Pennsylvanian in this area is less than 3,000 feet. As observed in the area of its outcrop in eastern Kansas, the Pennsylvanian consists of a thick series of alternating shale and limestone members with irregular beds of sandstone and some beds of coal. From a quantitative standpoint, the shales are the most important of the Pennsylvanian rocks. The limestones are mainly light-colored, fossiliferous, fine-grained rocks, many of the beds being also very cherty. Named in order from top to bottom, the following formations would be encountered in the well: Wabaunsee, Shawnee, Douglas, Lansing, Kansas City, Marmaton, and the Cherokee shale. (See table, page 12.) Of these, the Wabaunsee is the only one which appears at the surface in Cowley county.

Members belonging to the Wabaunsee formation, which has a total thickness of about 500 feet, outcrop in the southeastern part of the county. The Wabaunsee consists of alternating limestone and shale beds, the top member being the Eskridge shale, which immediately underlies the Cottonwood limestone, and the basal member the Burlingame limestone.

The succeeding lower members of the Pennsylvanian as they would be encountered in a well are exposed in the same order as the state is crossed from west to east from the eastern edge of Cowley county. The Cherokee shale, the basal formation of the Pennsylvanian, which should be encountered in a well near Arkansas City at a depth of about 3,100 feet, is exposed in the southeastern part of the state, covering most of Cherokee and parts of Crawford, Labette and Bourbon counties. This formation contains numerous sandstone beds which have proven productive of oil and gas in areas where it is covered. In addition to the sands in the Cherokee, there are other very good sands found in higher formations of the Pennsylvanian. Some of the more important of these are in shale members of the Marmaton and Kansas City formations.

Immediately below the Cherokee shale, the Mississippian system, commonly spoken of as the "Mississippi lime," would be encountered. It was found at a depth of 3,270 feet in the Marland well south of Arkansas City. The Mississippi lime is exposed at the surface in Kansas in a very small area in the southeast part of Cherokee county, in the extreme southeast part of the state. It consists chiefly of a crystalline limestone containing an unusual amount of hard chert, and contains at least two sand "breaks" which have been productive of oil in southern Kansas and Oklahoma. The total thickness of the Mississippian in Kansas is estimated at about 350 to 400 feet.*

ECONOMIC GEOLOGY.

The natural resources of the Arkansas City district are oil and gas, clay, road materials, cement, building stone, sand and gravel, and water supply.

OIL AND GAS.

The Arkansas City district is centrally located with reference to a number of producing fields in both Kansas and Oklahoma. (See figure 2.) The nearest fields are those in Kay and Osage counties, Oklahoma, and in Chautauqua, Elk and Butler counties, Kansas. There is some production in Cowley county near Dexter and Maple City in the eastern part, and near Winfield in the central part of the county. (See plate III.) A southern extension of the Fox-Bush pool of Butler county extends a short distance into Cowley county on the north.

DEVELOPMENT.

The Dilworth field, a northern extension of the Blackwell field, is located about 16 miles southwest of Arkansas City in Oklahoma. The field was opened about 1912 and development has continued intermittently up to the present time. The deep production in the Blackwell field occurs at a depth of about 3,300 feet. There are a number of producing sands at shallower depths, a fairly good gas sand being found at about 750 feet.

In the field located northwest of Newkirk, about 12 miles south of Arkansas City, production has been encountered in the Mississippi lime at a depth of about 3,400 feet. There is also considerable production in the vicinity of Ponca City, development work having been started in this field as early as 1904.

Chautauqua county, east of Cowley, has been an important oil- and gas-producing area for a good many years. Production in the Peru and Sedan fields is encountered in three sands —the Bartlesville, Peru and Red—found there at depths of

* It is possible, indeed probable, in some cases that these "breaks" are below the Mississippian.—STATE GEOLOGIST.

about 1,200, 1,000 and 950 feet, respectively. Most of the oil wells in Chautauqua county are small producers, but are noted for their long life, some of the wells having produced for as long as 12 or 15 years.

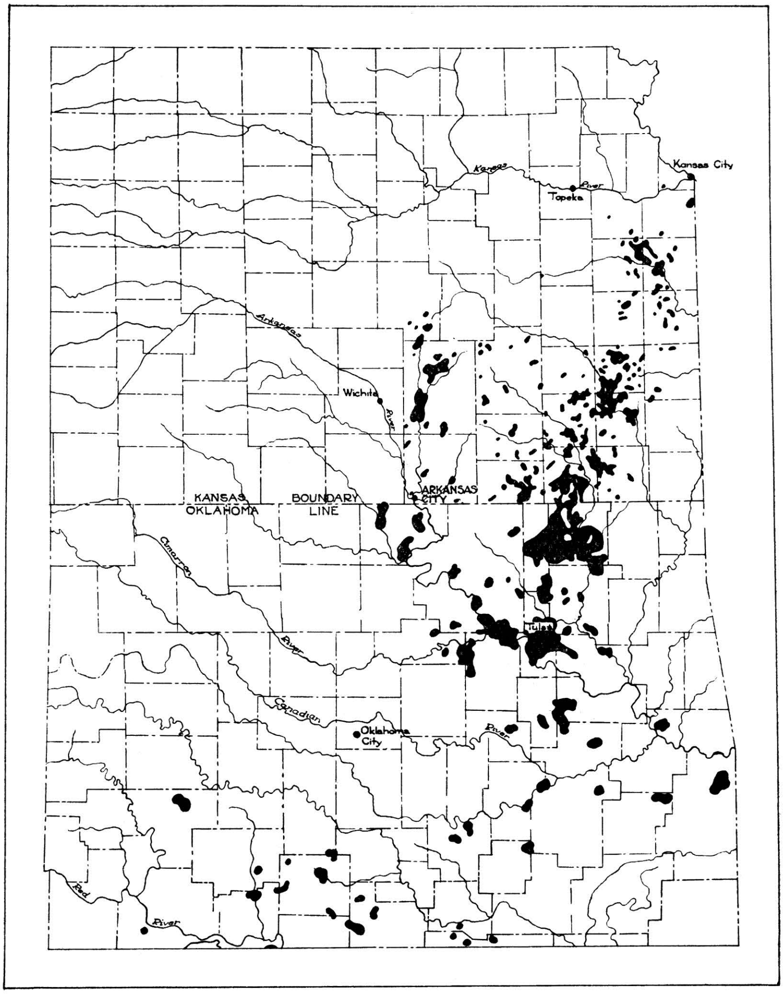


FIGURE 2. Map showing location of Arkansas City with reference to the oil and gas fields of Kansas and Oklahoma.

The area of largest oil and gas production in Kansas is in Butler county, just north of Cowley. Oil was first discovered in commercial quantities near Augusta in 1914, although the county had been producing gas for a number of years previous.

Most of the production in the Butler county fields is found in sands varying in depth from 1,700 to 2,700 feet. In the Fox-Bush field, in the southern part of the county, the main producing horizon is the Burgess sand, found at a depth of about 2,700 feet.

There are a number of small oil and gas fields in Cowley county. One area of considerable importance is located about seven miles southeast of Maple City, in sec. 17, T. 35 S., R. 7 E. Eleven wells have been drilled in the northeast quarter of this section, all of which are producing. The first well was drilled in 1917. One well is producing gas at the rate of six million cubic feet per day from a sand at 1,400 feet. Another well was drilled to the Bartlesville sand at a depth of 2,665 feet and came in at about 200 barrels. The remaining wells get their production from the Peru sand at a depth of about 2,000 feet. The average initial daily production of the ten oil wells was about 100 barrels and the settled daily production about 80 barrels per day.

An area in which considerable gas and oil is being produced is located southeast of Winfield. The production here is obtained largely from sands from 1,400 to 1,700 feet in depth. A very good gas sand is found in this area at a depth of from 650 to 700 feet.

There are a few wells near Dexter, in eastern Cowley county, some of which have been producing oil for several years. Production in this area is found at a depth of about 2,200 feet, from what is reported to be the Bartlesville sand.

There has been some development work within a radius of a few miles of Arkansas City, some production, principally gas, being encountered north of town as early as 1906. These wells, however, have been abandoned. There are several fairly good gas wells about 4 miles southeast of town in sec. 4, T. 35 S., R. 4 E. These wells are producing from a sand at a depth of about 1,925-1,950 feet, which probably belongs to the Chanute or Cherryvale shale member of the Kansas City formation.

A well of considerable importance in this district is the Marland well, located about 5½ miles southeast of Arkansas City, in sec. 16, T. 29 N., R. 3 E., Kay county, Oklahoma. This well was brought in at 700 barrels in May of 1920, and has settled to about 300 barrels. The production is obtained from a sandy lime in the Mississippian at a depth of 3,635-3,669 feet. The Mississippi lime was encountered at 3,270 feet.

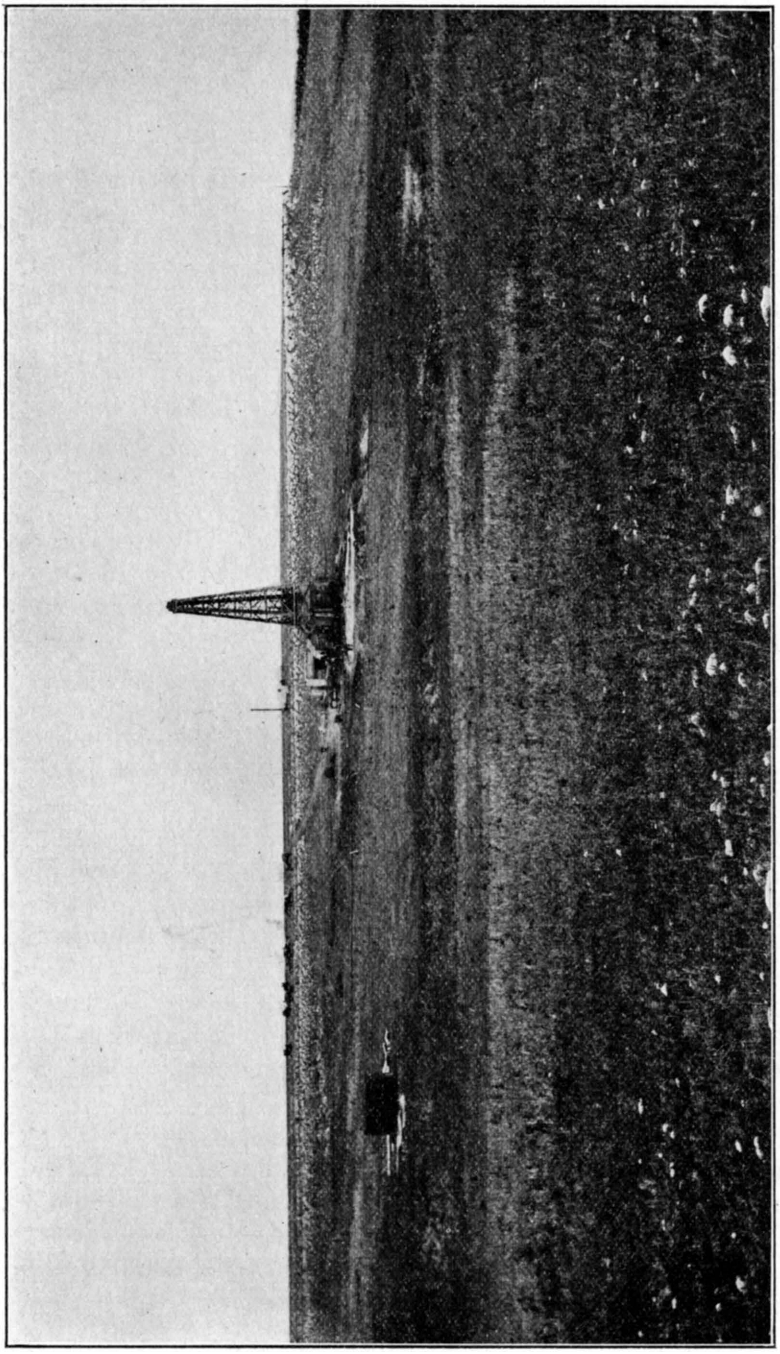


PLATE VII. Oil well in sec. 16, T. 29 N., R. 3 E., Kay county, Oklahoma, 5½ miles southeast of Arkansas City, showing also the outcrop of the Winfield limestone.

STRUCTURE.

In this area, as in other areas in the Midcontinent field, geologic structures such as anticlines, domes and terraces are most favorable for the accumulation of oil and gas. It should be remembered, however, that the location of a well on favorable geologic structure does not guarantee the finding of oil or gas. Nevertheless, such a location does greatly diminish the risk attached to oil and gas prospecting. A number of conditions may exist beneath the surface, any one of which may cause a structure to be unproductive. There may be no porous stratum or "sand" capable of holding commercial deposits of oil or gas, and even if such a porous stratum is present it may be dry. The sand may be so tightly cemented that there is very little pore space, and consequently oil and gas cannot be present in large quantities. There is also possibility that the oil- and gas-bearing horizons do not conform to the surface formations, surface structure not being precisely reflected, therefore, in the lower strata. This latter condition is of importance in the Arkansas City district, owing to the fact that a part of the production may be expected from the Mississippi limestone, and there is a known unconformity between the Mississippian and the overlying Pennsylvanian formations. However, experience has shown that Mississippian production follows surface structure in general rather closely.

A detailed structural examination was made in Townships 34 and 35, South, Range 3 East, with the aid of a telescopic alidade and a plane table. The strata in this area have a general dip a little south of west, which amounts on the average to about 30 feet per mile. This normal dip is interrupted in a number of places by small folds, which form domes, anticlines or synclines. The arrangement of these folded areas is not regular, but in general they appear to trend slightly east of north.

The geologic structure is shown on the map (plate VIII) by structure contours, which are imaginary lines connecting all points of equal elevation of the rock stratum. Since no single limestone bed is found over the entire area, it was necessary to secure elevations on two different beds, the Winfield and Herington limestones. The interval between these beds was determined in a number of favorable localities and the elevations all reduced to a datum, the top of the Winfield limestone. The elevations shown on the contour lines indicate height above sea level, and the contour interval is 5 feet.

The largest and most favorable structure in this area is located in secs. 3, 4 and 9, T. 35 S., R. 4 E. This structure has a maximum east dip of 23 feet in a distance of about three-fourths of a mile. The north dip cannot be determined on account of lack of exposure in the broad valley of Arkansas river, but it is probable that the structure closes on the north. Several gas wells are located in the valley in the northeast quarter of section 4, which are thought to be on the north extension of this structure. A dry hole was drilled in the southwest corner of section 4 to a depth of over 3,400 feet and was abandoned in the Mississippi lime. As seen from the accompanying structure map, this well is located down on the west side of the structure. A well was drilled in the southwest quarter of the northwest quarter of section 3 to a total depth of 3,645 feet. This well encountered several gas sands, one near 1,400 and one at 1,951, corresponding to those found in the producing gas wells in section 4, and also got an oil showing at 3,240-3,276 feet. This test was located slightly east of the structure. (See plate VIII.) Probably the best location for a deep test of this structure would be the center of the north line of the southeast quarter of section 4.

South of the structure just described, in the eastern part of sections 9 and 16, is another structure, smaller than the first, having an east dip of only a little over 10 feet in about one-half mile. The exact outline of this structure could not be determined on account of the lack of exposures in parts of sections 15 and 16, but it is very nearly as shown on the structure map. Although this structure is not as large as that to the north, it is probably worth testing. It is interesting to note that this structure, with the one in sections 4 and 9, are almost in line north and south with the structure on which the Marland well is located, just a mile south of the state line, and it seems very probable that there is some connection between them.

There is a terrace-like structure in secs. 13 and 14, T. 34 S., R. 4 E. The maximum east dip here is not over 5 feet, but the "flat" covers an area of about a square mile. On the north of

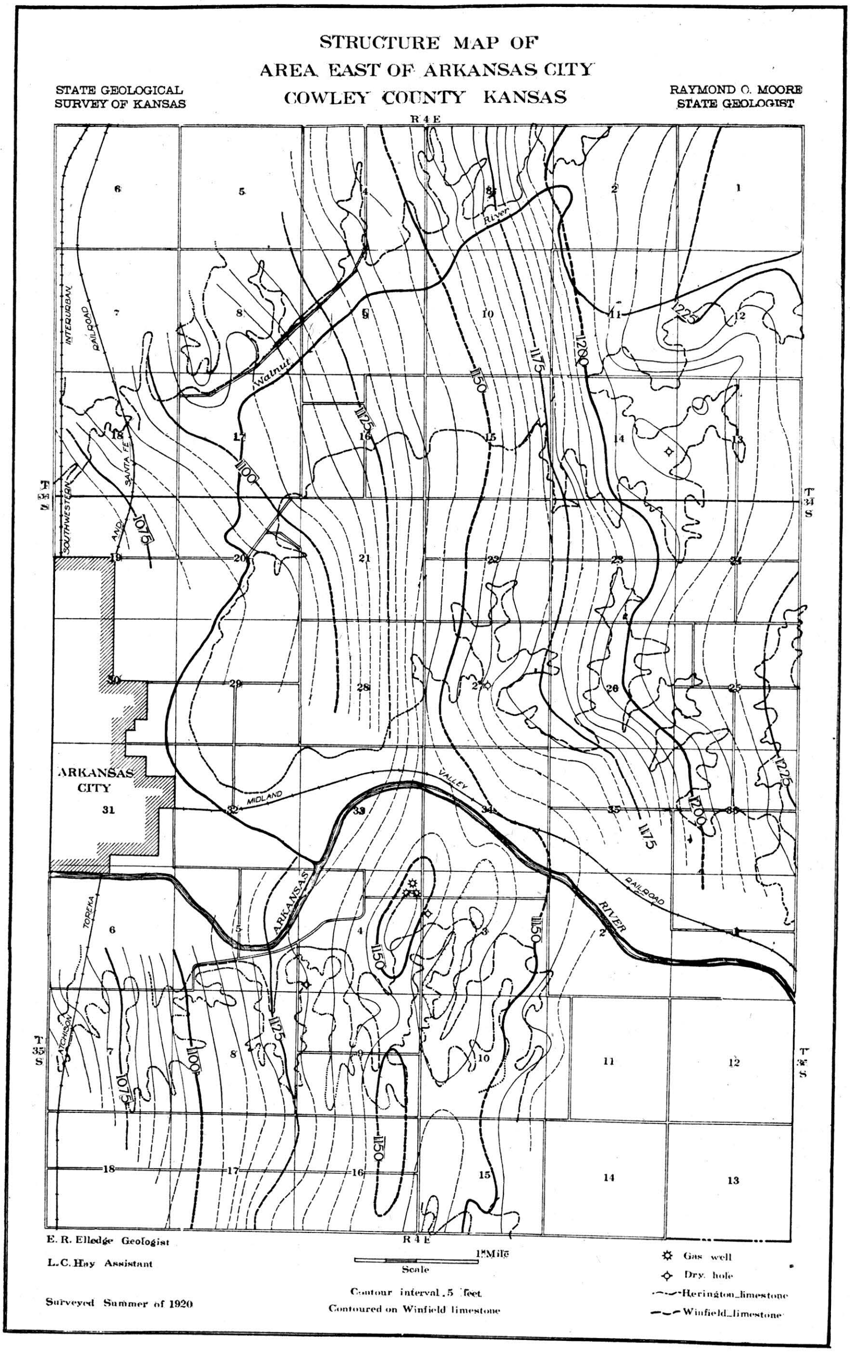

STRUCTURE MAP OF
AREA EAST OF ARKANSAS CITY
COWLEY COUNTY KANSAS
STATE GEOLOGICAL
SURVEY OF KANSAS
RAYMOND C. MOORE
STATE GEOLOGIST
R 4 E
Walnut
River
INTERURBAN
RAILROAD
SOUTHWESTERN
AND
SANTA FE
ARKANSAS
CITY
MIDLAND
VALLEY
ARKANSAS
RIVER
RAILROAD
TOPEKA
ATCHISON
T
34
S
T
35
S
E. R. Elledge Geologist
L. C. Hay Assistant
Surveyed Summer of 1920
1 Mile
Scale
Contour interval 5 feet
Contoured on Winfield limestone
Gas well
Dry hole
Herington limestone
Winfield limestone

PLATE VIII.

this terrace, in sections 11 and 12, is a "nose" with an east dip of 9 feet and a south dip of 20 feet. A well was drilled in the northeast corner of the southeast quarter of section 14 on what is probably as favorable a location as any on the terrace. This well was abandoned, but is reported to have been drilled to a depth of less than 2,000 feet, so cannot be considered as a thorough test of the structure. A location near the northwest corner of the southwest quarter of section 12 should prove whether or not the "nose" will prove productive.

There is also evidence of a small dome just north of Arkansas City, in sections 8 and 17. On account of the character of the Herington limestone in this area, it was not possible to determine its exact size and shape. This is the area in which a number of gas wells were drilled several years ago, but so far as is known, no deep test has ever been made. The fact that the gas wells were found here makes a deep test very desirable.

It is reported that a favorable structure has been mapped just east of Silverdale and that a well is being drilled on it. This area was not mapped in detail, so its exact location and size are not known.

Although several dry holes have been drilled in the area under discussion, it will be seen from the structure map that, with one exception, they were not located on the most favorable structures, and consequently do not condemn the area. The well drilled in sec. 14, T. 34 S., R. 4 E., was not drilled to sufficient depth to be a thorough test of the structure on which it is located. The fact that a number of good gas wells have been drilled on the structures discussed, and that the Marland well, which has a settled production of 300 barrels, is located just a mile from the southern edge of this area, and that there are several producing areas located within 25 miles of Arkansas City, make desirable, in the writer's opinion, the testing of these structures. In order to make these tests thorough, the wells should be drilled at least to the second "break" in the Mississippian. Since recent subsurface investigations[2] in Kansas and Oklahoma indicate that much important production is coming from rocks even older and lower than the Mississippian, thorough testing of the Arkansas City structures should require drilling deeply into or through these pre-Mississippian rocks.

2. Aurin, F., Clark, G. C., and Trager, E.; Pre-Pennsylvanian stratigraphy of the Midcontinent region: Bull. Am. Assn. Petroleum Geol., vol. 5, No. 2; March, April, 1921.

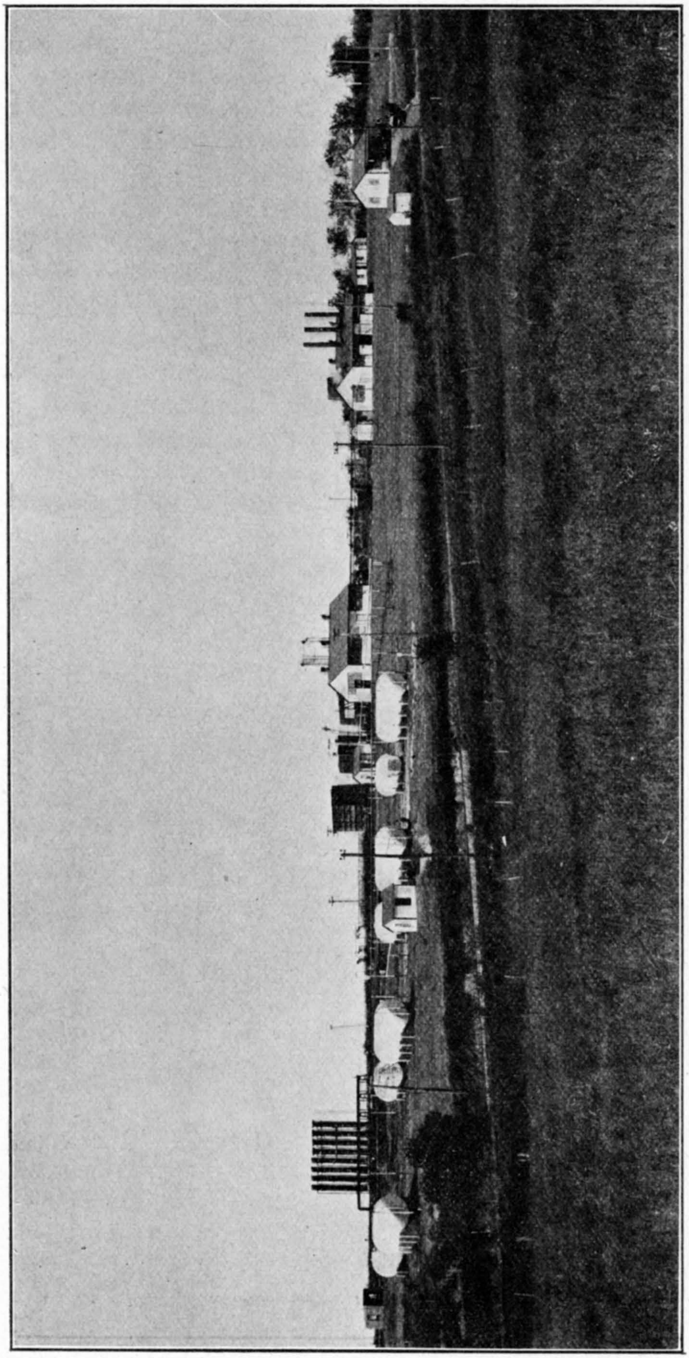


PLATE IX. The Empire natural-gas gasoline refinery at Arkansas City.

REFINERIES.

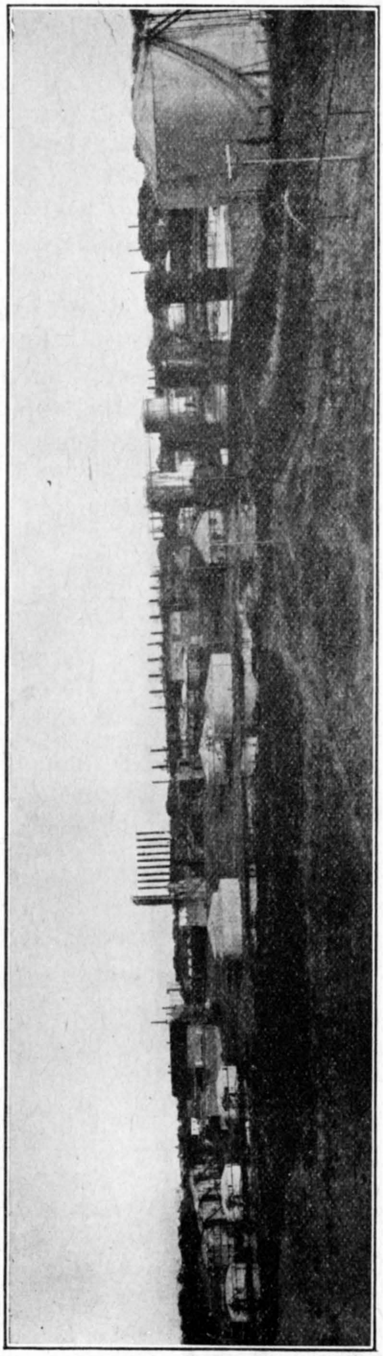
The four refineries located in Arkansas City are centrally located with reference to production in both Kansas and Oklahoma. They also have the advantage of adequate transportation facilities, the town being connected by railroad lines with the fields of Butler, Chautauqua and other counties in Kansas, and with those in Kay and Osage counties in Oklahoma. The refineries in operation at the present time include three crude-oil refineries and one natural-gas gasoline plant. These are the Millikan refinery, now being operated by the Mid-Co. Oil Company, capacity, 6,000 barrels of crude oil daily; the Kanotex refinery, capacity, 3,500 barrels of crude oil daily; the National Oil Company refinery, capacity, 40,000 barrels of crude oil monthly; and the natural-gas gasoline plant of the Empire Gas and Fuel Company, capacity, 60,000,000 cubic feet of gas per day, yielding 8,000 gallons of gasoline.

CLAY.

An investigation of the clay and shale resources of the Arkansas City area was made in order to locate any deposits which might be of value in the manufacture of clay products. Samples of the clay deposits which might be suitable were taken under the direction of Mr. Paul Teetor, ceramic engineer of the Geological Survey, and were sent to the ceramic laboratory for testing. The final results of these tests are discussed in an accompanying report by Mr. Teetor.

There is an inexhaustible supply of clay shales in the vicinity of Arkansas City, but their possible utilization in a commercial way depends, of course, on a variety of factors: first of all, the chemical and physical properties of the clay; next, the locally available quantity, accessibility, amount of overburden, etc. In the field examination, samples were taken from localities where these geographic conditions were favorable.

In order to make the field investigation as complete as possible, samples were taken from all the shale members which appear at the surface. These members are the Pearl shale, the Enterprise shale, and the Doyle shale. On account of the fact that these individual geologic horizons are similar over the entire area, their physical and chemical properties



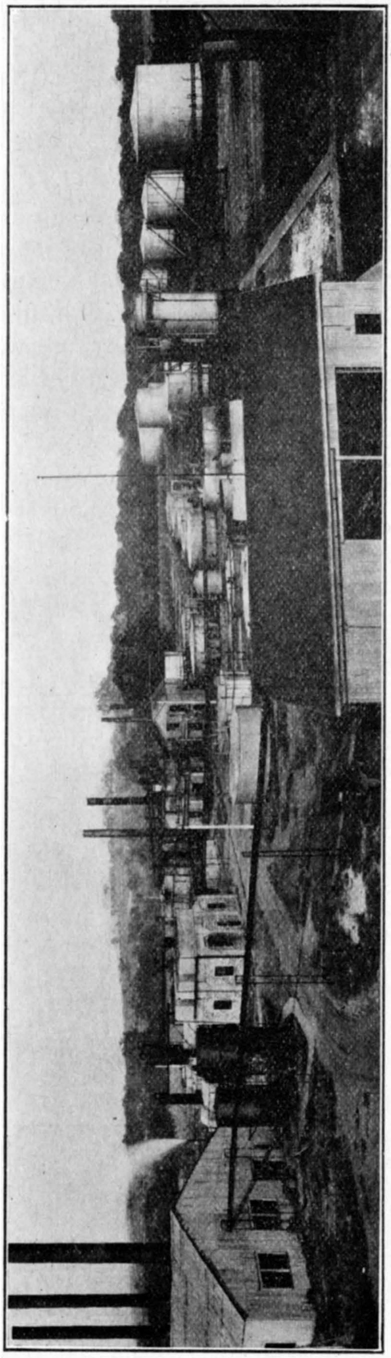


PLATE X. *Above:* Milliken oil refinery. *Below:* Kanotex oil refinery.

will vary only slightly in a distance of two or three miles, and the number of samples taken is sufficient to determine the value of all the shales appearing in the area.

ROAD MATERIALS.

Owing to the commercial opportunities and advantages of good roads to any community, the subject of road materials is of vital interest to all residents of the Arkansas City district. The expense of road improvement is dependable to a large extent on the character, abundance and accessibility of local materials. If suitable materials are readily available in the vicinity of a proposed highway, the cost of construction is reduced to a minimum, but if it is necessary to transport the materials a great distance the cost is very materially increased.

The materials which are found in this district which are available for road construction are limestone, sand and gravel. In studying these materials, samples of all which it was thought might prove satisfactory were collected and sent to the State Road Materials Testing Laboratory at Manhattan, where tests were made to determine their physical properties.

These tests as made at the laboratory determine the specific gravity, per cent of wear, French coefficient of wear, hardness, toughness and cementation of the material submitted. In order to meet the specifications for use in a concrete rod, stone for use in the base course should have a French coefficient of wear of not less than 5 and toughness not less than 4; and for use in the surface course, French coefficient of 8 and toughness 6.

SAMPLES.

The report on a sample of limestone collected from the SW¼ of sec. 10, T. 35 S., R. 4 E., shows that this material has a French coefficient of wear of 5 and would probably give satisfactory results if used in the base course of a concrete or macadam road. This material was taken from the lower bed of the Herington limestone member. The thickness of the bed is about 2½ feet.

A sample of limestone was taken at the quarry in sec. 1, T. 35 S., R. 4 E. Tests on this material show that the French coefficient is slightly below specifications, being only 4.8. This was sampled from the Fort Riley limestone member, which is about 40 feet thick. The stone varies in its physical properties, but the sample was thought to be representative of the quarry. The better grade of this material would be satisfactory for use in the base course.

A sample of the Herington limestone was collected in NW¼, sec. 7, T. 35 S., R. 4 E. This stone has a French coefficient of 4.5, slightly below specifications, but would probably give satisfaction if used in the base course. The thickness of the ledge exposed in this locality is about 5 feet.

Tests on a sample of the Winfield limestone taken in NW¼, sec. 36, T. 34 S., R. 4 E., indicate that this stone is too soft for use in road construction.

A sample was taken of the sand which is being pumped from Arkansas river east of Arkansas City by the Arkansas City Sand Company. The report from the laboratory states that this is a good, clean sand and would be satisfactory for use as fine aggregate in concrete work. It is a medium coarse sand, and the supply is practically unlimited, as a good grade of sand can probably be found at a number of places along the river.

A sample of washed gravel from the pit three miles north of Silverdale was sent to the laboratory, and their report states that this is a very hard and well-graded material which will give excellent results as road material. This gravel as taken from the pit is mixed with a red clay, and has been used locally for road building just as taken out, with good results. After a little use, the gravel with the clay binder forms a hard, comparatively impervious road bed. With a little care this type of road will give very satisfactory results.

CEMENT.

There are not at the present time any cement plants in operation in the vicinity of Arkansas City, but it is reported that a small amount of cement was manufactured several years ago from material obtained from the quarry in the Fort Riley limestone in sec. 1, T. 35 S., R. 4 E. The project was abandoned, however, before the cement had been manufactured in commercial quantities. No samples of the materials which are necessary for the production of cement—namely, limestone and shale—were taken, as the Survey is not at the present time equipped to make the necessary tests. It is probable, however, that satisfactory materials are present in this area.

BUILDING STONE.

The most satisfactory stone for building purposes found in the Arkansas City district is the Fort Riley limestone. This is due both to the character of the stone and the thickness of the ledge. The Fort Riley is quarried for building stone at the quarry two miles north of Silverdale. The Winfield limestone is too soft and porous for use as building stone. The Herington is hard enough in some localities, but in others is much too soft. The lower bed of the Herington has been used locally for building stone from a quarry in sec. 10, T. 35 S., R. 4 E.

WATER SUPPLY.

The city of Arkansas City has an abundant supply of good water obtained from four wells located in the Arkansas river valley, the source of supply being the underflow of the river. These wells are about 60 feet deep, and combined have a pumping capacity of four million gallons per day. The water is practically inexhaustible, as the valley here is nearly five miles wide and the alluvial material is from 30 to 100 feet thick, thus affording an enormous reservoir. A plentiful supply of water can be obtained at comparatively shallow depths any place in the valleys of the Arkansas and Walnut rivers in this area. That from the Walnut is, however, so highly mineralized on account of salt water and other waste products from the oil fields to the north that it cannot be used for domestic purposes. In the higher areas back from the rivers the water is obtained from shallow wells drilled in the sedimentary rocks and from numerous springs. Most of the area has an adequate supply of ground waters at comparatively shallow depths.

Throughout the area in which the Winfield limestone is exposed there are numerous springs located near the top of this limestone which furnish a good supply of water. One such spring is located about two miles southeast of Arkansas City, in the southwest corner of sec. 5, T. 35 S., R. 4 E. Another is about two miles northeast of town, in the NE¼, sec. 20, T. 34 S., R. 4 E. So far as was learned, these springs are not intermittent, and furnish a large amount of water during the entire year.

Eight miles northwest of Arkansas City, at the little town of Geuda Springs, is situated a rather remarkable group of

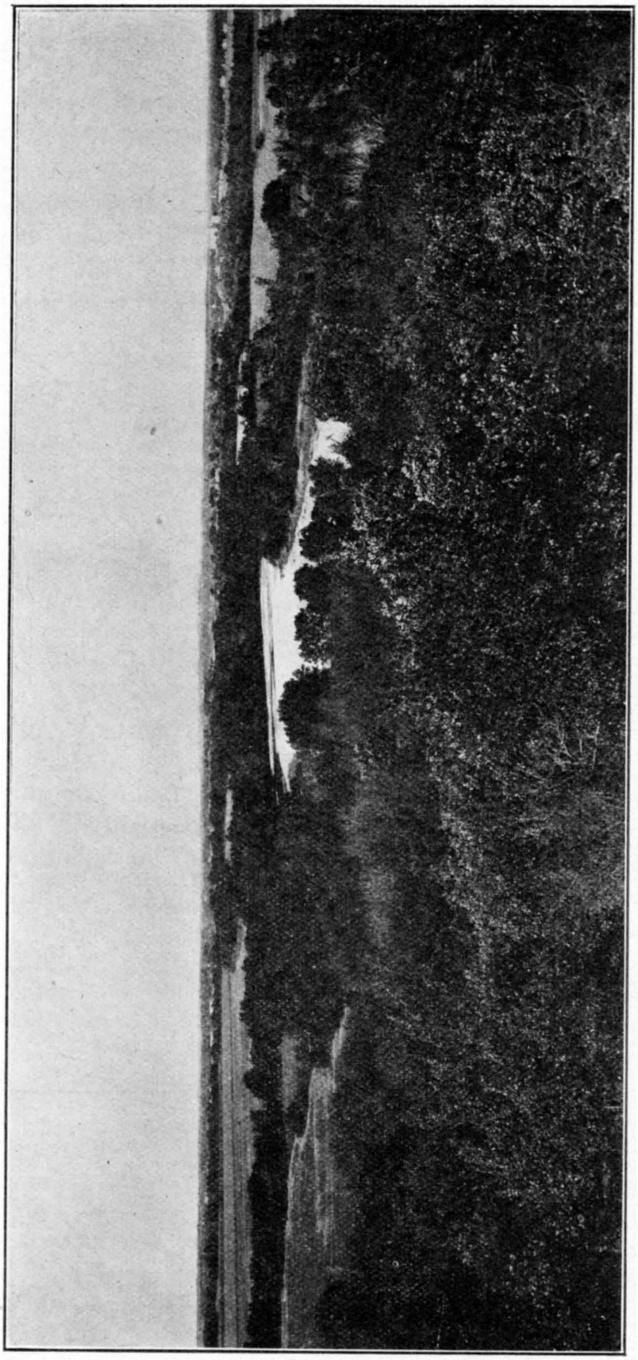


PLATE XI. View of the flood plain of Arkansas river, looking west toward Arkansas City.

seven springs. The water which flows from these springs is highly mineralized and is considered beneficial for medicinal purposes. As a result of the medicinal properties of this water, Geuda Springs is more or less of a health resort, and has a hotel, a bathhouse and hospital for the accommodation of visitors.

Clay and Shale Resources in the Vicinity of Arkansas City, Kan.

By Paul Teetor.

INTRODUCTION.

An investigation of the clays and shales was made in connection with the work which was conducted under the coöperative arrangement made between the State Geological Survey of Kansas and the Chamber of Commerce of Arkansas City, Kan.

The field work—that is, the locating and sampling of the clay and shale deposits—was done by the writer, assisted by Mr. E. R. Elledge and Mr. Lawrence Hay. The entire area around Arkansas City was thoroughly prospected and samples were taken of every deposit which had any possibility of being of commercial value.

PROPERTIES AND TESTING OF CLAYS.

The clays and shales occurring in the Arkansas City region belong to the class which is utilized in the manufacture of structural products. These products are practically all made by either the stiff-mud process or the dry-press process of shaping. In the former case the clays or shales are crushed and mixed with sufficient water to form a plastic mass which can be forced through a die to produce a column of plastic clay of the proper cross section. The column is then sliced into units of proper thickness. In the dry-press process the clays or shales are crushed and mixed with from 6 to 10 per cent of water, and the moist, finely divided material is fed into a metal die box and sufficient pressure exerted upon the top and bottom of the die to compress the clay into a mass of sufficient strength to withstand the ordinary handling in the process of manufacture. For this second type of clay the following tests are of importance in determining the commercial value of the deposits.

The working properties of the plastic mass, after the proper amount of water has been added to produce best working properties, are of prime importance. If the clay is not plastic enough the clay column will not hold together as it issues from the die; if too plastic it will develop laminations while being shaped, and is also very likely to crack while drying.

The percentage of drying shrinkage is also of importance, because a clay with a high drying shrinkage is very apt to crack during drying.

The properties of the clay after it has been burned at different temperatures are of prime importance, the three most important properties being color, burning shrinkage, and porosity. From the burning shrinkage can be estimated the warping and cracking which can be expected during burning. The porosity gives an estimate of the strength and also of the range of temperature in which the clay can be properly matured in the kiln. By porosity is meant the pore space present in the burned specimen, and this is determined by dividing the weight of water absorbed by the specimen while submerged in water under a vacuum, by the volume of the piece.

It is also a well-known fact that the presence of limestone particles, coarser than 30-mesh, in a clay render it useless for the manufacture of structural clay products, owing to the fact that during the firing of the clay the limestone is converted to lime. Upon exposure to the atmosphere the lime absorbs water and is converted into lime hydrate, with an increase in volume and a resulting pressure on the surrounding clay particles sufficient to cause a rupture known as a "popped brick."

ARKANSAS CITY CLAYS.

There are a number of shales in the Arkansas City area. Some are soft shales containing limestone concretions and are easy to cut with a pick and shovel, while others are very hard and might be termed shaly limestone. In each case a ten-pound sample was secured by cutting away the weathered face of the outcrop and taking the sample so as to represent the entire depth of the exposed deposit. These samples were sent to the ceramic laboratory of the State Geological Survey for detailed testing to determine the commercial value of the various deposits. There were in all eight deposits of shale which appeared worthy of tests. A description of these deposits and the results of the tests follow.

PEARL SHALE.

Sample No. 505 represents a typical deposit of the Pearl shale located in the southeast corner of sec. 21, T. 34 S., R. 3 E., three miles from Arkansas City and three-fourths mile from the railroad. It has a thickness of 10 to 12 feet, is 500 feet long (estimated), and is probably 300 to 400 feet wide. There is an overburden of 15 to 20 feet, which contains limestone. This overburden is so thick compared to the thickness of the deposit itself, that it could be removed only at a cost prohibitive, under normal conditions, to the manufacture of structural material such as brick and tile. It is therefore probable that this deposit is of no commercial value.

This clay has poor working properties as regards its fitness for working by the stiff-mud process, even when ground to pass the 10-mesh sieve, although when passed through a 20-mesh sieve its working properties are slightly better. It should work best by the dry-press method of shaping. Its water of plasticity is 19.8 per cent and its drying shrinkage 4.83 per cent. The clay, after being ground and mixed with water to produce the best working properties, was molded by hand into briquettes. These were dried and the drying shrinkage obtained. They were then placed in a kiln for the purpose of determining the properties of the clay at higher temperatures. Pieces were drawn from the kiln at temperatures of Seger cones listed below, the approximate equivalents in the Fahrenheit scale as reported by the manufacturers being also given.

Cone 010	174½° F.
Cone 07	1,850° F.
Cone 05	1,922° F.
Cone 02	2,030° F.
Cone 1	2,102° F.
Cone 3	2,174° F.
Cone 5	2,246° F.
Cone 7	2,318° F.

The final specimens were examined for burning shrinkage, porosity, color, and hardness. These data are given in table 1.

Sample No. 505, when ground to pass a 10-mesh sieve or coarser, produces a brick of dark-brown color and one that disintegrates rapidly when exposed to the weather. This is due to the formation of lime hydrate from free lime particles which are present. When ground to pass a 20-mesh sieve it produces a sound brick at cone 4, with a beautiful brown color.

Table No. 1.

Sample No.		Temperature.							
		Cone 010.	Cone 07.	Cone 05.	Cone 02.	Cone 1.	Core 3.	Cone 5.	Cone 7.
505	Burning shrinkage, per cent....	....	0.69	1.60	1.60	2.12	3.19	2.29	28.96
	Porosity, per cent....	....	45.94	43.90	43.98	39.50	38.70	20.33	68.02
	Hardness.....	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.
	Color........	Grey brown.	Light brown.	Light brown.	Light brown.	Brown.	Brown.	Brown.	Brown.
506	Burning shrinkage, per cent....	-3.33	-3.33	-3.33	-3.33	-4.03	-2.67	0.89	7.64
	Porosity, per cent....	56.50	55.30	55.30	55.42	54.82	54.17	44.97	29.45
	Hardness.....	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.
	Color........	Light cream.	Light cream.	Light cream.	Light cream.	Light cream.	Cream.	Cream.	Cream.
507	Burning shrinkage, per cent....	-2.27	-1.34	-2.24	-2.02	....	3.18	1.80	-2.02
	Porosity, per cent....	63.75	61.31	62.82	62.78	62.91	63.14	61.82	62.56
	Hardness.....	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.
	Color........	Light cream.	Light cream.	Light cream.	Light cream.	Light cream.	Light cream.	Light cream.	Light cream.
508	Burning shrinkage, per cent....	1.87	3.26	3.96	2.13	2.82	6.66	Melted.	Melted.
	Porosity, per cent....	25.61	25.31	21.30	22.06	15.43	4.05	....	....
	Hardness.....	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	....	....
	Color........	Light red.	Light red.	Red.	Red.	Red.	Red.	....	....
509	Burning shrinkage, per cent....	2.92	5.46	6.12	6.35	6.13	6.36	Melted.	Melted.
	Porosity, per cent....	23.72	22.13	19.58	16.81	13.01	3.62	....	....
	Hardness.....	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	....	....
	Color........	Brown.	Brown.	Brown.	Brown.	Brown.	Brown.	....	....

Table No. 1—Concluded.

Sample No.		Temperature.							
		Cone 010.	Cone 07.	Cone 05.	Cone 02.	Cone 1.	Cone 3.	Cone 5.	Cone 7.
510	Burning shrinkage, per cent....	-1.17	....	0.70	1.88	0.93	1.40	4.94	....
	Porosity, per cent....	43.11	....	45.05	44.51	43.77	43.48	33.49	....
	Hardness.....	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.	Softer than steel.	....
	Color........	Light cream.	Light cream.	Light cream.	Light cream.	Light cream.	Cream.	Cream.	....
511	Burning shrinkage, per cent....	0.71	0.71	....	2.13	1.90	0.69	6.99	....
	Porosity, per cent....	44.58	45.27	46.60	36.10	25.27	31.70	2.11	....
	Hardness.....	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	....
	Color........	Dark gray.	Dark gray.	Greenish gray.	Greenish gray.	Greenish gray.	Green-yellow.	Mustard.	....
512	Burning shrinkage, per cent....	0.95	1.41	1.63	2.34	5.15	6.55	5.15	....
	Porosity, per cent....	26.16	....	26.39	25.57	13.93	8.35	1.85	....
	Hardness.....	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	Harder than steel.	....
	Color........	Light red.	Light red.	Red.	Red.	Red.	Dark red.	Dark red.	

To obtain this degree of fineness in commercial manufacture, however, would require the installation of special grinding equipment. The maturing range of the clay is also very short. Therefore, while making a satisfactory brick under certain conditions, this clay is not a promising one from a commercial standpoint.

ENTERPRISE SHALE.

Sample No. 506 represents a deposit of clay which is a part of the Enterprise member, located in the northeast corner of the NE¼ NW¼, sec. 7, T. 34 S., R. 4 E. This deposit is 9 feet thick, 300 feet long (estimated), and 150 feet wide. It carries a 6-inch ledge of limestone in the center and has 6 to 8 feet of overburden. The exposure from which the sample was taken is three miles from Arkansas City, one-fourth mile from a railroad, and one-fourth mile from the interurban railroad. This clay was tested by the same method as described for No. 505. It has very poor working properties in the plastic state and could not be worked by stiff-mud methods. Its water of plasticity is 20.61 per cent; drying shrinkage is 2.71 per cent. The properties of the fired specimens are given in table 1. It is interesting to note that this clay, upon being fired, expands instead of shrinking. It contains a high percentage of limestone in a fine state of subdivision. The poor working properties and the softness of the fired material render this clay unfit for the manufacture of structural clay products.

Sample No. 507 represents another part of the Enterprise shale located in the northeast corner of the NW¼, sec. 35, T. 33 S., R. 4 E., 8½ miles from Arkansas City, 4 miles from the railroad, and 4 miles from the interurban. It is so similar to No. 506 that the same statements hold true for both clays. The available clay at this locality is 40 feet thick, 1,000 feet wide, and covered with a 3-foot ledge of limestone.

Sample No. 509 was collected from the Enterprise shale located in the SW¼ NE¼, sec. 18, T. 34 S., R. 4 E. The workable deposit here is 18 feet thick, 500 feet wide, and 500 feet long (estimated), and is covered with 15 feet of limestone. When ground and mixed with water to produce maximum working qualities it is found that 18.17 per cent water is required. The working properties are very poor and it would not be possible to work the clay by modern stiff-mud methods. Its drying shrinkage is 3.83 per cent. The properties of the specimen when fired at different temperatures are given in table 1. This shale contains a large amount of coarse limestone which renders it practically useless, because when burned at a low temperature it will disintegrate upon exposure to the weather, and at higher temperatures it softens out of shape.

Sample No. 510 represents a deposit of the same shale outcropping in the NE¼ SW¼, sec. 18, T. 34 S., R. 4 E., on the southwest side of the same hill in which sample No. 509 occurs. The water of plasticity of this clay is 20.88 per cent. The drying shrinkage is 6.55 per cent. This clay, unlike sample No. 509, has very good working properties in the plastic condition. When fired in a kiln, however, it is found that the material does not develop sufficient strength and hardness to be of value for the manufacture of brick and tile. It also contains limestone particles of sufficient size to cause disintegration of the bricks after they come from the kiln. The properties of the fired specimen are given in table 1.

Sample No. 511 was also collected from a deposit of the En-

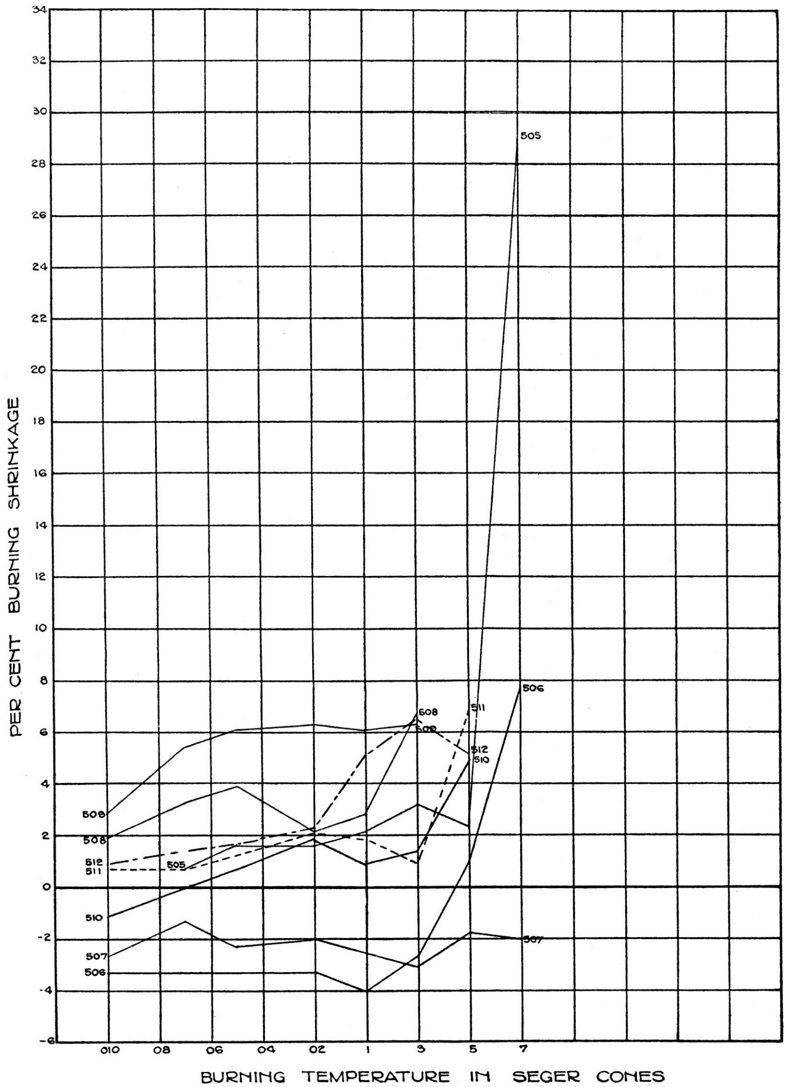


Plate XII. Burning shrinkage-temperature curves of Arkansas City clays.

terprise shale in the northwest corner of the SW¼, sec. 3, T. 35 S., R. 4 E., 4½ miles from Arkansas City, 3 miles from the railroad, and 4½ miles from the interurban railroad. The available deposit is at least 6 feet thick, 300 feet wide and 500 feet long (estimated), and with little or no overburden. It required 20.19 per cent water to develop best plasticity. It has very good working properties and can be easily shaped in the stiff-mud condition. The drying shrinkage is 9.33 per cent. The properties of the burned test pieces are given in table 1. When fired at a temperature of cone 05 or lower, the pieces disintegrate owing to the coarse particles of limestone present. At cone 4 it has softened sufficiently to cause the pieces to stick together. This gives it a narrow maturing range. Therefore, it is not a good clay from a commercial viewpoint. Further tests might develop the fact that it could be utilized for the manufacture of a yellowish buff-colored face brick.

DOYLE SHALE.

Sample No. 508 represents a deposit of the Doyle shale located in the southeast corner of the SW¼, sec. 35, T. 33 S., R. 4 E., which is 7½ miles from the interurban railroad. It is a mixture of red, green and yellow clays located on top of limestone, and is 8 to 10 feet thick, 300 feet wide, and 500 feet long (estimated). The overburden consists of limestone and varies in thickness from a few inches to 15 feet. This clay when ground and properly mixed with water has very good working properties and could be worked by any of the methods in common use for the manufacture of such products as brick, tile, etc. Its water of plasticity, or the amount of water necessary to add to produce the best working properties, is 22.25 per cent of its dry weight. The drying shrinkage is 7.06 per cent. The clay also has very good burning properties as regards shrinkage, porosity, color and hardness. It needs to be burned at a temperature not below that of cone 05, but cone 1 would be a more suitable temperature, as it would produce a product of better color and strength. Data for the burned clay are given in table I. The briquettes made from this clay, after being fired to the best maturing temperatures, slowly disintegrate, due to the presence of lime particles. This deposit is, therefore, of no commercial value.

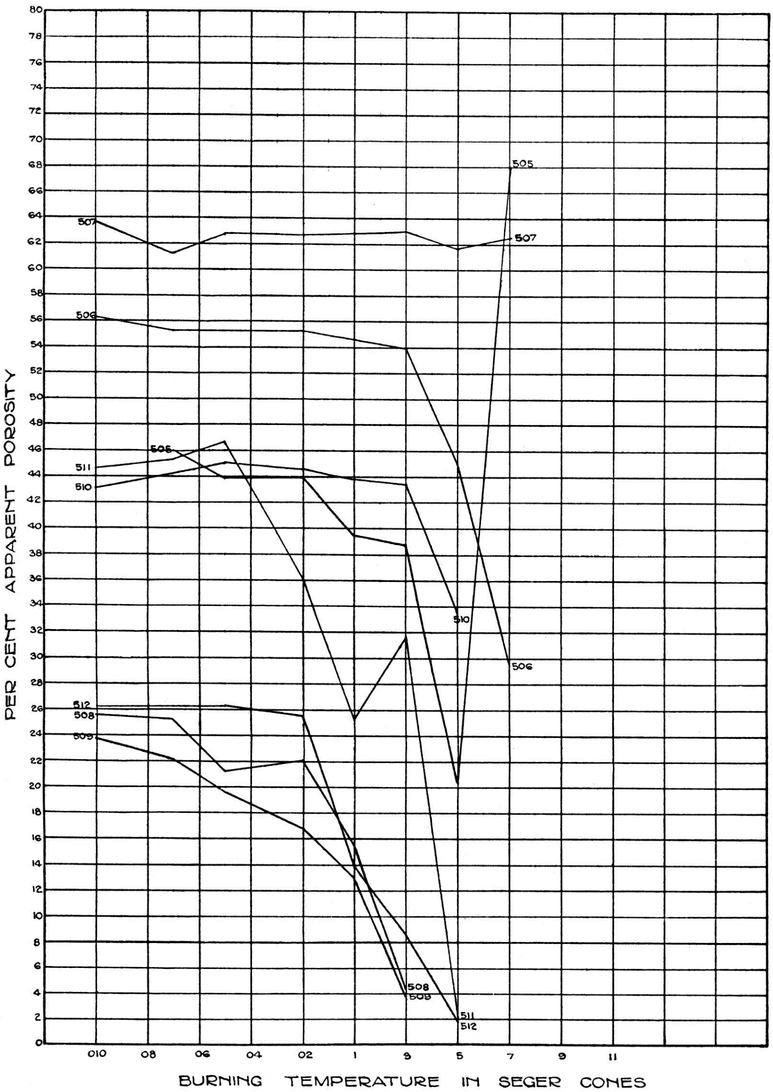


PLATE XIII. Porosity-temperature curves of Arkansas City clays.

Sample No. 512 was also taken from a deposit of the Doyle shale located in the northwest corner of the NW¼, sec. 17, R. 34 S., R. 4 E. It is one mile from the interurban railroad and about one-half mile from the Santa Fe. The exposed portion is 5 feet thick and 150 feet wide. The overburden is from 4 to 10 feet thick. The water of plasticity is 21.38 per cent.

Drying shrinkage is 6.55 per cent. When ground and mixed with water it has good working properties and good plasticity, and can be shaped by the stiff-mud process now in common use. The properties of the burned specimens are given in table 1. When fired, the clay disintegrates when exposed to the atmosphere. At cone 5 it has softened sufficiently to cause slight sticking. It develops a good red color, with an occasional yellow spot due to lime particles. This clay could be utilized for the manufacture of brick and tile in so far as the color of the clay is concerned, but on account of the lime which is contained, is of little commercial value.

It is of interest to note that the samples collected from the Doyle shale member, Nos. 508 and 512, are by far the best clays tested and practically the only ones possessing properties approaching commercial value. It would appear that the most promising field for future prospecting would be for outcrops of the Doyle shale member. The burning shrinkage-temperature relations of these clays are graphically shown in plate XII. The porosity-temperature relations are shown in plate XIII. These curves are self-explanatory.

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