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GEOLOGY AND MINERAL RESOURCES OF TULSA COUNTY OKLAHOMA

(INCLUDES PARTS OF ADJACENT COUNTIES)

BY

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With sections on:

OIL AND GAS

BY GLEN S. DILLE

AND

WATER RESOURCES

BY JOHN H. WARREN

Norman

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GEOLOGY AND MINERAL RESOURCES OF TULSA COUNTY, OKLAHOMA

BY MALCOLM C. OAKES

ABSTRACT

Tulsa County is in northeastern Oklahoma. It lies both east and west of the 96th meridian and is crossed from northwest to southeast by the Arkansas River. The area of Tulsa County is about 593 square miles, but the total area mapped for this report is about 1,000 square miles.

The detailed study of the rocks that crop out in Washington and adjacent counties to the north has been reported in *Oklahoma Geological Survey Bulletin* 62, 1940, and a similar study of the same rocks was made southward across Tulsa County, 1940-1942. In so doing it was necessary to map part of southeastern Osage County and part of eastern Pawnee County. Also, in order to cover all of Tulsa County, it was necessary to map rocks lower in the geologic column than any mapped in Washington County.

Subsequent to completion of the field work for this report the author has made an extensive but less detailed study of the same rocks as far south as the South Canadian River, primarily for the new Geologic Map of Oklahoma, now in preparation. He has also had the benefit of field work by graduate students of the University of Oklahoma. Such results as are pertinent to the correlation and classification of the rocks that crop out in Tulsa and adjacent counties are given in this report. Uppermost Senora beds are continuous with the uppermost beds of the Cherokee shale of Kansas. The base of the Calvin sandstone is for all practical purposes equivalent to the base of the Fort Scott limestone. The Lenapah limestone is continuous with uppermost beds of the Wewoka formation. The Memorial shale in the area east of the city of Tulsa is equivalent to the Holdenville shale. The Seminole formation extends from the north flank of the Arbuckle Mountains into Kansas. Its base marks the top of the Des Moines series. Thus the lower and upper limits of the equivalents of the Marmaton group of Kansas are the base of the Calvin sandstone and the base of the Seminole formation, respectively, in the area north of the Arbukle Mountains. The Checkerboard limestone and the DeNay limestone are not connected in outcrop but are stratigraphically equivalent for all practical purposes. The lower part of the Francis formation is equivalent to the Coffeyville formation and the upper part is equivalent to the Nellie Bly formation. Southward equivalents of the Dewey (Drum) limestone are sandstone and shale with

a minor amount of limestone, as in western Tulsa County, and the Belle City limestone is in all probability basal Dewey. At least the lower part of the Chanute formation is represented by sandstone and shale in Okfuskee County and probably in Seminole County, but the Iola formation and the Wann formation are terminated southward by an unconformity at the base of the Okesa sandstone. The author has included the Okesa sandstone and overlying rocks up to the base of the Bigheart sandstone in a new formation to which he has applied the name Barnsdall formation. The base of the Virgil series is not at the base of the Bigheart sandstone in eastern Osage County, Oklahoma, as formerly thought, but at the base of the Cheshewalla sandstone, considerably higher in the geologic column, and the base of the Cheshewalla is stratigraphically equivalent to the base of the heavy chert conglomerate in the lower part of the Vamoosa formation in Seminole County. The author has applied the name Tallant formation to the rocks from the base of the Bigheart sandstone up to the base of the Virgil series. The Tallant is terminated in northern Okfuskee County by the unconformity at the base of the Virgil series.

The extent, thickness, and character of rocks not exposed in Tulsa County but encountered in drilling for oil and gas are given briefly. For many years new discoveries of oil and gas have been rare in Tulsa County and adjoining areas. However, secondary recovery of oil, remaining after production by ordinary means has been virtually exhausted, is leading to renewed activity and may ultimately result in additional production of more oil than has been produced to date. The greater part of this additional oil will come from the "Cherokee" rocks of Pennsylvanian age.

Coal has been successfully mined in the county and should there be a shortage of the presently cheap petroleum fuels coal mining could again be an important industry.

Ground water in sufficient quantity for domestic use and for live stock is rather common in all the rocks of Tulsa County, but supplies large enough for industrial use are not plentiful. The most productive water wells are in the alluvium of the larger present streams and in terrace sands and gravels deposited by former streams or by the present streams when they flowed at higher elevations.

INTRODUCTION

Scope and purpose. The primary purpose of this investigation was to study in detail the character, distribution, and thickness of the rock formations exposed in Tulsa County, in order (1) to locate deposits of mineral materials of economic value, and to collect samples for analysis and experimentation in the laboratories of the Geological Survey; and (2) to obtain such detailed information on the exposed rocks as would advance our knowledge of the geology of Oklahoma and facilitate the more precise correlation of beds exposed in Tulsa County with those in other areas of surface exposures and with corresponding units found by drilling for oil and gas in areas to the west.

FIG. 1. Index map of Oklahoma showing area covered by this report.

Location. Tulsa County is in northeastern Oklahoma and lies both east and west from the 96th meridian and both north and south from Arkansas River. It is irregular in shape but its entire area is included in Ts. 16 to 22 N., Rs. 10 to 14 E., Indian Meridian. It contains about 593 square miles.

This report is concerned primarily with Tulsa County, but it was necessary to map in equal detail 300 square miles in southeastern Osage County and a small area in southeastern Pawnee County in order to correlate beds in western Tulsa County with equivalents previously studied farther north, in Washington County. Also two areas were mapped in Creek County comprising an additional 36 square miles in order to embrace suitable geologic units. Also, it was necessary to examine and correlate, in the field, part of the work previously done in Osage County by various geologists of the United States Geological Survey.[1] The northeast part of the map includes 52 square miles in Rogers County.

Previous investigations. The naturalist-geologist, Thomas Nuttall,[2] probably crossed the area now included in Tulsa County in 1819. The journal of his travels is not at hand but Drake said of him: "In 1819 Thomas A. Nuttall made several excursions across this region to study its botany and geology. He passed over the country southwest of Ft. Smith, Ark., between Sugar Loaf and Cavaniol mountains and across Winding Stair mountains; then he went up the Arkansas river to Verdigris river and across the country in a southwesterly direction from Verdigris river. He also went up Grand river to the Salt springs and made short excursions in the vicinity of Sallisaw and Lee's creeks."[3] Drake himself spent six months making a geological reconnaisance of the coal fields of the Indian Territory, during the spring, summer and late fall of 1896, and probably visited Tulsa County. He mentions coal northwest of Oologah and along Caney River which was, in all probability, the Dawson vein.

Tulsa County is included on the map accompanying a report on oil and gas by Adams[4] in 1901. However, little field work seems to have been done in this part of the area. Adams, Girty, and White[5] included the north part of Tulsa County in a study of stratigraphy and paleontology in 1903. Taff[6] included the county in a report on the progress of coal work in 1904, in which he discussed the Dawson vein coal.

1. White, David, and others, "Structure and Oil and Gas Resources of the Osage Reservation, Oklahoma": *U. S. Geol. Survey Bull.* 686, 1922.
2. Nuttall, Thomas, "A Journal of Travels into the Arkansas Territory During the Year 1819 . . .": Philadelphia, 1821.
3. Drake, N. F., "A Geological Reconnaissance of the Coal Fields of the Indian Territory": *American Philosophical Society Proceedings*, Vol. 36, pp. 326-419, 1897: Also, *Leland Stanford University, Contribution to Biology*, Vol. 14, pp. 226-419, 1898.
4. Adams, George I., "Oil and Gas Fields of the Western Interior and Northern Texas Coal Measures": *U. S. Geol. Survey Bull.* 184, pp. 11-29, 1901.
5. Adams, George I., Girty, George H., and White, David, "Stratigraphy and Paleontology of the Upper Carboniferous Rocks of the Kansas Section": *U. S. Geol. Survey Bull.* 211, 1903.
6. Taff, Joseph A., "Progress of Coal Work in Indian Territory": *U. S. Geol. Survey Bull.* 260, pp. 382-401, 1904.

Siebenthall[7] included Tulsa County in his discussion of the "Mineral Resources of Northeastern Oklahoma," 1907. Gould, Ohern, and Hutchison[8] proposed a classification of the Pennsylvanian rocks of eastern Oklahoma, 1910, which included the rocks of Tulsa County. Ohern included that part of Tulsa County north of Arkansas River in his study of "The Stratigraphy of the Older Pennsylvanian Rocks of Northeastern Oklahoma,"[9] 1910. The geology of Tulsa County was discussed briefly in Oklahoma Geol. Survey Bull. 19, pt. 2, "Petroleum and Natural Gas in Oklahoma," 1917, and again in Oklahoma Geol. Survey Bull. 40, Vol. 3 "Oil and Gas in Oklahoma," 1930. Shannon and others included a brief discussion of the Dawson coal in Oklahoma Geol. Survey Bull. 4, 1926.

References to field observations in Tulsa County appear in various articles published by petroleum geologists, principally in the Bulletin of the American Association of Petroleum Geologists, the Tulsa Geological Society Digest, and the guide books of the various geological societies.

Present investigation. The present investigation was begun in June, 1940, and continued as opportunity afforded during the remainder of that field season and during the field season of 1941. The field work was completed in July, 1942, and the drafting of the map and the preparation of the report were nearing completion a year later when other work, connected with civilian production for the second World War, intervened. Revision of the map and text were resumed in January, 1951, and continued intermittently, as other work permitted, to June, 1952.

During the field seasons of 1947 to 1950, inclusive, the author did considerable mapping in the area between Tulsa County and the Arbuckle Mountains in preparation for a new edition of the Geologic Map of Oklahoma, and this mapping has shed much-needed light on the correlation of certain strata of Tulsa County

7. Siebenthal, C. E., "Mineral Resources of Northeastern Oklahoma": *U. S. Geol. Survey Bull.* 340, pp. 187-228, 1907.
8. Gould, Charles N., Ohern, D. W., and Hutchison, L. L., "Proposed Groups of Pennsylvanian Rocks of Eastern Oklahoma": *The State University of Oklahoma Research Bull.*, No. 3, 1910.
9. Ohern, D. W., "The Stratigraphy of the older Pennsylvanian Rocks of Northeastern Oklahoma": *The State University of Oklahoma Research Bull.*, No. 4, 1910.

with equivalents in east-central Oklahoma. As a result of that work we are also able to show the base of the Virgil series on the western edge of the areal geologic map that accompanies this report.

In the summer of 1941, while mapping in Tulsa County was in progress, the writer supervised two graduate students of the University of Iowa who selected a study of Marmaton rocks in Nowata and Rogers Counties, Oklahoma, as their theses problems. As a result of this arrangement the Oklahoma Geological Survey obtained copies of the resulting theses and copies of all field notes including both graphic and written descriptions of all measured sections. A study of the data collected resulted in a much better understanding than had theretofore been possible of the relations of the Oologah limestone in eastern Tulsa County to equivalent strata that crop out northward to the Kansas-Oklahoma line.

The Oklahoma Geological Survey now uses contact aerial photographs as a field base map for all geologic mapping and this results in a rather high degree of accuracy, especially in geographical location. When the Tulsa County work was begun, this technique was in experimental stages, and base maps of several sorts were used in various parts of the area mapped. Across the southeastern part of Osage County and in adjacent parts of Pawnee, Creek, and Tulsa Counties contact prints of aerial photographs, scale 1:20,000, were used, and studied stereoscopically in the field. Such outcrops as could be traced readily on the stereoscopic image were marked on the photographs in the office. Later the same prints were taken into the field where all office work was checked, correlated, and extended by tracing outcrops in the usual manner, using the photograph as a base map. For much of the western and southern part of Tulsa County and for the area mapped in Creek County, aerial photographs were available only in the form of index sheets with an approximate scale of 2 inches per mile. They served as a superior sort of base map on which outcrops could be marked with more than ordinary accuracy as they were traced in the field in the usual manner. For that part of Tulsa County north and east of the City of Tulsa, the best base available was one having a scale of 1 inch per mile which was prepared by the drafting department of the Oklahoma Geological Survey from reports of the State Mineral Survey[10] and corrected by reference to aerial photographs and to the State Highway Planning Map of Tulsa County. It showed the drainage, roads, railroads, schools and other cultural features. Outcrops were mapped on this base by automobile traverse and by pace and compass.

Geologic sections were measured, where possible, by hand level at exposures where no corrections for dip were necessary. Wherever such corrections were necessary, the component of dip in the direction of measurement was determined from aneroid elevations over one or more courses in the immediate vicinity. Where the section measured extended over a considerable distance, the greater differences in elevation were determined from aneroid barometer observations. All barometer readings were corrected for atmospheric changes by returning to the starting point without delay or by having an assistant make synchronized readings on a stationary barometer.

In no instance was it possible to measure a completely continuous section across all strata mapped. Instead, sections shown on Pl. II were compiled from measured sections having overlapping portions that could be correlated. In a few instances several measured sections were combined and generalized.

Each sample for chemical analysis was so taken as to include proportional amounts of material from all parts of the deposit represented by that sample. Samples as taken in the field weighed from 20 to 50 pounds. Each sample was taken between definite stratigraphic limits which, together with the geographic location, were carefully described, in order that later workers may identify the locality and strata sampled. If stratigraphic differences in lithology or other characteristics within a single exposure suggested differences in chemical composition a separate sample from each phase was taken.

Acknowledgments. Thanks are due to citizens of Tulsa County, too numerous to be mentioned individually, for many courtesies and much assistance during the field work.

10. *Works Progress Administration Project No.* 65-65-538, sponsored and directed by the Oklahoma Geological Survey, 1936-37.

Dr. A. N. Murray, of the University of Tulsa, contributed a map of the Lenapah limestone north of the Arkansas River. He also gave the author free access to his field notes, principally on the Fort Scott, Oologah, and Lenapah limestones. Joseph L. Borden, Ralph A. Brant, and Robert H. Wood were very helpful with the geology of western Tulsa County, eastern Pawnee County, and southwestern Osage County. Louis Desjardins helped with the interpretation of the aerial photographs of the western part of the area mapped.

C. Edwin Mohler, then a graduate student of the University of Oklahoma, was an able field assistant during the summer of 1940. Fred L. Travis and Charles W. Alcock, graduate students of the University of Iowa, studied the Marmaton Rocks of Nowata and Rogers Counties, Oklahoma, during the summer of 1941 and contributed to a better understanding of the relations of the Oologah limestone to equivalent rocks northward to the Kansas-Oklahoma line.

This study was undertaken at the direction of Robert H. Dott, and his encouragement and infectious enthusiasm for Pennsylvanian stratigraphy have ever affected the field work and the preparation of this report.

J. O. Beach, Administrative Assistant of the Survey, has labored many hours editing and checking the manuscript and the illustrations, including the geologic map. He has added materially to the accuracy and clarity of this report.

The author wishes to express his gratitude for the courteous treatment he has received from the numerous geologists who live in Tulsa and vicinity. He still remembers with warm appreciation the Tulsa County field trip that was sponsored for him by the officers and members of the Tulsa Geological Society in the late fall of 1942 soon after the field work was completed. The officers for 1940-42 were: J. L. Ferguson, President; Louis H. Lukert, First Vice President; Howard J. Conhaim, Second Vice President; M. R. Spahr, Secretary-Treasurer; Charles Ryniker, Editor; and John S. Redfield, Business Manager.

GEOGRAPHY

Topographic features.[11] Maximum relief in Tulsa County is about 450 feet. Arkansas River has an elevation of about 650 feet where it enters the county in the vicinity of Keystone, 600 feet about 3 miles south of Tulsa, and about 550 feet where it flows out of the county southeast of Leonard. In that part of the county east of Tulsa few points rise as high as 900 feet above sea level. West of Tulsa a few small areas are more than 1,000 feet above sea level. Notable high points are: Turkey Mountain, on the west bank of Arkansas River about 6 miles south of Tulsa, more than 900 feet; Turley Mountain, immediately northwest of Turley, more than 950 feet; the hills immediately northwest of Red Fork, more than 900 feet.

The present topography of Tulsa County is the result of erosion on beds of unequal hardness. Rocks at the surface over most of the county are predominantly shales, which are relatively non-resistant to erosion, interspersed at relatively large intervals with beds of sandstone and limestone, which though much thinner, are harder and more resistant than the shales. All these beds were originally deposited essentially level but have been subsequently uplifted and tilted so that they now dip or slope in a direction generally slightly north of west at rates mostly ranging from 30 to 50 feet per mile.

Over much of the county east of Tulsa, erosion, principally by water, has worn away the soft shales, thus producing extensive plains, and causing the eroded edges of harder beds to stand up in high, eastward-facing ridges overlooking these plains. Such ridges are called escarpments or cuestas. The principal one of these escarpments is capped by the Oologah limestone and may be seen conveniently where it is crossed by U. S. Highway 66 about 10 miles east of the business district of Tulsa, near the KVOO radio transmitter.

The escarpments are characterized by steep eastward faces, opposed by gentle back-slopes that descend to the level of the plains. The height of the escarpment is primarily dependent on

11. "Topographic Atlas of the United States": *U. S. Geol. Survey, Hominy and Claremore Quadrangles.*

the thickness of the underlying, non-resistant shale, and the depth of erosion. The back or westward slopes generally descend somewhat less steeply than the dip of the rocks, but are called dip-slopes, which they approximate. The harder beds are eroded somewhat by the processes of weathering, but in the main their removal is accomplished by a process of undermining in the softer shale and slumping or caving of blocks of the harder beds. As this process continues the escarpment migrates westward, in the direction of dip.

The escarpment is modified, locally, by greater erosion along streams which head in or cross it. This produces a sinuous trace, characterized by promontories and re-entrants, or the escarpment may be severed by streams heading west of it. Headward cutting by tributary streams may completely sever a promontory from the rest of the escarpment, producing an isolated hill or butte. Of such origin are the sandstone hills southeast of Tulsa and east of Arkansas River, where relatively resistant sandstone beds of the Seminole formation cap thick, non-resistant shale.

West of Tulsa, especially in eastern Osage County, erosion has not yet proceeded far enough to produce the simple, escarpment-and-plain type of topography found in the eastern part of the area. In contrast, the streams have generally cut deep, narrow valleys flanked by hills whose steep sides are broken by cliffs and protruding ledges formed by the more resistant beds of limestone and sandstone. The tops of the highest hills lie at about 1,000 feet, and the valley floors at 750 to 800 feet above sea level. The sharp relief and dendritic drainage pattern result in extremely complex and rugged topography.

Drainage. All the drainage is by Arkansas River and its tributaries, but waters from several of the latter reach the Arkansas beyond the limits of Tulsa County. The Arkansas enters the area west of Prue, flows in a general southeasterly direction by way of Tulsa, and leaves 2 miles east of Leonard. West of Tulsa it is deeply incised; the flood plain is generally less than 2 miles wide with hills on both sides rising precipitously 250 to 300 feet. East of Tulsa the flood plain is generally wider and flanking topography generally much subdued. Tributaries flowing from the south are

Cimarron River, Salt Creek, Bakers Branch, Anderson Creek, Coal Creek, Posey Creek, and Snake Creek. Tributaries from the north are Mud Creek, Shell Creek, Euchee Creek, Haikey Creek and Broken Arrow Creek.

From a line connecting Tulsa and Broken Arrow northward to the latitude of Collinsville, drainge is by Bird Creek and its tributaries into Verdigris River beyond the eastern limits of Tulsa County. The waters finally reach Arkansas River at the mouth of the Verdigris at Muskogee, Muskogee County. Main tributaries of Bird Creek are: Hominy, Delaware, Flat Rock, and Mingo Creeks, from the southwest; and Ranch and Elm Creeks, from the northeast.

The extreme northern part of the county, north of the latitude of Collinsville, is drained by Horsepen Creek, which flows into Caney River, another tributary of Verdigris River.

Economic development. The time has past when actual production of oil and gas within the limits of Tulsa County was the chief industry. Prospective territory is well drilled up and production is in the stripper stage, that is the gas pressure is practically exhausted and operators are engaged in recovering what oil will drain to the wells by gravity. Secondary recovery methods, such as water flooding, are next in order. However, the life of the community is still definitely tied to the oil and gas industry. Many of the nationally active companies have division offices in Tulsa and a large part of the manufacturing activity serves the oil industry. In addition, many of the organizations that supply special services to the oil industry are located in Tulsa or have important offices, shops, and personnel there.

Prior to the development of oil and gas production in Tulsa County, ranching was the chief industry, closely seconded by farming. General farming, dairying, and stock raising are still important. In addition, fruit and vegetable production, along with canning, are considerable industries.

Manufacturing is healthy and growing, and there are many phases of it, aside from that which serves the oil industry. The Tulsa County Manufacturers Directory, published by the Tulsa

Chamber of Commerce for 1951, tabulates a total of 634 manufacturing plants with 22,384 employees. The same publication quotes figures applicable to Tulsa County, from the U. S. Census of Manufacturers for 1947, that show wages paid to production workers as $29,565,000.00 and value added by manufacture as $96,462,000.00. Most of the establishments are in light industries, but the range is from heavy forgings and steel castings through scientific instruments to light cotton fabrics.

Some mineral manufactures in Tulsa County are refined petroleum products, glass, muriatic acid, potassium sulfate, commercial fertilizers, brick and tile, asphaltic products, crushed stone, building blocks, agricultural limestone, and mineral wool insulation.

SURFACE STRATIGRAPHY

Rocks belonging to the Des Moines and Missouri series, of middle and upper Pennsylvanian age, respectively, are exposed in Tulsa County. They are shales, sandstones, and limestones, in order of abundance and are part of the sequence of Pennsylvanian rocks that is so well exposed in the northern Mid-Continent area.

A large part of the same section was studied in Washington and adjacent counties to the north and the results have been published.[12] It was found that in common with other parts of the northeast Oklahoma section, many individual beds continue with unbroken outcrops across the state line from Kansas. Other Kansas units exhibit complete change of facies before the state line is reached, and consequently are unrecognizable in Oklahoma. A sufficient number of Kansas units are present in northern Oklahoma to establish definite correlations, and to permit a broad classification that corresponds in a general way with the classification used in Kansas and that classification is here extended to equivalent strata in Tulsa County.

In order to correlate beds in western Tulsa County with equivalents in Washington County, it was necessary to map in equal detail a considerable area in southeastern Osage County and southeastern Pawnee County. Also, in order to embrace a satisfactory geologic unit, it was necessary to map two relatively small areas in Creek County. A small part of Rogers County is also included. Formations that crop out in eastern Tulsa County are lower in the section than any mapped in Washington County but their equivalence to named units in Kansas is thought to be correctly established.

Field work done by the author, in 1947 to 1950 inclusive, for the new Geologic Map of Oklahoma, now in preparation, has permitted rather detailed correlation of certain strata in southern Tulsa County with equivalent strata in the area north of the Arbuckle Mountains.

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12. Oakes, Malcolm C., "Geology and Mineral Resources of Washington County, Oklahoma": *Oklahoma Geol. Survey Bull.* 62, 1940.
Oakes, Malcolm C., "Results of Recent Field Studies in Osage, Washington, and Nowata Counties, Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, pp. 716-730, 1940.

PENNSYLVANIAN SYSTEM

There are four main divisions of the Pennsylvanian rocks of northern Oklahoma. In ascending order they are: the Morrow, Des Moines, Missouri, and Virgil series. Rocks studied in this investigation include the upper part of the Des Moines and all of the Missouri series and are roughly mid-Pennsylvanian in age.

Des Moines Series

Along the outcrop in the latitude of Tulsa County the Des Moines series is limited below by an unconformity and rests upon the eroded top of the Morrow series as far north as the vicinity of Pryor, where it overlaps the Morrow, and from that locality northward to the Kansas-Oklahoma line it rests upon eroded rocks of the Mississippian system. It is overlain unconformably by the Missouri series.

Only the upper part of the Des Moines series is exposed in Tulsa County. The rocks so classified belong to the Marmaton group, at the top of the Des Moines, with a maximum of 250 feet of underlying strata that have equivalents in the upper part of the Cherokee group, of Kansas, and in the Senora formation of south-central Oklahoma.

PRE-MARMATON ROCKS

The greatest thickness of pre-Marmaton rocks at the surface in Tulsa County is in secs. 35 and 36, T. 17 N., R. 14 E., below the Fort Scott limestone, which marks the base of the Marmaton group in the prominent escarpment in sec. 35. However, the pre-Marmaton rocks in that locality are so covered by debris from higher beds, and by other surficial material, as to preclude their detailed study, and the following nearly equivalent section has been compiled from several shorter sections measured by the author in T. 18 N., R. 15 E., Wagoner County, immediately east of Tulsa County.

It has long been known that these rocks are equivalent to the upper part of the Cherokee group of southeastern Kansas. As a result of field mapping done by the author recently for the new Geologic Map of Oklahoma, now in preparation, we can say that they are equivalent to the upper part of the Senora formation in

TABLE I

MEASURED SECTION OF PRE-MARMATON ROCKS
T. 18 N., R. 15 E., Wagoner County
Measured and compiled by Malcolm C. Oakes

		Feet
15.	Shale: black, fissile containing phosphatic nodules; lies immediately below the Fort Scott limestone	3.0
14.	Limestone: Breezy Hill	6.0
13.	Covered: probably shale, dark and silty	40.0
12.	Sandstone: thin-bedded, silty	5.0
11.	Shale: dark	5.0
10.	Limestone: sandy, gray to brown	2.0
9.	Sandstone: silty to shaly, brown	15.0
8.	Shale: dark	75.0
7.	Limestone: Verdigris	2.5
6.	Shale: dark to black	20.0
5.	Coal: Broken Arrow	1.5
4.	Shale	10.0
3.	Sandstone	20.0
2.	Shale: dark	40.0
1.	Sandstone: not measured; top of Chelsea sandstone.	

the area north of the Arbuckle Mountains. Indeed, such work by the author, and by faculty members and graduate students of the department of Geology of the University of Oklahoma has extended named Oklahoma equivalents of the Cherokee group from the area north of the Arbuckle Mountains to the Kansas-Oklahoma line. The Oklahoma Geological Survey will probably not apply the term Cherokee to Oklahoma rocks in future publications.

Detailed sections. For measured outcrop sections showing pre-Marmaton rocks see sections numbered 46, 47, 48, 85, 86, 87, Appendix A.

MARMATON GROUP

In Kansas "strata from the base of the Fort Scott limestone to the disconformity which marks the upper limit of the Des Moinesian series are designated the Marmaton group."[13] The Marmaton of Oklahoma north of the Arkansas River has the same limits. As a result of field work done by the author, 1947-50, for the new Geological Map of Oklahoma, now in preparation, it can be stated that, for all practical cartographic purposes, the limits of Marmaton equivalents in the area north of the Arbuckle Mountains are the base of the Calvin sandstone, below, and the base of the Seminole formation, above.

13. Moore, Raymond C., "Divisions of the Pennsylvanian System in Kansas": *State Geological Survey of Kansas Bull.* 83, p. 47, 1949.

TABLE II

SUBDIVISIONS OF THE MARMATON GROUP IN TULSA COUNTY, OKLAHOMA

Missouri series.
- Seminole formation.

Unconformity

Des Moines series.
- Marmaton group.
  - Holdenville shale.
  - Lenapah limestone.
  - Nowata shale.
  - Oologah formation.
  - Labette formation.
  - Fort Scott limestone.
- Pre-Marmaton rocks.

Fort Scott Limestone

According to present usage the term Fort Scott limestone is applied to two limestones and an intervening shale at the type locality, Fort Scott, Kansas, where the aggregate thickness is about 30 feet. The lower limestone member is about 6 feet thick. The middle shale member, also about 6 feet thick, is black and fissile, contains phosphatic nodules, and, locally, coal. The upper limestone member is about 18 feet thick.

According to Howe and Warren[14] the formation maintains its tripartite character southward into Oklahoma, but the upper limestone member does not extend south of T. 25 N., R. 16 E., southeastern Nowata County. The lower limestone member extends southward beyond the limits of Tulsa County, and is overlain, at least locally, by the middle shale member. These two members of the Fort Scott limestone are not more than 10 feet thick in most exposures south of Arkansas River.

First reference. Swallow, 1866.[15]

Nomenclator. Swallow, 1866, redefined by Bennett, 1896[16] and finally by Adams, 1903.[17]

Type locality. Vicinity of Fort Scott, Kansas. Jewett says:

> In all probability Bennett . . . regarded the exposure in the cut a short distance east of the Missouri Pacific Railway station in Fort Scott as the type exposure of the

14. Wallace B. Howe, of the Missouri Geological Survey, and John H. Warren, of the Oklahoma Geological Survey, verbal communications, 1951.
15. Swallow, G. C., *Kan. Geol. Survey, Prelim. Rept.*, p. 25, 1866.
16. Bennett, J., *The University Geological Survey of Kansas*, Vol. 1, pp. 88-91, 1896.
17. Adams, G. I., "Stratigraphy and Paleontology of the Upper Carboniferous Rocks of the Kansas Section": *U. S. Geol. Survey Bull.* 211, p. 29, 1903.

Fort Scott limestone. A better view of the whole formation can now be seen in the cement plant quarry in the NE¼ sec. 19, T. 25 S., R. 25 E., northeast of Fort Scott, Kansas. This quarry is cut in the valley wall of Marmaton River and the strata will remain well exposed for a long time, even though operation of the quarry ceases. This outcrop is here considered the type exposure.[18]

Original description.

No. 212—Fort Scott Limestone; is a blueish-drab and brown, irregularly bedded limestone, with many *Producti, Chonetes, Spirifers* etc., 8 to 18 feet. Locality, Little Osage, Fort Scott, and south to the Drywood and Bone Creek, and west to the Neosho.[19]

History of usage. Swallow, 1866,[20] applied the name to the upper limestone member of the Fort Scott of present usage at Fort Scott, Kansas. In the same publication he applied the name Fort Scott coal series to about 100 feet of beds including the Fort Scott limestone at the top; the Fort Scott marble to a limestone in the Cherokee shale; and the name Fort Scott marble series to a group of beds that included the Fort Scott marble.

Broadhead, 1873-74,[21] applied the name Oswego limestone to the beds now known as the Fort Scott limestone from exposures at Oswego, Kansas, but the name was preoccupied by a Silurian formation in New York.

Haworth, 1896,[22] suggested that the name Fort Scott be used instead of Oswego if the upper limestone is excluded. But it is this upper limestone to which the name Fort Scott limestone was originally applied by Swallow, 1866.[23]

Bennett, 1896,[24] included the "cement rock" and overlying limestone under the name Oswego or Fort Scott limestone and Haworth, 1898,[25] called the lower limestone the "Fort Scott cement rock."

18. Jewett, John M., "Classification of the Marmaton Group, Pennsylvanian, in Kansas": *State Geol. Survey of Kansas Bull.* 38, p. 303, 1941.
19. Swallow, G. C., *Kan. Geol. Survey, Prelim. Rept.*, p. 25, 1866.
20. *Idem.*
21. Broadhead, G. C., *Missouri Geol. Survey Rept.*, 1873-74, pp. 101, 126, and 158, 1874.
22. Haworth, E., *The University Geological Survey of Kansas*, Vol. 1, p. 42, 1896.
23. Swallow, G. C., *op. cit.*
24. Bennett, J., *The University Geological Survey of Kansas*, Vol. 1, pp. 88-91, 1896.
25. Haworth, E., *The University Geol. Survey of Kansas*, Vol. 3, p. 36, 1898.

Adams, 1903,[26] notes that Oswego is preoccupied and definitely applied the term Fort Scott limestone to the two limestones and intervening black shale at Fort Scott, Kansas, thus establishing the present usage which later writers have generally followed.

Cline[27] has named the lower limestone the Blackjack Creek and the upper limestone the Higginsville. Jewett[28] named the intervening shale the Little Osage.

In Oklahoma the terms Oswego and Fort Scott have been used interchangeably in well logs and in subsurface studies, and no doubt the terms are often used to include limestone beds lower than the Fort Scott.

In surface outcrop two limestones and an intervening black, fissile shale containing phosphatic nodules extends from the Kansas-Oklahoma line southward beyond the southern limits of Tulsa County, and these have been generally correlated with the Fort Scott limestone. Howe and Warren[29] now state that field mapping by Howe in southern Kansas and by Warren in Oklahoma shows that the upper limestone member of the Fort Scott limestone extends only as far as T. 25 N., R. 16 E., Oklahoma; that the upper of the two limestones, heretofore generally considered the upper Fort Scott in Oklahoma, is in reality the lower member of the Fort Scott; and that the lower limestone is continuous with the Breezy Hill limestone in the upper part of the Cherokee shale of Kansas. In this report we follow Howe and Warren.

Distribution. Representatives of the Fort Scott limestone, together with the Breezy Hill limestone, crop out in this area in four localities along the east line of T. 19 N., R. 14 E. and extend across the eastern part of T. 18 N., R. 14 E. to the terrace deposits north of Arkansas River. South of Arkansas River, the lower

26. Adams, G. I., "Stratigraphy and Paleontology of the Upper Carboniferous Rocks of the Kansas Section": *U. S. Geol. Survey Bull.* 211, p. 29, 1903.
27. Cline, L. M., "Traverse of Upper Des Moines and Lower Missouri Series from Jackson County, Missouri, to Pappanoose County, Iowa": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, p. 36, 1941.
28. Jewett, John M., "Classification of the Marmaton Group, Pennsylvanian, in Kansas": *State Geol. Survey of Kansas Bull.* 38, p. 306, 1941.
29. Wallace B. Howe, of the Missouri Geological Survey, and John H. Warren, of the Oklahoma Geological Survey, verbal communication, 1951.

limestone member of the Fort Scott is exposed from place to place across secs. 33, 34, and 35, T. 17 N., R. 14 E., and the outcrop passes out of Tulsa County a short distance east of the S¼ cor. sec. 35. In most of these localities, immediately below the Fort Scott, in the uppermost Senora is a black fissile shale a few feet thick that contains phosphatic nodules, and below this shale, in turn, is the Breezy Hill limestone.

Representatives of the Fort Scott limestone extend southward into Okmulgee County. The Fort Scott crops out northward across southeastern Kansas,[30] across Missouri, and into Iowa.

Thickness. The Fort Scott limestone is about 30 feet thick in the type locality, Fort Scott, Kansas. It is said to be thicker at the Kansas-Oklahoma line. The upper limestone member does not extend far into Oklahoma, and south of Nowata County, the lower limestone and middle shale members together are 10 to 20 feet thick. In Tulsa County they are rarely more than 10 feet thick.

Character. There are three members of the Fort Scott limestone in southern Kansas and northern Oklahoma: a lower limestone member; a middle dark to black, fissile shale member which contains small, rounded, black, phosphatic concretions or nodules; and an upper limestone member. It is the lower limestone member and the middle shale member that crop out in Tulsa County.

The Fort Scott limestone and the associated Breezy Hill limestone in the upper part of the Senora may be conveniently examined in this area in the following localities:

On the east side of Spunky Creek on State Highway 33, south and west of the NE cor. sec. 6, T. 19 N., R. 15 E., where the Breezy Hill limestone and its overlying black shale are exposed together with the lower part of the lower limestone member of the Fort Scott. The lower limestone member of the Fort Scott is well exposed about ½ mile west and ¼ mile north of this location along a small, northward-flowing tributary of Spunky Creek.

The top of the lower limestone member of the Fort Scott and the middle shale member are exposed in the bed of a stream a

30. Moore, Raymond C., "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas": *State Geol. Survey of Kansas Bull.* 22, p. 60, 1935.

short distance south of the turn in U. S. Highway 66 at the NE cor. sec. 12, T. 19 N., R. 14 E.

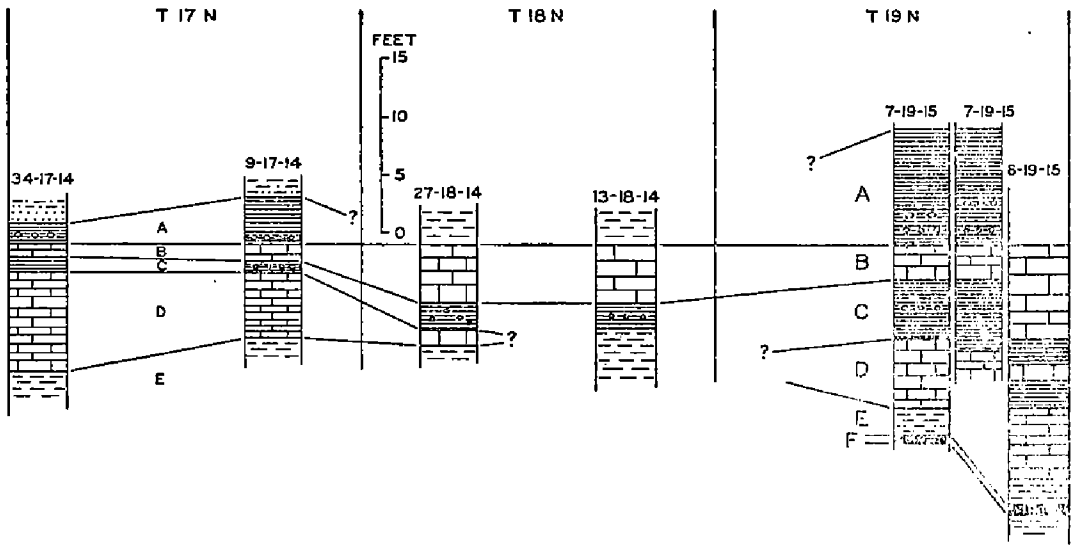

FIG. 2. Graphic measured outcrop sections of Fort Scott limestone and upper Senora rocks.

Fort Scott limestone.

Higginsville limestone member, not present in this latitude.

A. Little Osage shale member; typically black fissile shale with phosphatic nodules, not typical in T. 18 N.

B. Blackjack Creek limestone member.

Senora formation.

C. Shale, black, fissile with phosphatic nodules.

D. Breezy Hill limestone.

E. Kinnison shale.*

F. Iron Post coal.*

In the vicinity of the SE cor. sec. 12, T. 19 N., R. 14 E. the middle shale member of the Fort Scott is exposed at the corner, and the Breezy Hill limestone with the intervening black shale crop out along the northeastward-flowing stream.

Southeast of Broken Arrow, in the draw behind the farm house immediately south of the E¼ cor. sec. 27, T. 18 N., R. 14 E., the lower limestone member of the Fort Scott is well exposed followed in descending order by black shale and the Breezy Hill limestone.

In the road leading up the hill south from Leonard, near the center of the SE¼ NE¼ sec. 34, T. 17 N., R. 14 E. the lower limestone member of the Fort Scott and the Breezy Hill are well exposed.

*Howe, Wallace B., "Bluejacket Sandstone of Kansas and Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 35, p. 2087, 1951.

Stratigraphic relations. The Fort Scott limestone rests conformably upon the Senora formation, below, and conformably underlies the Labette shale, above.

Correlations. The Fort Scott limestone of Oklahoma is continuous with the Fort Scott limestone of Kansas. Only the lower limestone member and the middle shale member are present in Tulsa County.

In the course of mapping for the new Geologic Map of Oklahoma, now in preparation, the author has traced representatives of the Fort Scott limestone southward into Okmulgee County. Both the lower limestone member of the Fort Scott and the Breezy Hill limestone grade gradually into calcareous shale, and limestone was not found south of the SE cor. sec. 17, T. 15 N., R. 14 E., but the associated black shale and phosphatic nodules were traced in a southwesterly direction as far as The Twins (Bald Hill) in sec. 29, T. 15 N., R. 14 E., thus confirming earlier work by Dr. A. N. Murray and his students, of the University of Tulsa. The author traced the black shale and phosphatic nodules still farther south into sec. 14, T. 14 N.. R. 13 E. where they lie a few inches below the base of a shaly siltstone that grades southward into silty sandstone that constitutes the lowest part of the Calvin sandstone east of Okmulgee.

In view of the fact that, farther south, there are tongues of the Calvin lower than the one that immediately overlies the southernmost representatives of the Fort Scott, we should consider that for all practical purposes, the base of the Calvin sandstone marks the base of Marmaton equivalents in the area north of the Arbuckle Mountains.

Some such correlation of the Fort Scott limestone with the Calvin sandstone was anticipated by several of the early writers: C. E. Siebenthall, *U.S.G.S. Bull.* 340, p. 191, 1908; Charles N. Gould, D. W. Ohern, and L. L. Hutchison in *State University of Oklahoma Research Bull.* No. 3, March, 1910; and D. W. Ohern in *State University of Oklahoma Research Bull.* No. 4, December, 1910.

Detailed sections. For measured outcrop sections showing representatives of the Fort Scott limestone see sections numbered 29, 47, 48, 82, 84, 85, 86, 87, 88, Appendix A.

Labette Shale

The Labette shale, in its type locality, near Labette, Labette County, Kansas, includes all the strata from the top of the Fort Scott limestone, below, to the base of the Pawnee limestone, above. South of T. 23 N., Oklahoma, the Pawnee and Altamont limestones merge to form the Oologah limestone, whose base marks the top of the Labette from that point southward to the vicinity of Broken Arrow, Tulsa County, where the Oologah grades abruptly into calcareous shale that is difficult to distinguish in the field.

The Labette shale in Tulsa County consists of clay shale, silty to sandy shale, and lenticular sandstone and ranges in thickness from 180 to 250 feet.

First Reference. Swallow, 1866,[31] included the Labette in his Pawnee limestone series, which included strata from the top of the Fort Scott limestone, below, to the top of the Pawnee limestone, above.

Nomenclator. Haworth, 1898, defined the Labette in accordance with present usage.

Type locality. The village of Labette, Labette County, Kansas.
Original description.

> First above the Oswego limestones is a bed of shales varying from 30 to 60 feet in thickness for which the name Labette shales is adopted. . . .
>
> At Fort Scott they are 35 feet thick; at Labette city they are fully 60 feet. Southward they decrease in thickness until at the state line one can hardly notice them. Westward the deep wells show that they likewise decrease in thickness. The section at Fort Scott gives them less than 30 feet thick; the one at Cherryvale about 30 feet, where they carry a thin seam of coal; at La Harpe, Iola, and Toronto they are hardly visible, the overlying limestone going down and almost coalescing with the Oswego limestone below.[32]

History of usage. The term has always been used in its present sense. Strata south of Broken Arrow equivalent to the

31. Swallow, G. C., *Kansas Geol. Survey, Prelim. Rept.* p. 24, 1866.
32. Haworth, E., *The University Geol. Survey of Kansas,* Vol. 3, p. 36, 1898.

Labette have been included in beds called the Broken Arrow formation[33] and in the Wetumka shale.[34]

Distribution. From the type locality the Labette extends northeastward across Kansas, and equivalent strata extend across Missouri into Iowa.[35] Southward the Labette extends into Oklahoma as far as Arkansas River. In Tulsa County the outcrop is 1½ to 2 miles wide.

Thickness. In Tulsa County the Labette is 180 to 250 feet thick. Ohern[36] says that northward, in the Vinita and Nowata quadrangles, Oklahoma, the Labette is 100 to 140 feet thick. Jewett[37] says that it is 40 to 80 feet thick in northeastern Kansas and, in general, much thinner in Missouri.

Character. In Kansas and Missouri the Labette consists predominantly of shale, in part silty to sandy. It contains limestone and coal locally. Also, it contains lenticular sandstones, some of which are channel fillings. The channels were eroded in late Labette time.[38]

In this area, as in Kansas and Missouri, the Labette is shale, in part sandy or silty. Neither limestone nor coal has been found, so far as the author knows. The Labette of this area also contains sandstones, some of which may be channel fillings. Others may be equivalent to the Calvin sandstone and still others to sandstone in the lower part of the Wewoka formation.

Stratigraphic relations. The Labette formation rests conformably upon the Fort Scott limestone and is overlain conformably by the Oologah formation, in Oklahoma. The Oologah grades abruptly into calcareous shale in the vicinity of Broken Arrow. Consequently the top of the Labette is difficult to map south of that locality.

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33. Gould, Charles N., "Index to the Stratigraphy of Oklahoma": *Okla. Geol. Survey Bull.* 35, p. 71, 1925.
34. Miser, Hugh D., "Geologic Map of Oklahoma": *U. S. Geol. Survey*, 1926.
35. Moore, Raymond C., "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas": *State Geol. Survey of Kansas Bull.* 22, p. 61, 1935.
36. Ohern, D. W., "Geology of the Nowata and Vinita Quadrangles": *unpublished manuscript.*
37. Jewett, John M., "Classification of the Marmaton Group, Pennsylvanian, in Kansas": *State Geological Survey of Kansas Bull.* 38, p. 309, 1941.
38. Jewett, John M., "Classification of the Marmaton Group, Pennsylvanian, in Kansas": *State Geol. Survey of Kansas Bull.* 38, p. 311, 1941.

Correlations. The Labette of this area is continuous northward with the Labette of Kansas and Missouri. Its exact equivalents southward are not known, but it corresponds to the Calvin sandstone, the Wetumka shale, and to strata in the lower part of the Wewoka formation.

Detailed sections. For measured outcrop sections showing the Labette formation see sections numbered 49, 80, 82, 83, 84, 88, Appendix A.

Oologah Formation

The following discussion of the Oologah formation is based upon work by Kirk and Goodrich,[39] and by Travis and Alcock,[40] supplemented by the writer's field observations.

The Oologah formation takes its name from the town of Oologah, Rogers County, where it consists of about 50 feet of limestone beds with minor amounts of black fissile shale that contains phosphatic nodules and is exposed locally in the upper part of the formation. In northern Rogers County and in Nowata County the Oologah consists of three members which are, in ascending order, the Pawnee limestone, Bandera shale, and Altamont limestone.

First reference. Drake, 1897.

Nomenclator. Drake, 1897.

Original description.

> At and in the vicinity of Oologah this limestone is massive, hard, gray, rather unevenly textured, and in places contains gray, chert nodules. On weathering the limestone breaks into irregular-shaped pieces.[41] A foot-

39. Charles T. Kirk and H. B. Goodrich made a detailed study of the Oologah limestone for the State Mineral Survey, *Works Progress Administration Project* No. 65-65-538, sponsored and directed by the Oklahoma Geological Survey, 1936-37. Their unpublished report is in the files of the Oklahoma Geological Survey.

40. Fred L. Travis and Charles W. Alcock studied the upper Marmaton rocks of Nowata and Rogers Counties, Oklahoma, including the Oologah limestone and its northward equivalents, under supervision of the author in preparation of their theses offered in partial fulfillment of the requirements for the M.S. degree at the University of Iowa, 1941-42. Copies of their sections and a copy of the thesis by Travis are in the files of the Oklahoma Geological Survey.

41. Drake, N. F., "A Geological Reconnaissance of the Coal Fields of the Indian Territory": *American Philosophical Society Proceedings,* Vol. 36, pp. 326-419, 1897: Also, *Leland Stanford University, Contributions to Biology,* Vol. 14, pp. 226-419, 1898.

note says: "This bed has been called the Oologah limestone because it is finely exposed in Oologah, along Fourmile Creek at the west edge of Oologah, and in an escarpment some three miles east of that place."

History of usage. The term Oologah formation has heretofore been applied to the thick limestone formation which extends from the vicinity of Broken Arrow to a locality about 4 miles

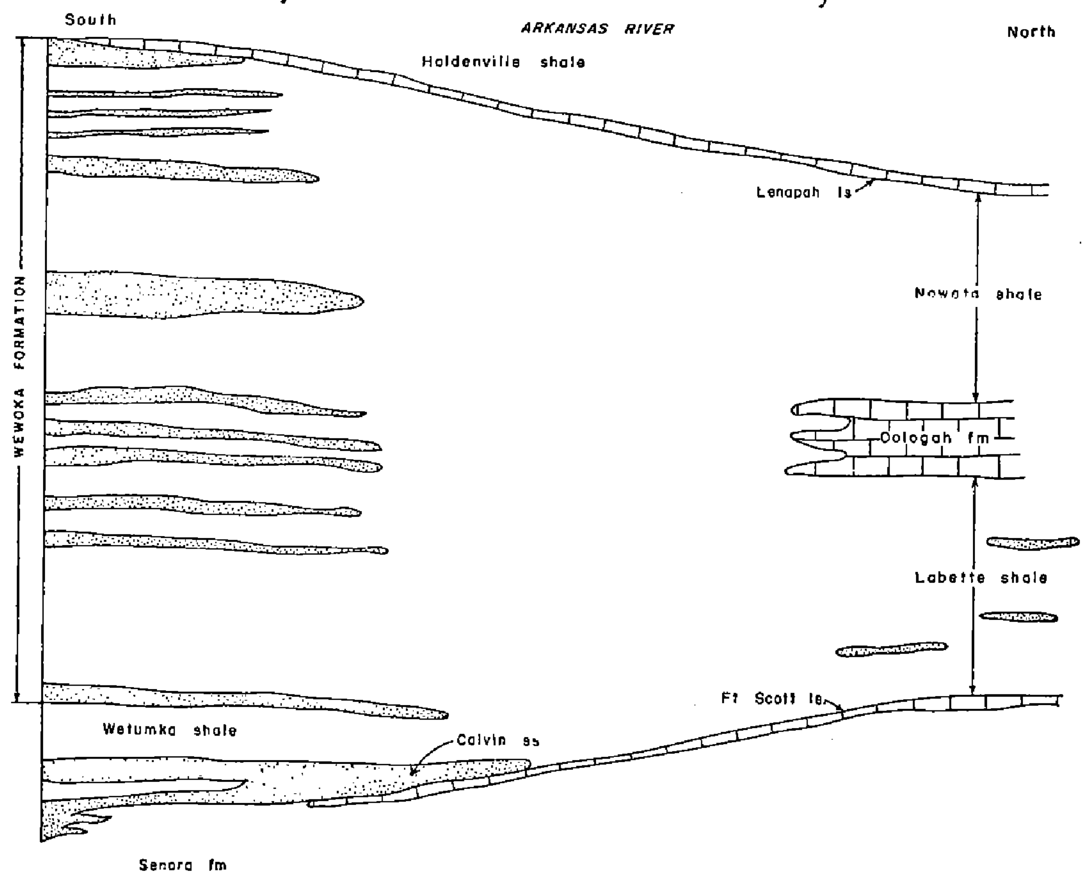

FIG. 3. Diagram, not to scale, showing the stratigraphic relations of the Fort Scott limestone to the Calvin sandstone, and the stratigraphic relations of the Lenapah limestone to the Wewoka formation. This diagram also indicates the correlation of the Calvin sandstone, the Wetumka shale, and the Wewoka formation, south of the Arkansas River, with the Labette shale, the Oologah formation, and the Nowata shale, north of the Arkansas River.

northeast of Oologah, where it bifurcates. The term is here extended to the Kansas-Oklahoma line to include, in ascending order, the Pawnee limestone, the Bandera shale, and the Altamont limestone as members. South of Broken Arrow, Oologah equivalents were included in beds called the Broken Arrow formation.[42]

42. Gould, C. N., "Index to the Stratigraphy of Oklahoma": *Oklahoma Geol. Survey Bull.* 35, p. 71, 1925.

Distribution. As here redefined the Oologah formation is conspicuous from the vicinity of Broken Arrow, Tulsa County, northward to the Kansas-Oklahoma line. Calcareous shale stratigraphically equivalent to some part of the Oologah extends southward from the vicinity of Broken Arrow to the Arkansas River and is shown on the accompanying map as Oologah, largely for cartographic reasons, to separate the Labette shale from the Nowata shale.

Thickness. The Oologah formation is about 40 feet thick immediately north of Broken Arrow, thicker northward to a maximum of about 100 feet in the latitude of Catoosa, Rogers County, and progressively thinner farther north; it is only about 60 feet thick in the type locality around Oologah. At the Kansas-Oklahoma line its three northern members have a combined thickness of about 165 feet.

Character. From the north part of T. 23 N., R. 15 E., where the Bandera shale member pinches out and the Pawnee and Altamont limestone members seem to merge, southward to the south part of T. 20 N., R. 14 E., the Oologah formation consists of dark gray, massive to thin-bedded limestone, argillaceous at many places, with a very small amount of black fissile shale which contains phosphatic nodules and is exposed only locally in the upper part of the formation.

From the south part of T. 20 N., R. 14 E., southward to Broken Arrow, the Oologah consists of three more or less well defined zones; a lower limestone zone, a middle zone composed of calcareous shale and limestone, and an upper limestone zone. Residual patches of fossiliferous chert in the north part of T. 19 N., R. 14 E., may represent a still higher member of local development, but if so, practically all of it has been removed along the outcrop. It is suspected that some of the exposures of black fissile shale with phosphate nodules, mentioned in the preceding paragraph, represent both the Bandera shale member to the north and the middle shaly zone of this paragraph, but it is far from certain that this is true. Instead, at least some of them may represent similar shale known to occur in the Altamont limestone member, or they may be merely local lenses. Because of these uncertainties, the three northern members have not been formally differentiated southward to Broken Arrow.

The lower limestone zone, east of Tulsa, consists of light gray to dark gray limestone, moderately fossiliferous and somewhat cherty. The chert content increases southward so that in the conspicuous road cut near the SE cor. sec. 27, T. 19 N., R. 14 E., the zone consists of cherty limestone and limy, cherty siltstone. In the outlier in which the underground water supply reservoir is constructed, NE part sec. 11, T. 18 N., R. 14 E., immediately northeast of Broken Arrow, the lower part of the lower zone consists almost entirely of cherty, limy siltstone; and in the roadside ditches along the west side of sec. 2, T. 18 N., R. 14 E. the upper part of the lower member consists of flaggy, platy beds that seem to be also cherty, limy siltstone.

The middle shaly zone is only a few feet thick in the latitude of Tulsa but is thicker southward to a maximum of 15 to 20 feet

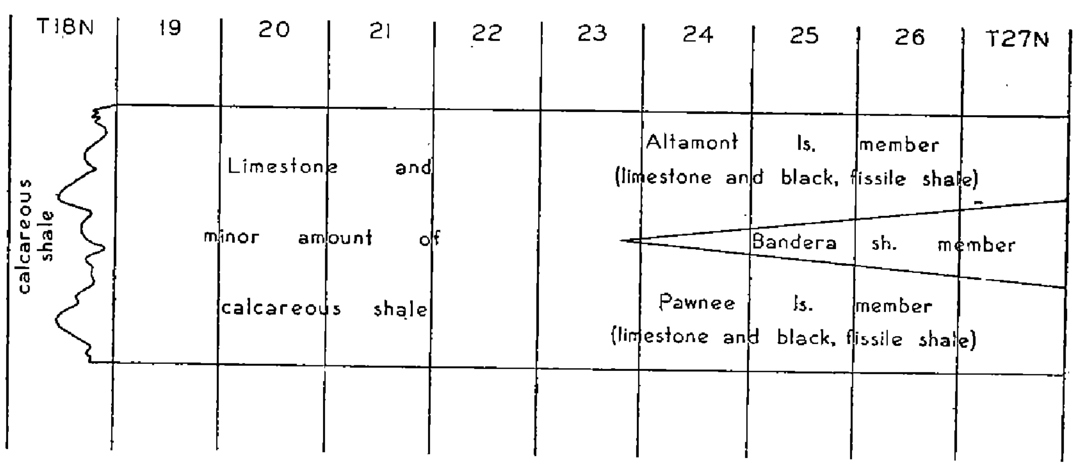

FIG. 4. Diagram, not to scale, of the Oologah formation showing its character and the relations of its members.

in sec. 3, T. 18 N., R. 14 E., northwest of Broken Arrow. It consists of gray shale and dark to black flaky shale, all more or less calcareous in fresh exposures. The upper limestone zone consists of light gray to dark gray limestone, moderately fossiliferous and massive to thin-bedded.

The limestone outcrop of the Oologah formation terminates so abruptly immediately north of Broken Arrow as to indicate, on superficial observation, that the formation has been removed by post-Oologah erosion. However, detailed observation along streams in the northwest part of Broken Arrow and west of the town disclosed a few outcrops of calcareous shale and lenticular stringers of shaly, limy siltstone; which lead to the conclusion that the apparent abrupt termination of the outcrop is due to abrupt gradation into calcareous shale, a conclusion which is born out by studies of logs of wells drilled for oil and gas in the area immediately to the west.

During the field season of 1950, as part of the field work for the new Geologic Map of Oklahoma, now in preparation, the author made a more intensive study of the area southward from Broken Arrow to the terrace deposits north of the Arkansas River, in an effort to extend the mapping of the Oologah and thus separate the Nowata shale from the Labette shale. In addition to a few outcrops of calcareous shale, an abundance of calcareous nodules were found in the B layer of the soil along the logical extension of Oologah equivalents. This is taken as evidence of a calcareous shale, equivalent to the Oologah, from which the soil is derived.

The outcrop of the Oologah formation is, therefore, extended on both the Geologic Map of Oklahoma and the geologic map accompanying this report, to the terrace deposits north of the Arkansas River. This is, frankly, a cartographic expedient. Certainly, the Oologah should not be extended south of the Arkansas River.

Stratigraphic relations. The Oologah formation rests conformably on the Labette formation and is overlain conformably by the Nowata formation.

Correlations. The Oologah formation is continuous northward with the Pawnee limestone, Bandera shale, and Altamont limestone of southeastern Kansas. Across the Arkansas River to the south, equivalents of the Oologah formation lie in the middle part of the Wewoka formation.

Detailed sections. For measured outcrop sections showing the Oologah formation see sections numbered 45, 49, 79, 81, 82, 83, 116, 144, Appendix A.

Nowata Shale

The Nowata shale, in its type locality, the latitude of Nowata, T. 26 N., R. 16 E., lies between the Altamont limestone member of the Oologah formation, below, and the Lenapah limestone, above. The Altamont member of the Oologah formation merges with the Pawnee member in the north part of T. 23 N., R. 15 E., to constitute the Oologah limestone which underlies the Nowata shale southward to the vicinity of Broken Arrow, in the north part of T. 18 N., R. 14 E., where the Oologah grades abruptly into calcareous shale. The Oologah is difficult to distinguish across T. 18 N., R. 14 E., but is extended on the accompanying map to the terrace deposits north of the Arkansas River, thus separating the Nowata shale from the Labette shale. None of these three units can be delimited south of the Arkansas River.

From the south part of T. 25 N., R. 15 E., southward to the latitude of Owasso, south part of T. 21 N., R. 14 E., the Lenapah limestone and part of the Nowata shale were removed, except locally, by pre-Seminole erosion, and the Nowata is unconformably overlain by the Seminole formation. Alluvium along Bird Creek obscures relations south of Owasso but limestone correlated with the Lenapah crops out from place to place from the E¼ corner of sec. 14, T. 20 N., R. 13 E. southward to the south side of Tulsa County, and conformably overlies the Nowata as in the type locality.

The Nowata consists predominantly of shale, ranging in character from clay shale to sandy shale. It contains also minor amounts of lenticular sandstone. A band of limy flagstones in the upper part of the Nowata in the latitude of Talala, T. 24 N., R. 15 E., is correlated with a similar band of limy flagstones that occurs from the latitude of Tulsa southward.

First reference. Ohern, 1910.

Nomenclator. Ohern, 1910.

Original description.

> Lying above the Oologah formation and constituting the highest beds of the Tulsa group (extending up to the base of the Lenapah limestone) is a series of shales with a few interstratified sandstones . . . for which the name

Nowata shales is here proposed. The name is from the town Nowata where the shales are widely exposed and well developed. It is used by Hutchison (L. L. Hutchison) in his unpublished work.

* * * * * * * *

For the most part the Nowata shales have no lithologic features which are not possessed by others of the region. They generally are bluish or greenish in color, but give, almost always, on weathering, a soil, green or buff according to the stage of oxidation of the iron. They are essentially clay shales but not infrequently are highly arenaceous.[43]

History of usage. Apparently it has been the intent of all writers to use the term in its original sense, but owing to failure to recognize the unconformity at the base of the Seminole formation, and to the assumption by Ohern[44] that the Dawson coal is the southward equivalent of the Lenapah limestone, the term has unwittingly been made to include the lower part of the Seminole formation from the south part of T. 25 N. southward, and in addition the Holdenville (Memorial) shale and the Lenapah limestone from the latitude of Tulsa southward. As a result, the Nowata shale has been erroneously assigned a thickness of 600 feet or more in the latitude of Tulsa. In recent years the term has been used to designate equivalent strata in Kansas.[45] Equivalent strata south of the latitude of Broken Arrow were included in the Broken Arrow formation.[46]

Distribution. Outcrops of the Nowata shale extend northward from the type locality across northeastern Oklahoma and southeastern Kansas,[47] and southward to the Arkansas River.

Thickness. The Nowata shale is about 60 feet thick at the Kansas-Oklahoma line and increases in thickness southward to a maximum of about 200 feet in the latitude of Broken Arrow. The formation has a minimum thickness of 20 to 30 feet in T. 21

43. Ohern, D. W., "The Stratigraphy of the Older Pennsylvanian Rocks of Northeastern Oklahoma": *The State University of Oklahoma Research Bulletin* 4, p. 23, 1910.
44. Ohern, D. W., "Discussion": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 2, p. 122, 1918.
45. Moore, Raymond C., "Division of the Pennsylvanian System in Kansas": *State Geol. Survey of Kansas Bull.* 83, p. 60, 1949.
46. Gould, Charles N., "Index to the Stratigraphy of Oklahoma": *Okla. Geol. Survey Bull.* 35, p. 71, 1925.
47. Jewett, John M., "Classification of the Marmaton Group, Pennsylvanian, in Kansas": *State Geol. Survey of Kansas Bull.* 38, p. 335, 1941.

N., R. 14 E., where the greater part was removed by pre-Seminole erosion.

Character. The Nowata shale consists predominantly of shale that ranges in character from clay shale to sandy shale. The Nowata contains also a minor amount of lenticular sandstone, which has produced oil locally west of the outcrop. In the lower part there are a few limestone lentils, generally less than 1 foot thick and of only local occurence. In the latitude of Talala, T. 24 N., R. 15 E., the Nowata contains in the upper part a band of limy flagstones and interbedded marly shale. Farther south this band of flagstones was probably removed by pre-Seminole erosion, but it is present in the area south of Bird Creek and southward to the south side of Tulsa County. In this southward extension the band of flagstones is thicker, contains thin fossiliferous limestone flags, locally, and extends up to, and at some places may include, the Lenapah limestone. The author has traced the flags southward into the uppermost part of the Wewoka formation.

Stratigraphic relations. The Nowata formation rests conformably on the Oologah formation in Oklahoma and on the Altamont limestone in Kansas. (In Oklahoma the Altamont is regarded as the uppermost member of the Oologah.) The Nowata formation is conformably overlain northward from the type locality by the Lenapah limestone, and likewise southward to the south part of T. 25 N., R. 15 E. From that locality to the vicinity of Owasso, T. 21 N., R. 14 E., the Lenapah limestone and part of the Nowata were removed by pre-Seminole erosion, except locally, and the eroded Nowata is overlain unconformably by the Seminole formation. The alluvium along Bird Creek, north part of T. 20 N., R. 13 E., obscures relations in that vicinity, but farther south the Nowata is again overlain conformably by the Lenapah limestone.

Correlations. The Nowata shale in Oklahoma is continuous with strata in Kansas between the Altamont and Lenapah limestones, and now mapped as Nowata.[48] The Nowata is not easily delimited, below, south of the vicinity of Broken Arrow, north part of T. 18 N., R. 14 E., where the underlying Oologah forma-

48. Jewett, John M., *op. cit.*

tion grades abruptly into calcareous shale. However the outcrop of this calcareous shale equivalent of the Oologah is shown on Plate II as far south as the terrace deposits north of the Arkansas River. South of the Arkansas River, equivalents of the Nowata shale lie in the upper part of the Wewoka formation.

Detailed sections. For detailed outcrop sections showing the Nowata shale see sections numbered 39, 42, 44, 73, 76, 77, 79, 82, 144, Appendix A.

Lenapah Limestone

The following discussion of the Lenapah limestone is based on work done by Murray[49] and by Alcock[50] as well as on field work done by the author.[51]

In the type locality at Bell's Spur, sec. 30, T. 28 N., R. 16 E., near Lenapah, Nowata County, the lower part of the Lenapah limestone, about 20 feet, consists of massive, siliceous limestone, mottled dark gray and light gray. The upper part consists of relatively regular and thin-bedded limestone and, rarely, there are still higher thin limestone beds with intercalated shale, some of which is black and fissile and contains phosphatic nodules. These higher beds are though to be remnants left by pre-Seminole erosion, which removed the upper part of the Lenapah in this area.

From the south side of T. 25 N., R. 15 E., southward to the vicinity of Owasso, south part of T. 21 N., R. 14 E., the Lenapah was completely removed, except locally, along with much of the underlying Nowata formation. South of Owasso the alluvium of Bird Creek and tributaries obscures relations but the Lenapah crops out from the E¼ cor. sec. 14, T. 20 N., R. 13 E. southward to the south side of Tulsa County. In this part of Tulsa County

49. Dr. A. N. Murray, now at the University of Tulsa, mapped the Lenapah (Eleventh Street) limestone from the latitude of Tulsa southward to terrace deposits north of the Arkansas River in 1935 while in the employ of the Oklahoma Geological Survey. In 1942 the author went over the outcrop with Dr. Murray who was able to add details exposed in excavations subsequent to his mapping.

50. The Lenapah limestone in Nowata County, Oklahoma, was studied in considerable detail by Charles W. Alcock, under the author's supervision, in the course of preparation of his thesis offered in partial fulfillment of the requirements for the M.S. degree at the University of Iowa, 1941-42.

51. The author mapped the Lenapah from Arkansas River to the south limit of Tulsa County.

the unconformity at the base of the Seminole formation does not cut so deep and the Lenapah limestone is overlain conformably by the Holdenville (Memorial) shale. The Lenapah in this area is thinner and more sandy than in its type locality near Lenapah, Nowata County. In fact, in many localities it is merely a limy sandstone which weathers readily to sandy soil so that it is difficult to find exposures. For all practical cartographic purposes the top of the Lenapah limestone should be considered equivalent to the top of the Wewoka formation.

First reference. Gould, Ohern and Hutchison, 1910.[52]

Nomenclator. Gould, Ohern and Hutchison, 1910.

Type locality. Vicinity of Lenapah, Nowata County.

Original description.

> The lithologic character of the Lenapah is very constant. It is, when unaltered, a dense, blue, partly crystalline limestone usually containing an abundance of fossils, especially of brachipods. On weathering it gives little or no chert, thus differing markedly from similar beds below it.[53]

History of usage. From the vicinity of Nowata, Nowata County, northward, the term has always been used in its present sense. The Lenapah was once shown on a published map extending as far south as North Canadian River, in Okfuskee County,[54] but this was an error and the limestone so shown south of the latitude of Nowata is in reality the Checkerboard limestone which is considerably higher in the section. At a later date the Dawson coal was supposed to have its northward beginning in the black shale observed locally in the uppermost part of the Lenapah limestone and was for several years supposed to be the southward equivalent of the Lenapah.[55] Greene[56] noted a limestone in the

52. Gould, C. N., Ohern, D. W., and Hutchison, L. L., "Proposed Groups of Pennsylvanian Rocks of Eastern Oklahoma": *The State University of Okla. Research Bull.* 3, p. 6, 1910.

53. Ohern, D. W., "The Stratigraphy of the Older Pennsylvanian Rocks of Northeastern Oklahoma": *The State Univ. of Okla. Research Bull.* 4, p. 26, 1910.

54. Gould, C. N., Ohern, D. W., and Hutchison, L. L., "Proposed Groups of Pennsylvanian Rocks of Eastern Oklahoma": *The State Univ. of Okla. Research Bull.* 3, map, 1910.

55. Ohern, D. W., "Discussion": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 2, p. 22, 1918.

Bloesch, Edward, "Nowata County": *Okla. Geol. Survey Bull.* 40, Vol. 3, p. 357, 1930.

56. Dott, Robert H., "Memorial Shale of Pennsylvanian Age, in Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, p. 1593, 1941.

area southeast of Tulsa which he named informally the Eleventh Street, from good exposures in the vicinity of the intersection of Memorial Drive and Eleventh Street (U. S. Highway 66), east of Tulsa, west of the SE cor. sec. 2, T. 19 N., R. 13 E. Later Dott[57] and Cullen found that in all probability the Eleventh Street is the southward extension of the Lenapah. The name Eleventh Street, for this southern occurrence, is abandoned in favor of the older term Lenapah.

Distribution. Jewett[58] who has done considerable work on the Lenapah of southeastern Kansas says that there should be little doubt that the Lenapah limestone extends into Missouri and possibly into Iowa. It is present continuously in Oklahoma as far south as the south part of T. 25 N., R. 15 E. From that point to the vicinity of Owasso, south part of T. 21 N., R. 14 E., it was removed, except locally, along with much of the underlying Nowata shale by pre-Seminole erosion. Alluvium of Bird Creek and its tributaries obscures relations immediately south of Owasso but the Lenapah limestone is exposed from place to place from the E¼ sec. 23, T. 20 N., R. 13 E., southward, and there is little doubt that it is continuously present, a few feet below the surface. The Lenapah limestone extends southward into the uppermost sandstone of the Wewoka formation, in sec. 15, T. 15 N., R. 12 E.

Thickness. According to Alcock,[59] who made a detailed study of the Lenapah limestone in Nowata County, the Lenapah is about 16 feet thick at the Kansas-Oklahoma line; 27 feet in the quarry NE¼ NE¼ sec. 30, T. 28 N., R. 16 E., Nowata County; and thinner southward to about 7 feet in the town of Nowata, T. 26 N., R. 16 E. He states that in T. 25 N., R. 15 E., only isolated exposures a few feet in thickness were observed. In Tulsa County where the Lenapah consists of interbedded limestone and calcareous shale and, in many localities, of limy sandstone it is difficult at many places to fix its upper limit, so that thicknesses may be assigned ranging from a few feet to as much as 20 feet. Generally it appears to be 5 to 10 feet thick.

57. *Idem.*
58. Jewett, John M., "Classification of the Marmaton Group, Pennsylvanian, in Kansas": *State Geol. Survey of Kansas Bull.* 38, p. 336, 1941.
59. Alcock, Charles W., "Stratigraphy of the Pawnee-Lenapah Formations, Nowata and Craig Counties, Oklahoma": *Univ. of Iowa, thesis,* 1941.

Character. In the northern part of Nowata County the lower part of the Lenapah consists of massive siliceous limestone 6 to 18 feet thick mottled dark gray and light gray. This lower massive part is overlain by a few inches of highly fossiliferous, marly limestone which is, in turn, overlain by 3 to 5 feet of gray to brown limestone. Locally there are still higher thin limestone beds with intercalated shale some of which is black and fissile and contains phosphatic concretions.

TABLE III

COMPOSITE OUTCROP SECTION OF THE LENAPAH LIMESTONE

In the area of its greatest thickness, secs. 19 and 30, T. 28 N., R. 16 E.:

8.	Limestone: nodular, fossiliferous; weathers red, brown, or yellow	0.5
7.	Shale: calcareous; light-colored	0.5
6.	Shale: black; fissile, with a few phosphatic nodules	1.0
5.	Shale: gray; weathers yellow	2.0
4.	Limestone: brown; thin-bedded	1.5
3.	Limestone: gray; massive	3.5
2.	Shale: Calcareous containing limestone nodules; extremely fossiliferous	0.8
1.	Limestone: siliceous; mottled light-gray and dark-gray; massive	19.0

The black fissile shale with phosphatic nodules as well as higher beds are found locally as far south as sec. 27, T. 26 N., R. 15 E., and are interpreted as remnants of once continuous beds which were removed from most of the area by pre-Seminole erosion. That part of the formation below the black fissile shale varies greatly in character and thickness both northward and southward. How much of the variation in thickness was an original feature and how much is due to pre-Seminole erosion is not readily determinable. The variation in the character of the Lenapah indicates a heterogeneous depositional environment, probably in shallow water. Not uncommonly beds which appear to be continuous change from calcareous shale and limestone nodules to thin-bedded crinoidal limestone within a few hundred feet. Generally, the limestone beds are thinner and the intercalated shale more abundant southward. Crinoidal beds are particularly noticeable in T. 25 and 26 N. Alcock records sandy limestone beds in the Lenapah in sec. 12, T. 26 N., R. 15 E.

From sec. 28, T. 25 N., R. 15 E., southward to the vicinity of Owasso, south side of T. 21 N., R. 14 E., the only exposure of the

Lenapah limestone known to the writer is in the road along the south side of the SW¼ sec. 33, T. 24 N., R. 15 E. Over most of this area the lower Seminole sandstone is abnormally close to the top of the Oologah, indicating removal of the Lenapah by pre-Seminole erosion.

TABLE IV

SECTION OF LENAPAH LIMESTONE

(Measured by Dott[60] and the author immediately west of the NE cor. sec. 28, T. 25 N., R. 15 E.)

4.	Limestone, marly and extremely fossiliferous: (fossils from this bed and from the roadside ditch are: *Chonetes granulifera*, abundant; *Mesolobus*, common; *Prismopera, Composita, Pustula, Spirifer*, and crinoids, present)	3.0
3.	Mostly covered, calcareous shale: upper 2 feet well exposed and crammed with fossils, mostly *Chonetes granulifera*	5.7
2.	Limestone, siliceous: gray to reddish, hard, even-bedded, crinoidal	0.6
1.	Limestone, siliceous: gray to brown, feruginous; weathers with rough pitted surface, crumbly where extremely weathered	1.2

From Bird Creek, T. 20 N., R. 13 E., to the south side of Tulsa County the Lenapah, in many localities, consists of interbedded limestone and calcareous shale, and in many others of sandy limestone or even limy sandstone.

The limy and sandy character of the Lenapah in the south part of Tulsa County is well exemplified by an exposure in a draw which crosses the road immediately north of the E¼ cor. sec. 8, T. 17 N., R. 13 E. No measured section for this place is available.

Farther south in Tulsa County the Lenapah is not well exposed but there is evidence that it consists of nonresistant, limy sandstone, at least in some localities. The band of limy flagstones already described as occurring in the upper part of the underlying Nowata shale, extends up to the sandy, limy Lenapah in southern Tulsa County wherever the Lenapah is exposed. In other localities in southern Tulsa County, and generally in Okmulgee County to the south, where the sandy phase of the Lenapah is not found, the uppermost flags are actually very thin-bedded, fossiliferous limestone and probably represent the Lenapah.

Stratigraphic relations. Wherever the Lenapah limestone is present it rests conformably upon the Nowata formation, below,

60. Dott, Robert H., Director, Oklahoma Geological Survey.

and it is conformably overlain by the Holdenville (Memorial) shale, above, wherever the latter was preserved from pre-Seminole erosion. Wherever the Lenapah was exposed by pre-Seminole erosion it is unconformably overlain by the Seminole formation. In some localities the Lenapah and more or less of the underlying Nowata shale were removed by pre-Seminole erosion and beds of the Seminole formation occupy the position that would normally be occupied by the Lenapah limestone.

Correlations. Jewett[61] thinks that there is little doubt that the Lenapah limestone extends across southeastern Kansas and into Missouri and that it may extend into Iowa. In 1950, incident to field work for the new Geologic Map of Oklahoma, now in preparation, the author traced the band of limy flagstones, previously described as occurring in the upper part of the Nowata shale and extending up to the Lenapah limestone, southward to the southwest part of sec. 15, T. 15 N., R. 12 E., Okmulgee County, where they merge with the uppermost sandstone of the Wewoka formation. In Okmulgee County, as in southern Tulsa County, the uppermost flags, in many localities at least, are actually thin-bedded, fossiliferous limestone and in all probability represent the Lenapah. For all practical cartographic purposes, then, the Lenapah limestone is equivalent to uppermost Wewoka beds.

Detailed sections. For measured outcrop sections showing the Lenapah limestone see sections numbered 2, 18, 19, 20, 21, 22, 24, 27, 39, 40, 41, 42, 44, 71, 73, 74, 76, 77, 78, 79, 82, Appendix A.

Wewoka Formation

In the course of his mapping for the new Geologic Map of Oklahoma, now in preparation, the author found that the uppermost beds of the Wewoka formation are continuous with the Lenapah limestone. He found, likewise, that representatives of the Calvin sandstone, about 40 feet thick, extend into southern Tulsa County, where they are immediately above the Fort Scott limestone. The Wetumka shale is probably less than 60 feet thick but its contact with the overlying Wewoka formation can not be precisely determined.

61. Jewett, John M., "Classification of the Marmaton Group, Pennsylvanian, in Kansas": *State Geol. Survey of Kansas Bull.* 38, p. 336, 1941.

The Labette shale, Oologah formation, and Nowata shale, north of Arkansas River, from the top of the Fort Scott limestone to the base of the Lenapah limestone, cannot be differentiated south of the river, but their equivalents are preponderantly in the Wewoka, and are shown as Wewoka on Plate I. The Wewoka, so mapped, contains the equivalents of the Calvin sandstone and the Wetumka shale in the lower part.

Sandstones are conspicuous in the Wewoka along the south side of the County, but are inconspicuous along the Arkansas River, where the Wewoka is composed mostly of shale.

Detailed sections. For measured outcrop sections showing the Wewoka formation see sections numbered 18, 19, 20, 22, 23, 24, 27, 29, Appendix A.

Holdenville (Memorial) Shale

The Memorial shale, by definition, extends upward from the top of the Lenapah limestone to the base of the Seminole formation, and likewise, the Holdenville shale extends upward from the top of the Wewoka formation to the base of the Seminole formation. As the Lenapah has been traced into uppermost Wewoka, the Memorial and the Holdenville lie between the same stratigraphic limits and are equivalent. Holdenville, being the older and more commonly used term, takes precedence.

The Holdenville (Memorial) shale in Tulsa County lies conformably on the Lenapah limestone and is overlain unconformably by the Seminole formation. Taff[62] said that it is 250 feet thick in the northwest corner of the Coalgate quadrangle, 3 miles south of Holdenville, Hughes County, Oklahoma. It is more than 200 feet thick in southern Tulsa County. Excepting very small patches, it is absent from Bird Creek, in Tulsa County, to the Kansas-Oklahoma line. It consists predominantly of shale but contains minor amounts of limestone and sandstone. A sandstone in the upper part is so prominent between Beggs, Okmulgee County, and the south line of Tulsa County that it has been mistaken for the

62. Taff, Joseph A., *U. S. Geol. Survey, Coalgate Folio, Geologic Atlas,* (No. 74), p. 4, 1901.

Seminole sandstone and appears as Seminole on the Geologic Map of Oklahoma.[63]

First reference. Taff, 1901.

Type Locality. Taff did not mention a type locality specifically, but probably had in mind the area west from Holdenville, Hughes County, to the top of the prominent escarpment capped by the cherty, conglomeratic, lower sandstone beds of the Seminole formation.

Original description.

> This shale, 250 feet in thickness, rests upon the Wewoka formation, and its crop in this quadrangle is limited to a small triangular area in the northwestern corner. The surface of the formation becomes broader northward in the more level country about Holdenville, 3 miles north of the border of the quadrangle.
>
> The formation is composed of friable, blue clay shale, with local thin beds of shelly limestone and shaly calcareous sandstone in the upper part. The sandstone ledges outcrop in terraces around the slopes of the hills bordering the north side of Little River. The thin limestone occurs about 35 feet below the top of the formation, and its outcrop is usually covered by the sandstone and conglomerate debris from the overlying (Seminole) formation. In its usual exposure 1 to 2 feet only of shaly limestone may be seen. At other places a bed of shell breccia loosely cemented is found, representing the thin hard plates of the shelly rock. The shales are rarely exposed. The smooth, grass-covered prairie soil, however, even in the steep slopes, bears evidence of the friable shale beneath.[64]

It will be noted that nowhere did Taff specifically define the top of the Holdenville, but the implications of both text and map are that the top of the Holdenville shale is at the base of the Seminole formation.

History of usage. The term Holdenville shale has always been used in its original sense. However, in Tulsa County, other names and classifications have been applied to beds belonging in the Holdenville. In the vicinity of Tulsa and southward strata now known to be in the Holdenville shale were erroneously included

63. Miser, Hugh D., "Geologic Map of Oklahoma": *U. S. Geol. Survey*, 1926.
64. Taff, J. A., *op. cit.*

in the Nowata shale, and so appear on the Geologic Map of Oklahoma,[65] because, by definition, the top of the Nowata is the base of the Lenapah limestone and it was thought that the Dawson coal had been traced into the black, fissile shale found locally in the upper part of the Lenapah and that consequently the base of the Dawson coal could be considered as stratigraphically the same as the base of the Lenapah.

Robert H. Dott and Ronald J. Cullen, in 1938, while working on a project of the Tulsa Stratigraphic Society, found that the Seminole formation included the Dawson coal in its middle part. They also found that the Seminole could be traced northward as far as the Kansas-Oklahoma line, and that the base of the Seminole marks the boundary between the Des Moines series and the Missouri series. It thus became evident that the Dawson coal is not the continuation of the Lenapah limestone, as was previously supposed.

Previously Frank C. Greene had applied the term Eleventh Street limestone informally to a persistent limestone bed in the area southeast of Tulsa. Dott and Cullen concluded that the Lenapah limestone had been scoured and in part removed by pre-Seminole erosion between Bird Creek, in Tulsa County, and the Kansas-Oklahoma line and that, in all probability, the Eleventh Street limestone of Greene is the southern extension of the Lenapah limestone, a conclusion confirmed by subsequent field work by the author.

Dott first applied the name Memorial shale to beds lying conformably upon the Lenapah (Eleventh Street) limestone and unconformably beneath the Seminole formation in an unpublished manuscript in 1935, when exact southward equivalents of the Lenapah had not yet been determined. The name came into use in informal discussions and was used in publications of the State Geological Survey of Kansas without formal definition. Dott defined the term formally in the Bulletin of the American Association of Petroleum Geologists, 1941 "The term Memorial shale is here applied to strata above the top of the Lenapah (Eleventh Street)

65. Miser, Hugh D., *op. cit.*

limestone and below the base of the Seminole formation."[66] Field work by the author has shown that the Lenapah is equivalent to uppermost beds of the Wewoka formation, and that Memorial shale and Holdenville shale are equivalent terms. Holdenville, being the older and more used, supersedes Memorial.

Distribution. The Holdenville (Memorial) shale extends southward from the type locality, west of Holdenville, Hughes County, Oklahoma, to a point midway between Ada and Fitzhugh, Pontotoc County, Oklahoma, where it is overlapped by the Seminole formation. Northward it extends in an unbroken band, except for alluvium associated with several streams, to the alluvium of Bird Creek and tributaries, in Tulsa County. Farther north it occurs only in patches, owing to pre-Seminole erosion. The northernmost known occurrence in Oklahoma is along the south line of the SW¼ sec. 33, T. 24 N., R. 15 E. Other patches are known in Kansas.

Thickness. The Holdenville is 250 feet thick in the area a few miles south of Holdenville, Hughes County, Oklahoma, and is overlapped by the Seminole formation, midway between Ada and Fitzhugh, Pontotoc County. It is more than 200 feet thick in the south part of Tulsa County, but only 40 feet thick in sec. 23, T. 20 N., R. 13 E., immediately south of Bird Creek. In northern Oklahoma and in Kansas, it occurs in thin, ragged patches.

Character. The Holdenville is predominantly shale but contains minor amounts of sandstone and still less limestone. In the latitude of Sasakwa, Seminole County, the Holdenville contains a prominent sandstone lentil near the middle of the formation. In the same area the Sasakwa and Homer limestones are prominent in the upper and lower parts, above and below the sandstone, respectively. There is, likewise, a prominent sandstone near the middle of the formation from the latitude of Beggs, Okmulgee County, northward into Tulsa County with zones of calcareous shale, fossils, and thin lenses of coquina-like limestone above and below at about the stratigraphic positions of the Sasakwa and Homer limestones. But neither sandstones nor limestones are present

66. Dott, Robert H., "Memorial Shale of Pennsylvanian Age, in Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, p. 1592, 1941.

continuously as prominent units along the entire outcrop of the Holdenville.

East of Tulsa the Holdenville shale is about 70 feet thick and contains about 10 feet of silty sandstone near the middle and a bed of limestone an inch or two thick about 10 feet below the top.

The Lenapah limestone crops out at the SW corner, sec. 4, T. 18 N., R. 13 E., and the Holdenville shale crops out northward along the road, up the hill, to the base of the Seminole formation, with a total thickness of 52 feet. At that place, a limestone bed about 2 feet thick occurs in the Holdenville shale about 10 feet below the base of the Seminole and can be traced northeastward about half a mile. In this distance the limestone increases in thickness to several feet and becomes markedly sandy.

The Holdenville shale is 116 feet thick in the SW¼ sec. 5, T. 17 N., R. 13 E., and contains two prominent limestone beds; one is 6 feet thick and 35 feet from the base, the other 5 feet thick and 30 feet below the top.

Along the south side of T. 17 N., Rs. 12 and 13 E., the Holdenville is about 180 feet thick. The following is compiled from measured outcrop sections along this line.

TABLE V

SECTION OF HOLDENVILLE SHALE ALONG THE SOUTH SIDE OF T. 17 N., RS. 12 AND 13 E., TULSA COUNTY

	Ft.
8. Sandstone: base of the Seminole formation, not measured, base near S¼ cor. sec. 35, T. 17 N., R. 12 E.	
7. Covered: shale, about	20.0
6. Limestone: dark weathers yellow, a few fossils (Exposures in road 1/8 and 1/4 mile east of SW cor. sec. 36, T. 17 N., R. 12 E.; also 1/4 mile south of NW cor. sec. 1, T. 16 N., R. 12 E.)	1.5
5. Covered: shale; contains limy flags in upper part	45.0
4. Sandstone: reddish brown; medium to fine-grained; forms prominent escarpment near SW cor. sec. 32, T. 17 N., R. 13 E., and a westward dip slope to SW cor. sec. 31, T. 17 N., R. 13 E.	10.0
3. Shale	7.0
2. Limestone: dark; coquinoidal, weathers yellow, about (Crops out in the road near the top of the escarpment east of the SW cor. sec. 32, T. 17 N., R. 13 E.)	1.0
1. Covered: probably shale, about (The base of No. 1 cannot be determined exactly. The equivalent of the Lenapah limestone in this vicinity and southward is a non-resistant sandstone, probably limy, which readily weathers to soil so that good exposures are rare. The top of the limy flags below the Lenapah lies at the SW cor. sec. 27, T. 17 N., R. 13 E.)	97.0

Stratigraphic relations. The Holdenville (Memorial) shale, in Tulsa County, lies conformably upon the Lenapah limestone, and farther south upon equivalent sandstone at the top of the Wewoka formation. It is overlain unconformably by the Seminole formation.

Correlations. Other than a few, patchy occurrences (heretofore mapped as Memorial shale), equivalents of the Holdenville are not known north of Oklahoma.

Detailed sections. For measured outcrop sections of the Holdenville (Memorial) shale in Tulsa County see sections numbered 1, 2, 3, 4, 5, 10, 11, 17, 18, 19, 20, 21, 24, 25, 26, 27, 28, 38, 39, 41, 42, 43, 44, 71, 74, 75, 76, 77, 82, 112, 113, 114, 115, Appendix A.

Missouri Series

The Missouri series is set off from the underlying Des Moines series by an unconformity and faunal change that has been observed from the Kansas-Oklahoma line to the area of the Arbuckle Mountains; and it is separated from the overlying Virgil series by a large unconformity which is marked by a faunal change and truncation of beds.

Moore, Newell, Dott and Borden[67] suggested a division of the Missouri rocks of Oklahoma and southern Kansas into two groups, Skiatook and Ochelata, using the unconformity at the base of the Chanute shale as the boundary. The logic of this division, as applied to rocks in Washington County, has been fully demonstrated by additional field studies, results of which have already been published;[68] and evidence of the unconformity separating the two was observed in the course of the present work, and in the course of field mapping by the author in Creek County, Oklahoma, for the new Geologic Map of Oklahoma, now in preparation.

SKIATOOK GROUP

The term Skiatook has long been used and was redefined as follows:

67. Moore, Raymond C., Newell, Norman D., Dott, Robert H., and Borden, Joseph L., "Definition and Classification of the Missouri Subseries of the Pennsylvanian Series in Northeastern Oklahoma": *Kansas Geol. Society, Guide Book, Eleventh Annual Field Conference*, pp. 39-43, 1937.

68. Oakes, Malcolm C., "Geology and Mineral Resources of Washington County, Oklahoma": *Okla. Geol. Survey Bull.* 62, 1940.

Oakes, Malcolm C., "Results of Recent Field Studies in Osage, Washington and Nowata Counties, Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, pp. 716-730, 1940.

> In bringing Skiatook back from the limbo of unused stratigraphic names, application is changed so that its lower boundary coincides with the disconformity that marks the base of the Missouri subseries (Missouri series) and its upper boundary is placed at the top of the Drum (Dewey) limestone (or where this limestone is absent, at the base of sandstone in the lowermost Chanute shale).[69]

It will be noted that the upper limit of the Skiatook group is thus placed at the top of the Dewey wherever the latter is present. The most conclusive evidence of this unconformity in southeastern Osage and Pawnee Counties and in western Tulsa County is local absence of the upper part of the Dewey formation and over-all thinning of the Dewey-Iola interval, notably in the vicinity of the rock school house in sec. 28, T. 21 N., R. 11 E., Osage County.

TABLE VI

SUBDIVISIONS OF THE SKIATOOK GROUP IN TULSA COUNTY AND IN SOUTHWESTERN OSAGE COUNTY

Missouri series.
- *Unconformity.*
- Skiatook group.
  - Dewey formation.
  - Nellie Bly formation.
  - Hogshooter formation.
    - Winterset limestone member.
    - Lost City limestone member.
  - Coffeyville formation.
  - Checkerboard limestone.
  - Seminole formation.
    - Sandstone and shale, contains thin coal seams of no economic importance.
    - Shale, contains Dawson coal.
    - Sandstone and shale, contains coal locally near the base, especially in pre-Missouri erosion channels.
- *Unconformity.*

Des Moines series.

Seminole Formation

Use of the name Seminole formation has been extended into northeast Oklahoma and applied to the shale and sandstone unit lying above the unconformity at the base of the Missouri series and below the base of the Checkerboard limestone.

69. Moore, Raymond C., Newell, Norman D., Dott, Robert H., and Borden, Joseph L., *op. cit.*

In Tulsa County the Seminole is composed of a lower sandy zone; a middle shaly zone, containing the Dawson coal; and an upper sandy zone. Coal occurs locally in all three members but the Dawson seam, in the middle shaly zone, is the only one of much economic importance.

First reference. Taff, 1901, called Seminole conglomerate.

Nomenclator. Taff, 1901.

Type locality. Taff's text and map imply the southeast part of the Seminole nation, now Seminole County, probably T. 6 N., Rs. 7 and 8 E.

Original description.

> About 50 feet of the lower part of the Seminole conglomerate is exposed in a small area in the northwest corner of the Coalgate quadrangle . . . . Forty to 50 feet from the base the conglomerate grades into brown sandstone which continues upward about 100 feet to the top of the formation. The Seminole formation crops out in rugged hilly country northwestward in the Seminole nation, making rough timbered land.[70]

History of usage. Taff defined the lower limit of the Seminole formation as the base of the conglomerate that by implication of text and map lies next above the Holdenville shale, but left the upper limit undefined except to imply that it is about 150 feet above the base of the conglomerate. Morgan definitely fixed the upper limit of the formation at the base of the DeNay limestone, which is about 150 feet above the base of the conglomerate in the extreme northeastern part of the Stonewall quadrangle.[71]

As a result of the work of various geologists, for the most part working in the interest of oil companies, the Seminole formation is shown on the Geologic Map of Oklahoma[72] as far north as the south line of Tulsa County. It is correctly shown as far north as Beggs, northwestern Okmulgee County, but from Beggs northward to the south side of Tulsa County a sandstone in the Holdenville (Memorial) shale is incorrectly shown as Seminole.

70. Taff, Joseph A., *U. S. Geol. Survey, Coalgate Folio, Geologic Atlas,* (No. 74), p. 4, 1901.

71. Morgan, George D., "Geology of the Stonewall Quadrangle, Oklahoma": *Bureau of Geology Bull.* 2, pp. 109-112, 1924.

72. Miser, Hugh D., "Geologic Map of Oklahoma": *U. S. Geol. Survey,* 1926.

In the area from the Arkansas River northward to the south part of T. 25 N., R. 15 E., the Dawson coal was erroneously thought to be equivalent to the Lenapah limestone,[73] an error already considered in the discussion of the Holdenville (Memorial) shale, and consequently that part of the Seminole below the Dawson coal was erroneously included in the Nowata formation. That part above the Dawson was included in the Coffeyville formation.

Robert H. Dott and Ronald J. Cullen,[74] in 1933 while working on a project of the Tulsa Stratigraphic Society, determined that the Seminole formation is continuous with sandstone that underlies the city of Tulsa and extends eastward to Sheridan Road. They also found that the Seminole included the Dawson Coal, that the formation could be traced northward as far as the Kansas-Oklahoma line, and that the base marks the boundary between the Des Moines and overlying Missouri beds.

Dott first proposed use of the term Seminole in northeastern Oklahoma informally at the Tulsa meeting of the American Association of Petroleum Geologists in 1936. Such use was proposed formally in 1937 by Dott and Ware[75] and in the same year by Moore, Newell, Dott, and Borden who are quoted in the following summary:

> Recent studies, especially by Dott, have indicated equivalence of sandy beds, formerly included in the lower part of the Coffeyville formation of northeastern Oklahoma, with at least part of the Seminole sandstone of southeastern Oklahoma. It is desirable in simplification of stratigraphic classification to extend application of Seminole into northern Oklahoma, its boundaries here being defined as the basal Missouri disconformity, below, and the base of of the Checkerboard limestone, above. It is not now established that the Checkerboard is the precise equivalent of the DeNay limestone, which in southern Oklahoma immediately overlies the Seminole, but the equivalence is sufficiently close to indicate that little violence will be done

73. Ohern, D. W., "Discussion": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 2, p. 22, 1918. Bloesch, Edward, "Nowata County": *Okla. Geol. Survey Bull.* 40, Vol. 3, p. 357, 1930.
74. Dott, Robert H., "Memorial Shale of Pennsylvanian Age, in Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, p. 1593, 1941.
75. Ware, John M., and Dott, Robert H., in a contribution to "A new Pennsylvanian Cephalopod Fauna from Oklahoma": by A. K. Miller and John Britts Owen, *Jour. Paleontology*, Vol. 2, No. 5, pp. 403-404, 1937.

in defining the upper limit of the northern Seminole as has been indicated.[76]

Distribution. The Seminole formation crops out in a relatively narrow band from the vicinity of Fitzhugh, north part of T. 2 N., R. 5 E., Pontotoc County, northeastward to the Kansas-Oklahoma line in the vicinity of South Coffeyville, Nowata County. Sandstone and shale, representing the upper part of the formation continue into Kansas.

The outcrop lies along the Creek-Tulsa county line from the south line of Tulsa County to the north line of T. 18 N., R. 12 E. It underlies the southeast part of the city of Tulsa and caps the high hills southeast of the city, north of Arkansas River. It is several miles wide in Tps. 21 and 22 N., Rs. 13 and 14 E. The lower part extends eastward into Rogers County. Basal sandstones of the Seminole cap the prominent escarpment north of Owasso. At Collinsville the sandstone hills east of town are covered by the lower, sandy zone; the coal pits are in the lower part of the middle, shaly zone; and the sandstone hills in the west part of town are covered by sandstone beds of the upper sandy zone.

Character. In Tulsa County and northward to the south side of T. 25 N., R. 15 E., the Seminole formation consists of three zones: a lower sandy zone, a middle shaly zone containing the Dawson coal, and an upper sandy zone. The upper and lower zones are sometimes called colloquially the upper and lower Seminole sandstones but this is not entirely appropriate because, although both contain conspicuous sandstone beds locally, both contain also much sandy shale and even minor amounts of clay shale.

In the type locality in Seminole County, the Seminole formation is described as containing 50 feet of chert conglomerate in the lower part. At many places in Tulsa County and northward the lower sandy zone contains, near the base, small, angular, non-calcareous, white fragments of chalky texture, which are presumed to be tripolitic chert. Locally, the basal beds of this zone are rela-

76. Moore, Raymond C., Newell, Norman D., Dott, Robert H., and Borden, Joseph L., "Definition and Classification of the Missouri Subseries of the Pennsylvanian Series in Northeastern Oklahoma": *Kansas Geol. Society, Guide Book, Eleventh Annual Field Conference,* pp. 39-43, 1937.

tively coarse. Stringers of coal an inch or two thick and a few feet long occur locally, in the lower few feet, and at a few places coal at this horizon is of local economic importance. Also, sandy limestone beds occur in the basal part of this zone at many places.

The middle shaly zone in Tulsa County is mostly clay shale and contains the Dawson coal, only a few feet above its base. In Tulsa County this zone is 40 to 100 feet thick but thinner farther north.

The upper sandy zone contains sandstone beds of considerable local thickness but, on the whole, it is more shaly than the lower sandy zone. All along the outcrop there is sandy shale at the top and limestone beds of considerable persistence occur at or a little below its base. Thin coal seams are known in this zone at various horizons and at several places, but none are of commercial importance. The upper sandy zone is probably over-simplified in Plate II on account of an insufficient number of exposures suitable for study and measurement. It rests upon a slightly scoured surface, with local channels several feet deep and several feet wide, but neither locally nor regionally does this channeling approach the magnitude of that at the base of the formation.

The following localities deserve special mention:

In the SW¼ sec. 17, T. 22 N., R. 14 E., the middle shale zone is exposed in the walls of a deep strip pit dug for coal.

A short distance east of the SW cor. sec. 12, T. 22 N., R. 13 E., a thin coal seam near the top of the formation is exposed in the road.

About ¼ mile east of the S¼ cor. sec. 7, T. 22 N., R. 15 E., Rogers County, stringers of coal an inch or two thick and several feet long occur in sandstone near the base of the formation.

Along State Highway 20, one mile south of the north line of T. 21 N., R. 14 E., are good exposures of a thick succession of sandstone and sandy shale beds of the lower zone. In this area the lower Seminole beds fill a deep, pre-Seminole erosion valley more than 10 miles wide, carved in Nowata shale. The valley extends north beyond Tulsa County. A sandy limestone on the south side of this road 1/8 mile east of the SW cor. sec. 1, T. 21 N.,

R. 14 E., is thought to be at the base of the Seminole formation. The Nowata shale is only about 20 feet thick in this locality. The south side of this erosion valley is conspicuously indicated on U. S. Highway 75, about a mile north of Owasso, where the basal sandstone of the Seminole caps the escarpment and crops out along a course only slightly north of east. The lower sandy zone is about 230 feet thick in this erosion valley and only a few feet thick to the north and south. (See Plate II.)

In sec. 26, T. 21 N., R. 13 E., the Oologah limestone is exposed at the top of a small, high, structural dome and the Nowata and Seminole beds dip away conspicuously on the north and west flanks.

Along the south side of secs. 14 to 18, T. 20 N., R. 13 E., the lower sandy zone is only a few feet thick but the middle shale zone and the upper sandy zone reach their maximum known thickness.

On the west side of the road south from Jenks, up the bluff south of Polecat Creek, near the E¼ cor. sec. 25, T. 18 N., R. 12 E., the lower sandstone zone rests conspicuously against the steep bank of an erosion channel in the Holdenville (Memorial) shale. In the north part of the SE¼ of sec. 25 a coal seam in the sandstone which fills this channel is worked to supply local demand. The slope mine near the S¼ cor. sec. 30, T. 18 N., R. 13 E., is also in the lower sandy zone.

A limestone at, or a little below, the base of the upper sandy zone is exposed in the road a short distance west of the SE cor. sec. 15, T. 17 N., R. 12 E., southwest of Glenpool.

Coal a few inches thick exposed in the east side of the road near the gate to the cemetery south of Mounds, near the center of sec. 17, T. 16 N., R. 12 E., Creek County, is in the upper sandy zone of the Seminole formation, and is not Dawson coal.

Stratigraphic relations. In Tulsa County and northward to the Kansas-Oklahoma line, the Seminole formation lies unconformably upon the Holdenville (Memorial) shale, Lenapah limestone, and Nowata shale. Southward from Tulsa County, the Seminole lies unconformably upon the Holdenville shale. The Seminole is overlain conformably by the Checkerboard limestone from the Kansas-Oklahoma line to sec. 23, T. 11 N., R. 9 E., Okfuskee

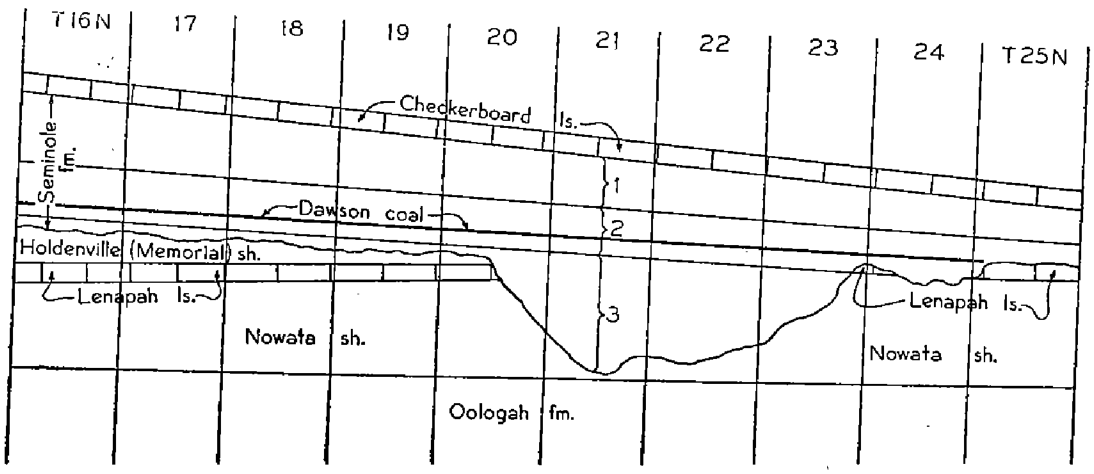

Fig. 5. Diagram, not to scale, showing character and stratigraphic relations of the Seminole formation. (1) Upper sandy zone. (2) Middle shale zone containing the Dawson coal. (3) Lower sandy zone.

County, by shale in the Francis formation from that locality south to sec. 20, T. 7 N., R. 8 E., Hughes County, and by the DeNay limestone from there southward.

Correlations. The Checkerboard limestone of northeastern Oklahoma occupies the stratigraphic position of the DeNay limestone of Pontotoc and Seminole Counties, but their outcrops are not continuous. The Seminole formation in Tulsa County is therefore equivalent to the Seminole of the type locality. Lower beds of the Seminole are progressively overlapped northward by higher beds in the area between Tulsa County and the Kansas-Oklahoma line. The upper 20 feet or so of the Seminole extends into southern Kansas and is there mapped as the Hepler sandstone and overlying shale.[77]

Detailed sections. For measured outcrop sections showing the Seminole formation see sections numbered 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 25, 30, 31, 33, 34, 35, 36, 37, 39, 40, 41, 42, 43, 44, 72, 76, 77, 110, 111, 112, 113, 114, 142, 143, 144, 145, 146, 147, 148, 160, 161, 164, 165, 166, 167, Appendix A.

77. Oakes, Malcolm C., and Jewett, John M., "Upper Desmoinesian and Lower Missourian Rocks in Northeastern Oklahoma and Southeastern Kansas": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27, pp. 632-640, 1943.

Checkerboard Limestone

The Checkerboard limestone lies immediately above the Seminole formation, and is overlain by the Coffeyville formation. In this area it consists of a single bed of fossiliferous limestone about 2.5 feet thick. On fresh surfaces it is dark blue but weathers to various shades of yellow and brown.

First Reference, Nomenclator, Type locality, Original description and History of usage are discussed in Oklahoma Geological Survey Bulletin 62, pp. 26-27.

Distribution. The Checkerboard limestone is shown on the Geologic Map of Oklahoma[78] extending from the latitude of Okmulgee to a point west of Nowata, and has since been mapped northward to the Kansas-Oklahoma line.[79] It extends many miles into Kansas.[80]

Thickness and character. The Checkerboard limestone, in this area, is composed of a single bed of limestone about 2.5 feet thick. It is massive, dark blue, fossiliferous, and breaks into blocky to splintery fragments in weathering.

The Checkerboard does not crop out conspicuously. It is commonly found in escarpments that owe their being to other strata, in stream beds, on prairie slopes, or at the tops of low, inconspicuous escarpments formed by the limestone itself. Criteria useful in finding exposures are as follows: (1) In this area it lies some 30 feet above the uppermost sandstone or silty shale beds of the Seminole formation. (2) It is overlain by the lowermost part of the Coffeyville formation, consisting of three or more feet of black, fissile shale, containing in its lower part a persistent zone of small, black, rounded phosphatic nodules. This black shale and the overlying clay shale of the Coffeyville formation yield a dark, sticky, clay soil, in sharp contrast to the more sandy and lighter colored soils derived from the underlying silty to sandy shale

78. Miser, Hugh D., "Geologic Map of Oklahoma": *U. S. Geol. Survey,* 1926.
79. Oakes, Malcolm C., "Geology and Mineral Resources of Washington County, Oklahoma": *Okla. Geol. Survey Bull.* 62, pp. 26-33, 1940.
80. Oakes, Malcolm C., and Jewett, John M., "Upper Desmoinesian and Lower Missourian Rocks in Northeastern Oklahoma and Southeastern Kansas": *Bull. Amer. Assoc. Petrol. Geol.,* Vol. 27, No. 5, pp. 632-640, 1943.

in the upper part of the Seminole formation. (3) The phosphatic concretions immediately above the Checkerboard in the lowermost part of the Coffeyville formation are much more resistant to weathering than the materials enclosing them, and in consequence, remain on the surface as a more or less continuous band of phosphatic nodules which affords a good basis for mapping the position of the Checkerboard between good exposures.

In T. 20 N., R. 12 E.: A few fragments of the Checkerboard were found in the railroad cut a short distance south of the north line of sec. 12 and a good exposure occurs in the stream bed a short distance southeast of the center of the same section. An excellent exposure occurs in the bed of Flat Rock Creek south of the NW cor. sec. 13 where the limestone is dark-blue and weathers gray, the top is pitted by erosion, and conspicuous joint cracks, 3 to 5 feet apart and nearly at right angles, break the rock into rectangular, nearly square blocks. This exposure is sometimes mistaken for Gould's type locality of the Checkerboard limestone, but is many miles removed from the true type locality which is on another Flat Rock Creek (renamed Checkerboard Creek) in sec. 22, T. 15 N., R. 11 E., Okmulgee County.

Stratigraphic relations. The Checkerboard limestone is underlain conformably by the Seminole formation, and overlain conformably by the Coffeyville formation. Only the lower member of the Checkerboard formation of Washington and Nowata Counties is present in this area and no evidence was observed of an unconformity at the base of the Coffeyville formation.

Correlation. As a result of field work[81] by Jewett in southeastern Kansas and by Oakes in northeastern Oklahoma, the Kansas equivalent of the Checkerboard limestone is now known to be a hitherto unnamed limestone above the Hepler sandstone of the Kansas section.

Heretofore we have hoped that the Checkerboard limestone would prove to be identical or at least stratigraphically equivalent to the DeNay limestone of Pontotoc and Seminole Counties. Now, the work of Ries in Okfuskee County, Weaver in Hughes County,

81. Oakes, Malcolm C. and Jewett, John M., *op. cit.*

and Tanner in Seminole County,* has shown that the Checkerboard and DeNay limestones are not continuous in outcrop but that they lie between the same conspicuous sandstone units and are stratigraphically equivalent within a few feet.

Detailed sections. For measured outcrop sections of the Checkerboard limestone see sections numbered 9, 13, 15, 30, 32, 35, 36, 68, 69, 70, 108, 110, 142, 159, 161, 162, 163, Appendix A.

Coffeyville Formation

As used here the name Coffeyville formation applies to strata between the Checkerboard limestone, below, and the Hogshooter (Dennis) formation, above. In Washington and Nowata Counties,[82] to the north, it consists of seven zones, four of shale and three of sandstone, but in this area the middle sandstone zone is lacking and, in consequence, the formation consists of five zones, two of sandstone and three of shale or sandy shale as shown in Fig. 6. Owing to the gradational nature of the sandstones and shales in many parts of the area, they are here called zones rather than members.

First Reference, Nomenclator, Type locality, Original description, and History of usage are discussed in Oklahoma Geological Survey Bulletin 62, pp. 33-34.

Distribution. The Coffeyville formation enters Oklahoma from Kansas in the vicinity of South Coffeyville, Nowata County, and extends southwestward across northwestern Nowata and southeastern Washington Counties. It enters Tulsa County across the north line of T. 22 N., R. 13 E., and continuing its southwestward trend, passes out of the county across the south line of T. 19 N., Rs. 11 and 12 E. The business section and large parts of the residential districts of Tulsa are on the outcrop of the Coffeyville formation. The Coffeyville formation has been mapped, as such, southward to the south limit of Okfuskee County.

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* Edward R. Ries, Oscar D. Weaver, and William F. Tanner each mapped the County indicated above under the supervision of the author (1947-1950) in partial fulfillment of the requirements for the Doctorate at the University of Oklahoma. Copies of their dissertations, including maps, are to be deposited in the University Library.

82. Oakes, Malcolm C., "Geology and Mineral Resources of Washington County, Oklahoma": *Okla. Geol. Survey Bull.* 62, pp. 33-39, 1940.

Thickness. The Coffeyville formation is about 240 feet thick at the north line of T. 22 N., and maintains that thickness southward to the middle of T. 21 N. It is 310 feet thick at the middle of T. 20 N., 390 feet thick at the middle of T. 19 N., and 440 feet thick where the formation leaves Tulsa County over the south line of T. 19 N. Individual zones are greatly different in thickness from place to place owing to lateral and vertical gradation.

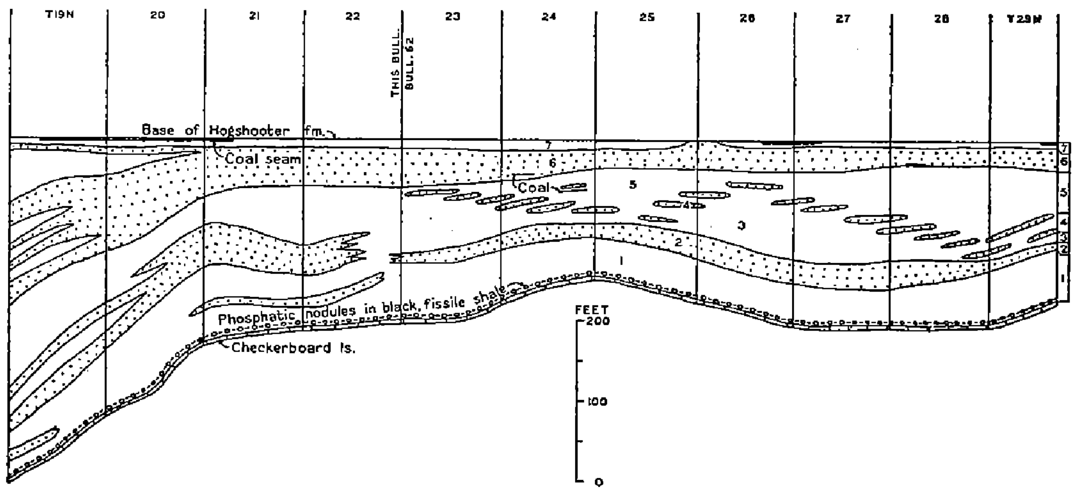

Fig. 6. Generalized outcrop section, from southern Tulsa County to the Kansas-Oklahoma line, showing the character and thickness of the Coffeyville formation and its conformable relations to the Checkerboard limestone, below, and to the Hogshooter formation, above.

Character. Zone No. 1 is predominantly shale. At the base is a black, fissile shale, generally less than 10 feet thick, which contains black phosphatic nodules in the lower part. The upper part of the zone contains sandy streaks and, locally, some sandstones.

Zone No. 2 is sandstone and sandy to silty shale.

Zone No. 3 is predominantly shale but contains some conspicuous sandstone lenses in the south part of T. 19 N.

Zone No. 4 is sandstone. It has been correlated with the Dodd's Creek sandstone of the Kansas section and with the Layton oil sand of the subsurface in Creek County, Oklahoma.

Zone No. 5 is shale, at many places calcareous in its upper part. One or more thin coal seams about 0.1 foot thick are generally present in the upper 1 to 3 feet. One of these coal seams, particularly persistent, lies a few inches below the Hogshooter limestone, at the top of the formation.

Stratigraphic relations. The Coffeyville formation is underlain conformably by the Checkerboard limestone, and is overlain conformably by the Hogshooter (Dennis) formation. North of sec. 20, T. 20 N., R. 12 E., the Winterset member of the Hogshooter formation is the overlying bed but south of that point the Lost City member of the Hogshooter formation overlies the Coffeyville formation.

Correlations. The Checkerboard limestone has now been mapped into Kansas and found to be equivalent to a hitherto unnamed limestone above the Hepler sandstone[83] and as the Hogshooter formation of Oklahoma is equivalent to the Dennis[84] formation of Kansas, the Coffeyville formation is equivalent to Kansas strata between the Checkerboard limestone below and the Dennis formation above. The Coffeyville formation is equivalent to the lower part of the Francis formation of south-central Oklahoma.

Detailed sections. For measured outcrop sections of the Coffeyville formation see sections numbered 30, 32, 35, 67, 69, 70, 108, 109, 140, 141, 158, 159, 162, 163, Appendix A.

Hogshooter Formation

The name Hogshooter formation is applied to a limestone unit overlying the Coffeyville formation and underlying the Nellie Bly formation. It generally consists of a single bed of limestone, called the Winterset limestone member, but at a few places in Washington and Nowata Counties[85] it consists of three members: a thin, siliceous, lower limestone, called the Canville limestone member; a middle, black shale, called the Stark shale member; and the main, massive, upper limestone, called the Winterset limestone member. In the vicinity of Sand Springs, Tulsa County, the

83. Oakes, Malcolm C., and Jewett, John M., "Upper Desmoinesian and Lower Missourian Rocks in Northeastern Oklahoma and Southeastern Kansas": *Bull. Amer. Assoc. Petrol. Geol.,* Vol. 27, pp. 632-640, 1943.

84. Oakes, Malcolm C., "Geology and Mineral Resources of Washington County, Oklahoma": *Okla. Geol. Survey Bull.* 62, pp. 40-41, 1940.

Oakes, Malcolm C., "Results of Recent Field Studies in Osage, Washington, and Nowata Counties, Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.,* Vol. 24, pp. 716-730, 1940.

85. Oakes, Malcolm C., "Geology and Mineral Resources of Washington County": *Okla. Geol. Survey Bull.* 62, pp. 39-47, 1940.

Winterset is underlain by the Lost City limestone member. The Lost City is probably a local depositional varient of the combined Canville and Stark members. The Hogshooter formation ranges from 1 to 50 feet thick across Tulsa County, the maximum being found in the exposures on the south side of Arkansas River.

First Reference, Nomenclator, Type locality, Original description, and *History of usage* are discussed in Oklahoma Geological Survey Bulletin 62, pp. 39-41.

Distribution. The Hogshooter limestone is shown on the Geologic Map of Oklahoma,[86] extending from the Kansas-Oklahoma line, a short distance west of South Coffeyville, Nowata County, to a point west of Okemah, Okfuskee County. The outcrop crosses the northwestern part of Tulsa County and disappears beneath the alluvium of Bird Creek in sec. 12, T. 22 N., R. 12 E. It emerges from beneath the alluvium of Hominy Creek, in sec. 2, T. 21 N., R. 12 E., Osage County, and reenters Tulsa County over the north line of sec. 6, T. 19 N., R. 12 E. It passes beneath the wind-blown sand and silt north of Arkansas River in sec. 1, T. 19 N., R. 11 E., and emerges near the SE cor. sec. 16, T. 19 N., R. 11 E. The outcrop covers a wide area from this point southward and eastward to the south line of sec. 35, T. 19 N., R. 11 E., where it passes into Creek County.

Thickness. The Winterset member, the only member present north of sec. 20, T. 20 N., R. 12 E., is generally less than 5 feet thick and at many places is only 1 foot thick. The Lost City member is about 3 feet thick in the north part of sec. 20, T. 20 N., R. 12 E., and is progressively thicker southward to the south side of Arkansas River, south of Sand Springs, where it is 40 to 50 feet thick. Thence it is progressively thinner southward, and is only a few feet thick at the south side of Tulsa County.

Character. The character of the Hogshooter formation can be most readily comprehended in the light of its probable depositional environment. It appears that at the close of Coffeyville time there was a slight warping of the depositional surface in northeastern Oklahoma, accompanied by a greatly reduced supply of clastic sediments. This warping resulted in several local, shallow troughs

86. Miser, Hugh D., "Geologic Map of Oklahoma": *U. S. Geol. Survey*, 1926.

which retained arms of the sea, and broad uplifts which raised parts of the surface slightly above sea-level. However, there is little evidence to indicate important sub-aerial erosion on this surface. It appears that the downwarped areas were further submerged in lower Hogshooter time and that in one of these areas, deeper and more open to the sea than others, the Lost City limestone member of the Sand Springs area accumulated. Other downwarps, more

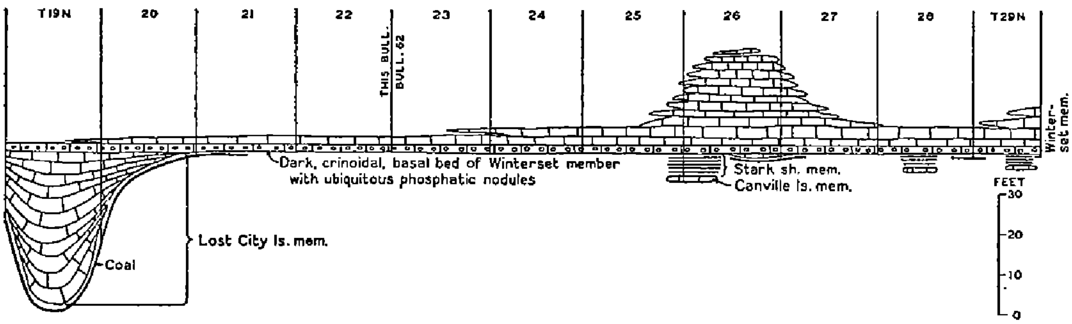

FIG. 7. Generalized outcrop section, from western Tulsa County to the Kansas-Oklahoma line, showing the character and thickness of the Hogshooter formation.

shallow and restricted, were filled by the Canville limestone and Stark Shale members of Washington and Nowata Counties. That these lagoonal areas were structural depressions and not erosion channels is evidenced by the fact that the upper shale zone of the Coffeyville formation, with the coal seams in its upper part, is not cut out but passes downward beneath the lagoonal deposits of the lower Hogshooter. Following the filling of the lagoons the Hogshooter seas spread rather uniformly over the entire area, and the wide-spread Winterset member was deposited.

The Lost City limestone member extends from the north side of sec. 20, T. 20 N., R. 12 E., southward to the south side of Tulsa County, T. 20 N., R. 11 E. In its northernmost exposure it is 3 feet or less thick, gray on fresh exposure but weathers red or reddish-brown. In sec. 6, T. 19 N., R. 12 E., it is gray, massive, fossiliferous, and about 18 feet thick. South of Arkansas River, in T. 19 N., R. 11 E., it reaches a maximum thickness of 50 feet, is commonly 40 feet thick, and is gray and massive. It contains some well-preserved fossils together with a great amount of fossil debris as well as structures thought to be of algal origin. It is above 90 percent calcium carbonate, is excellent for crushed stone and agricultural limestone, and is suitable for some chemical uses. It is an important asset of Tulsa County and adjacent territory. Along the south side of T. 19 N., R. 11 E., the Lost City limestone member is only a few feet thick and is less pure. The Lost City limestone is quarried for crushed stone.

The Winterset limestone is the upper and most wide-spread member of the Hogshooter formation. It is the original Hogshooter limestone of Ohern, and is directly continuous with the Winterset limestone member of the Dennis formation of Kansas, and with the Winterset limestone of Missouri and Iowa.

The Winterset consists wholly of limestone, locally sandy, with a basal bed which is a distinctive marker across Tulsa County. This basal bed is less than 1 foot thick, dark in color, packed with crinoidal debris, and contains sperical phosphatic nodules up to 1 inch in diameter, nearly everywhere arranged in one regular layer. The almost universal occurrence of this distinctive basal bed permits mapping the lower limit of the Winterset with assurance and differentiation of the Winterset from the underlying Lost City member, where the latter is present. Above the basal bed of the Winterset in most places is a lighter colored, fossiliferous limestone of irregular thickness which is sandy at some places in this area. The entire thickness of the Winterset member is generally less than 5 feet in Tulsa County, and locally only the basal bed is present.

The Hogshooter formation may be studied conveniently at the following places:

T. 22 N., R. 13 E. At the N¼ cor. sec. 5, top of the Winterset member in north road ditch. At the W¼ cor. sec. 5, Winterset member.

T. 21 N., R. 12 E. On north side of road a short distance east of the center of sec. 20, a small inlier of the Winterset member. In road immediately below the top of the hill and east of the W¼ cor. sec. 21, Winterset member, sandy and associated with sandstone beds. On the west side of the road leading up the north side of Turley Mountain and about 1/8 mile east of the W¼ cor. sec. 36, the Winterset member lies about 17 feet above the upper sandstone zone of the Coffeyville formation and about 23 feet below a local limestone of the Nellie Bly formation. In the road up the south side of Turley Mountain and in the SW part of sec. 35, the Winterset member.

T. 20 N., R. 12 E. Two exposures of the Winterset member, east and west sides of a hill, near the N¼ cor. sec. 3. In the road up the hill to the pumping power in the NE¼ sec. 8, the Winterset member. At the turn of the road one-fourth mile west of the center of sec. 20, the Winterset member, platy and containing many small crinoid stems, is underlain by the Lost City member which is fossiliferous, gray when fresh, weathers red, and is 2.5 to 3 feet thick. Southward from this point the Lost City member is more and more conspicuous. In the road up the hill along the west side of the NW¼ sec. 31, probably both Winterset and Lost City members are present. This exposure is above the lowest sandstone bench.

T. 19 N., R. 12 E. At the sharp turn in the road along the north side of sec. 6, a good exposure of the Lost City member, about 17 feet thick, is overlain by the Winterset member which is about 2 feet thick. At the old quarry in the SW¼ sec. 6 the lower bed of the Winterset member with phosphatic nodules is well exposed above the Lost City member which constitutes the greater part of the quarry face.

T. 19 N., R. 11 E. Along State Highway 51 and U. S. Highway 64, in the vicinity of the south end of the bridge over Arkansas River, near the NE cor. sec. 22, the Hogshooter is exposed in nearly its maximum thickness. The coal in the upper part of the underlying Coffeyville formation is also exposed. In this locality the Winterset is the upper, thin bed, separated from the underlying Lost City member by a thin, marly parting. The phosphatic nodules so generally found in the basal bed of the Winterset member, are present here also. There is an excellent exposure of the Winterset at the top of the face of the quarry a short distance west of the south end of the bridge. Near the N¼ cor. sec. 28, the road cut exposes the Lost City member, 22 feet thick and overlain by the Winterset member which consists of the basal bed only, 1 foot thick, dark, crinoidal, and containing small phosphatic nodules. Northward from this place the Hogshooter is overlain by gray to dark shale. Southward this overlying shale is progressively more sandy and maroon to red in color. In the vicinity of the SE cor. sec. 34 the Hogshooter is only a few feet thick, is sandy, and is overlain by reddish brown sandstone.

Stratigraphic relations. The Hogshooter formation is underlain conformably by the Coffeyville formation and overlain conformably by the Nellie Bly formation.

Correlation. The Hogshooter is equivalent to the Dennis formation of Kansas and the Winterset limestone member, at least, is continuous across the Kansas-Oklahoma line. The Hogshooter has been traced southward to sec. 35, T. 12 N., R. 9 E., north of Okemah, Okfuskee County. Farther south, shale, stratigraphically equivalent to the Hogshooter formation, lies at about the middle of the Francis formation.

Detailed sections. For measured outcrop sections of the Hogshooter formation, see sections numbered 64, 66, 107, 137, 138, 139, 140, 141, Appendix A.

Nellie Bly Formation

The name Nellie Bly formation is applied to the shale and sandstone above the Hogshooter formation and below the Dewey limestone.

First Reference, Nomenclator, Type locality, Original description, and *History of usage,* are discussed in Oklahoma Geological Survey Bulletin 62, pp. 47-48, 1940.

Distribution. The Nellie Bly formation crops out in a band of irregular width from the Kansas-Oklahoma line southwestward across northwestern Nowata County and across Washington County, Oklahoma. The outcrop touches the northwestern part of Tulsa County, crosses southeastern Osage County, covers a large area in T. 19 N., R. 11 E., southwest of Sand Springs, Tulsa County, and extends southward across Creek and Okfuskee Counties, to the North Canadian River, southwest of Okemah.

Thickness. The outcrop of the Nellie Bly formation is so wide that it is not practical to measure the total thickness in any one section. Figure 8 represents a continuous outcrop section from

T. 19 N. to the Kansas-Oklahoma line, and indicates that the Nellie Bly is about 165 feet thick along the north side of T. 22 N.; 280 feet in T. 21 N.; and 250 feet along the south line of T. 19 N. where the formation leaves Tulsa County.

Character. Northward in Nowata and Washington Counties the Nellie Bly consists generally of clay shale in the lower part, silty shale and siltstone in the middle, and a persistent zone of sandy shale and sandstone at the top. This character persists in a general way to the south side of T. 19 N., R. 11 E., where the outcrop passes out of Tulsa County. In the south part of the area, lying 10 to 50 feet below the upper persistent sandstone, is a massive sandstone that attains its maximum thickness of 40 feet in sec. 20, T. 20 N., R. 11 E. Northward from this locality this sandstone seems to split into several beds which thin rapidly northward and at the same time descend rapidly with reference to both top and base of the formation. Other, less conspicuous, sandstone beds below these show similar deltaic characteristics. This was first noticed by geologists[87] of the United States Geological Survey, working in Osage County, who considered the Nellie Bly in this area to be deltaic in origin and such beds to be the foreset beds of a delta deposited by a northward flowing river. The writer agrees, in principle at least, with this interpretation. The area provides opportunity for much more detailed study than the author has been able to give it.

There is at least one limestone bed in the lower part of the Nellie Bly. It is known to the writer at a single exposure on the west side of the winding road up the north flank of Turley Mountain, about 1/8 mile east of the W¼ cor. sec. 36, T. 21 N., R. 12 E. At this place the limestone is about 23 feet above the Hogshooter limestone, is about 1 foot thick, weathers bright yellow, and is nodular, broken, and recemented by calcite.

Convenient localities for examining the Nellie Bly section are as follows:

T. 22 N. Alluvium of Bird and Hominy Creeks covers a part of the Nellie Bly in this township, but the greater part may

87. White, David, and others, "Structure and Oil and Gas Resources of the Osage Reservation, Oklahoma": *U. S. Geol. Survey Bull.* 686, pp. 172 and 183, 1922.

be seen on the east end of the outlying hill in the SE¼ sec. 31, T. 22 N., R. 12 E., and eastward along Hominy Creek.

T. 21 N., R. 11 E. Along the road across secs. 25, 26, and 27, the Hogshooter limestone is no doubt concealed under the debris at the base of the escarpment east of the E¼ cor. sec. 25. The road immediately west of that corner is on one of the deltaic sandstone beds of the Nellie Bly which is much higher above the base southward across Delaware Creek. The prominent hill, in the northwest corner of sec. 25 and visible from the road, is capped by the persistent upper sandstone beds which also form the northwest slope of the hill in the SE¼ of sec. 26 and the S½ of sec. 27. The Dewey limestone crops out immediately above these upper persistent sandstone beds, in the road a short distance south of the W¼ corner of sec. 27.

T. 20 N., R. 11 E. The thickest deltaic sandstones may be seen by following the trail northward along the east side of secs. 36 and 25. An intersecting trail one-fourth mile north of the SE cor. sec. 24 gives access to outcrops of these deltaic sandstones, eastward, and follows the top of the deltaic beds westward to a good road leading northward through sec. 23.

A section of the Nellie Bly may be seen along the road north from Sand Springs through secs. 35, 26, 23, 14, 10 and 3, T. 20 N., R. 11 E., and continuing northward to the outcrop of the Dewey limestone one-fourth mile south of the W¼ cor. sec. 27, T. 22 N., R. 11 E.

T. 19 N., R. 11 E. Interesting exposures of the Nellie Bly occur in the escarpment north of the road which leads west out of Sand Springs on the north side of the Arkansas River. A good section may be seen by following the road from the outcrop of the Hogshooter limestone on Anderson Creek, near the N¼ cor. sec. 28, westward to a point west of the NW cor. sec. 29, thence southward to the outcrop of the Dewey limestone at the SW cor. sec. 29.

Stratigraphic relations. The Nellie Bly formation is conformably underlain by the Winterset member of the Hogshooter formation and overlain conformably by the Dewey formation entirely across the area covered by this report.

Correlations. In general the Nellie Bly formation is correlated with the lower part of the Kansas City group in Kansas, between the top of the Winterset limestone member of the Dennis formation and the base of the Drum limestone. Thus it is apparently equivalent to the Cherryvale shale of Kansas usage. It is represented by approximately the upper half of the Francis formation in the area north of the Arbuckle Mountains.

Detailed sections. For detailed outcrop sections of the Nellie Bly formation see sections numbered 56, 57, 63, 64, 100, 101, 106, 107, 125, 130, 134, 135, 136, 137, 138, 139, 141, 157, Appendix A.

Dewey Formation

The name Dewey formation is applied to a unit lying between the Nellie Bly formation, below, and the Chanute formation, above. In its type locality, near Dewey, Washington County, Oklahoma, it consists of limestone and calcareous shale, is sandy in the lower few feet, and rests upon and locally grades into the persistent upper sandstone and sandy shale zone of the underlying Nellie Bly formation. Across southeastern Osage County and western Tulsa County, the Dewey consists, in general, of three members: a lower limestone member, only a few feet thick and at some places sandy; a middle shale member up to 50 feet thick, generally dark, locally either clay shale, calcareous shale, or sandy shale and sandstone; and an upper limestone member which is generally only a few feet thick and is at many places only a limy sandstone. The base of the limestone next above the upper sandy zone of the Nellie Bly formation is taken as the base of the Dewey formation. The upper member of the formation can be established fairly surely by tracing and correlation.

First Reference, Nomenclator, Type locality, Original description, and *History of usage* are discussed in Oklahoma Geological Survey Bulletin 62, pp. 51-52, 1940.

Distribution. The outcrop of the Dewey limestone extends from the center of sec. 13, T. 28 N., R. 14 E., Nowata County, southwestward across Washington County and enters the area covered by this report over the north line of sec. 4, T. 22 N., R. 12 E. Thence it continues southwestward across southeastern Osage County and disappears beneath wind-blown material north of Arkansas River in sec. 36, T. 20. N., R. 10 E., west of Sand Springs, Tulsa County. It reappears south of Arkansas River, in the SE¼ sec. 11, T. 19 N., R. 10 E., extends southward, and passes out of Tulsa County a short distance west of the S¼ corner of sec. 35, T. 19 N., R. 10 E. The Dewey has been mapped southward to the North Canadian River and a representative, the Belle City limestone, extends to sec. 17, T. 4 N., R. 6 E., Pontotoc County.

Thickness. The maximum measured thickness of the Dewey limestone in Washington and Nowata Counties is 32 feet, but it is generally about 10 feet thick. In this area, in the north part of T. 22 N., R. 12 E., northwest of Skiatook, Osage County, the Dewey formation is 15 to 17 feet thick and as much as 60 feet thick in sec. 36, T. 22 N., R. 11 E., where it includes about 50 feet of shale. It is about 35 feet thick in sec. 14, T. 21 N., R. 11 E.; about 35 feet thick in sec. 33, T. 21 N., R. 11 E.; about 30 feet thick in sec. 4, T. 20 N., R. 11 E.; about 35 feet in sec. 16, T. 20 N., R. 11 E.; about 40 feet in sec. 19, T. 20 N., R. 11 E.; about 40 feet in sec. 36. T. 20 N., R. 10 E.; about 45 feet in sec. 11, T. 19 N., R. 10 E.; about 55 feet in sec. 14, T. 19 N., R. 10 E.; about 50 feet in sec. 31, T. 19 N., R. 11 E.; and about 60 feet in sec. 36, T. 19 N., R. 10 E.

Character. The Dewey limestone, in the vicinity of its type locality, near Dewey, Washington County, generally consists of alternating limestone beds and calcareous shale, the latter ranging

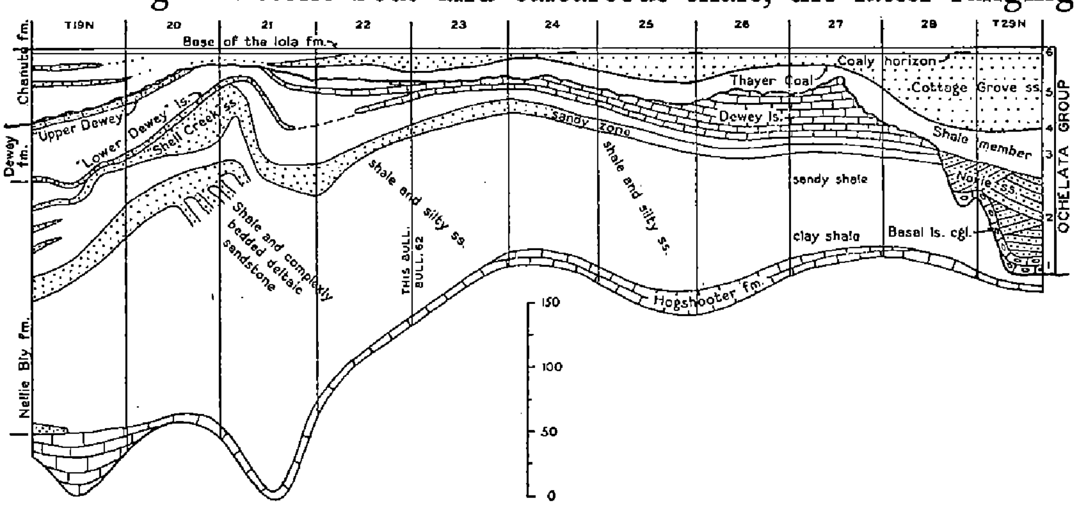

FIG. 8. Generalized outcrop section, from western Tulsa County to the Kansas-Oklahoma line, showing the thickness and character of the Nellie Bly formation, the Dewey formation, and the Chanute formation and the unconformable relation of the Chanute to older rocks.

from mere partings to beds a foot or more thick. Southward from its type locality the calcareous shale beds are more noticeable at some places and northwest of Skiatook, Osage County, they are conspicuous. Southward from the vicinity of Skiatook the Dewey formation consists of two distinct limestone members, one at the base and one at the top, and a much thicker shale member between.

The lower limestone member, south of Skiatook, consists of one or more limestone beds, locally sandy, and intervening shale beds, the whole commonly less than 10 feet thick. The base of this member rests upon the upper persistent sandy shale and sandstone of the Nellie Bly formation, as does the base of the Dewey throughout its occurrence in Washington and Nowata Counties.

The middle shale member, present south of Skiatook, consists of clay shale, locally calcareous, which grades southward into sandy shale and contains some sandstone beds in Tulsa County. It ranges in thickness as indicated in the following table:

TABLE VII

THICKNESS AND CHARACTER OF THE MIDDLE SHALE MEMBER OF THE DEWEY FORMATION

Sec.	T. N.	R. E.	Thickness	Character
31	22	12	57	Shale
4	21	11	30	Shale
33	21	11	28	Shale
4	20	11	20	Shale
16	20	11	30	Shale
19	20	11	36	Shale
36	20	10	35	Shale
31	19	11	27	Shale and ss.
11 & 12	19	10	40	Shale and ss.
14	19	10	50	Shale and ss.
36	19	10	60	Shale and ss.

The upper limestone member, south of Skiatook, generally consists of a single limestone bed only a few feet thick which is, at many places, very sandy. Locally, in sec. 36, T. 20 N., R. 10 E., it is marly, and resembles the upper part of the Dewey of Washington and Nowata Counties.

Outcrops of the Dewey formation at the following places are deemed worthy of mention or of more detailed discussion:

T. 22 N., R. 12 E. Along the winding road through the NW¼ sec. 10 the Dewey consists of a single limestone, as in Washington and Osage Counties to the north. It is the lowest limestone in the escarpment and the road crosses it twice.

In the road one-fourth mile north of Javine School, and one-fourth mile south of the NW cor. sec. 20, T. 22 N., R. 12 E., about 17 feet of the upper part of the Dewey is exposed and consists of wavy beds of limestone about 0.2 feet thick separated by thicker beds of fossiliferous marl. *Caninia torquium* (?), so common in the Dewey north of this place, is abundant here, but is not known from the Dewey farther south. The middle part of the Dewey is covered at this place, and is presumed to be marl or calcareous shale. Heavy limestone rubble in the draw east of the road indicates that there are thicker limestone beds at the base of the Dewey, immediately above the upper sandy zone of the Nellie Bly formation. From this locality southward a middle shale member constitutes the greater part of the Dewey formation.

On the west end of the outlying hill in SW¼ sec. 31, a conspicuous sandstone, well up the side of the hill, probably marks the top of the Nellie Bly formation and a thin limestone, indicated by fragments not in place, immediately above this sandstone is taken to be the basal part of the Dewey limestone. The shale member, 57 feet thick, is covered. The upper limestone member is fossiliferous, weathers yellow, and the exposed part is 2 feet thick.

T. 21 N., R. 11 E. On the spur of the hill one-fourth mile south of the N¼ cor. sec. 12 a limestone bed which is believed to be the upper limestone member of the Dewey formation is exposed in the ravines. It is 1 foot thick, weathers reddish yellow, and is fossiliferous. It is overlain by sandstone and shale containing coal. Such occurrences of coal are common in the Chanute formation immediately above the Dewey limestone.

Immediately north of the SW cor. sec. 12 the lower member of the Dewey is exposed across the road and the middle shale member forms the lower slope of the hill. The upper limestone member is represented by a distinct bench covered by persimmon trees.

In the roads a short distance east and a short distance south of the NW cor. sec. 24 limestone is exposed which weathers white to yellow and is about 3 feet thick. Joseph L. Borden named this bed, colloquially, the "Cowbarn" limestone, from a dairy barn which stands on the outcrop. Thirty feet higher topographically above this limestone and 300 feet north of this corner is an outcrop of light colored fossiliferous limestone about 1.5 feet thick; and a few feet above the limestone are sandstone beds. Coal found in the stream channel, not in place, about half a mile west of the E¼ corner of sec. 14 probably came from above this limestone, and is probably associated with the sandstones, a common occurrence in the Chanute formation above the Dewey limestone in Washington and Nowata Counties. Because of the associated sandstone and coal the upper limestone has long been considered Dewey limestone but the lower bed was considered some part of the Dewey or a limestone bed in the Nellie Bly. This lower bed is assigned to the lower limestone member of the Dewey because of its position above the upper sandy zone of the Nellie Bly.

The lower member of the Dewey crops out from place to place across the north part of sec. 23 and the upper member forms a persimmon covered bench in the escarpment.

About one-fourth mile south of the rock school house which stands at the E¼ cor. sec. 28 the lower member of the Dewey crops out as a gray, to pink, massive limestone which contains fusulinids and other fossils and rests on the upper sandy zone of the Nellie Bly formation. The upper limestone member of the Dewey formation does not crop out in this vicinity and was probably removed by pre-Chanute erosion.

The lower member is exposed in the road in the SE¼ SW¼ sec. 28, but higher members are covered.

The lower limestone member of the Dewey crops out over a considerable area in the vicinity of the outlying hill in sec. 33 where the shale member forms the lower slopes of the hill and the upper limestone member may be represented by the limy sandstone which forms the lowest bench around the hill.

T. 20 N., R. 11 E. The lower limestone member of the Dewey is exposed in a band of considerable width in the NE¼ sec. 4, along the west side of the SW¼ sec. 3, and in the NW¼ of sec. 10. The lower member in this vicinity is 9 feet thick and comprises three beds: a lower limestone bed about 2 feet thick, white and fossiliferous, which rests on the upper sandy zone of the Nellie Bly formation; a middle shale bed about 5 feet thick; and an upper limestone bed about 2 feet thick which is gray, fossiliferous, and weathers red. The middle shale member of the Dewey forms the lower slopes of the escarpment to the west and the upper limestone member is probably represented by the limy sandstone which forms the low bench in the escarpment, marked locally by a line of persimmon trees.

Across secs. 16, 17, and 20, the lower member of the Dewey crops out from place to place immediately above the upper sandy zone of the Nellie Bly formation. Generally it consists of a lower limestone bed, a middle shale bed, and an upper limestone bed. The middle shale member of the Dewey forms the lower slope of the escarpment to the northwest and the upper limestone member probably forms the lowest bench in the escarpment which is marked at many places by persimmon trees.

The lower member of the Dewey is exposed in a small stream a short distance north of the south line of the NE¼ sec. 19, where it is gray, fossiliferous and about 2 feet thick. Northeastward, up the hill, the middle shale member is covered but about 40 feet thick and the upper member is probably represented by a bench covered by persimmon trees.

T. 20 N., R. 10 E. At times of low water in Shell Lake the lower member of the Dewey limestone is exposed on the north side of the promontory on the west side of the lake in sec. 24. It is light colored to red and contains black phosphatic inclusions, many of which are angular.

Sandy limestone resting on the upper sandy zone of the Nellie Bly formation near the center of the E½ of sec. 36 is probably the lower limestone member of the Dewey. The middle shale member in this vicinity is about 35 feet thick and the entire formation is about 40 feet thick.

The Dewey formation is exposed in the hill south of State Highway 51 and U. S. Highway 64, in the SE¼ sec. 11 and the

SW$\frac{1}{4}$ sec. 12, south of Arkansas River. The lower limestone member, about 5 feet thick, rests on the uppermost sandstone of the Nellie Bly and is well exposed in the road cut a short distance west of the east line of sec. 11. At this place there are phosphatic nodules in the shale immediately above the limestone. The middle shale member is not well exposed but seems to contain some sandstone beds. It is about 40 feet thick. The upper limestone member, 5 feet thick, is exposed near the top of the hill in the NE SE sec. 12.

The lower limestone member of the Dewey is exposed in the north bank of the stream near the center of sec. 14 where it is a sandy, fossiliferous limestone about 3 feet thick. The middle shale member, about 50 feet thick, is covered in the hillside south of the stream. The upper limestone member, 4 feet thick, is well exposed: the lower 3 feet is gray, sandy, and weathers brownish red, and the upper 1 foot is gray, fossiliferous, and weathers white.

T. 19 N., R. 11 E. The Dewey formation is exposed along the north line of the NE$\frac{1}{4}$ sec. 31. The lower limestone member is well exposed near the NE corner of the section and westward across the small draw. It consists of three limestone beds separated by sandy to calcareous shale. The entire member is about 14 feet thick. The middle shale member is about 27 feet thick and sandy in the upper part. The upper limestone member, about 10 feet thick, is exposed near the N$\frac{1}{4}$ corner of the section and consists of limy sandstone, sandy limestone, and limy nodules in shale.

Stratigraphic relations. The Dewey formation is underlain conformably by the Nellie Bly formation. Across Nowata County and probably a large part of Washington County it is overlain unconformably by the Chanute formation. At most places in Osage and Tulsa Counties there is no indubitable evidence of unconformity at the contact of the Dewey with the overlying Chanute formation, but the absence of the upper limestone member and part of the middle shale member of the Dewey in the vicinity of the rock school house, E$\frac{1}{4}$ cor. sec. 28, T. 21 N., R. 11 E., indicates that the unconformity is present, at least locally, that far south.

Correlations. The Dewey formation is probably equivalent to the Cement City member of the Drum limestone of Kansas,[88] but the outcrop of the Dewey is not continuous with that of the Drum, owing to pre-Chanute erosion in southern Kansas and northern Oklahoma. The author thinks that there is now field evidence that the Belle City limestone, in the area north of the Arbuckle mountains, is equivalent to the lower part of the Dewey formation.

Detailed sections. For measured outcrop sections of the Dewey formation, see sections numbered 56, 57, 58, 63, 65, 96, 97, 99, 102, 103, 104, 105, 124, 126, 127, 128, 129, 130, 133, 153, 154, 157, Appendix A.

OCHELATA GROUP

In setting up the Ochelata as a group Moore, and others said:

> The name Ochelata was introduced as a stratigraphic term by Ohern for beds between the Dewey and Avant limestones, but subsequent usage has extended its application to include all the strata above the Dewey and beneath the Nelagoney formation. Since the base of the Nelagoney happens to coincide with the Missouri-Virgil boundary, the Ochelata beds comprise the upper Missouri deposits of northern Oklahoma. It is proper to consider them as a group, and also to extend application of the term slightly into Kansas on the north and to the northeastern flank of the Arbuckle Mountains on the south. The lower boundary of the group is defined at the base of the Chanute shale (*Chanute formation*) which corresponds to the top of the Drum (*Dewey*) limestone, where this rock is present, but in places where the Drum is absent (because of *pre-Chanute erosion*) the basal Chanute sandstone may extend downward a varying distance below the Drum horizon. The upper boundary of the Ochelata group is defined to coincide with the Missouri-Virgil disconformity.[89]

It was clearly the intent of Moore and others that the Ochelata group extend up to the base of the Virgil series, wherever that might be. Specifically they extended it up only to the base of the

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88. Oakes, Malcolm C., "Geology and Mineral Resources of Washington County, Oklahoma": *Okla. Geol. Survey Bull.* 62, p. 56, 1940.

89. Moore, Raymond C., Newell, Norman D., Dott, Robert H., and Borden, Joseph L., "Definition and Classification of the Missouri Subseries of the Pennsylvanian Series in Northeastern Oklahoma": *Kansas Geol. Society, Guide Book, Eleventh Annual Field Conference*, pp. 39-43, 1937.

Nelagoney formation, whose basal member, according to Gould,[90] is the Bigheart sandstone, and the base of the Bigheart was then thought to be the base of the Virgil series in northern Oklahoma. However, in the course of field work done in 1947-48 for the new Geologic Map of Oklahoma, now in preparation, the author found that the base of the Virgil is higher in the section, as shown on Plate I, and therefore he includes the Bigheart sandstone in the Ochelata group.

The most conclusive evidence of the unconformity at the base of the Chanute in southeastern Osage County and in western Tulsa County is local absence of the upper part of the Dewey formation and overall thinning of the Dewey-Iola interval, notably in the vicinity of the rock school house in sec. 28, T. 21 N., R. 11 E., Osage County.

TABLE VIII

SUBDIVISIONS OF THE OCHELATA GROUP IN WESTERN TULSA AND ADJACENT COUNTIES

Virgil series.
- *Unconformity.*

Missouri series.
- Ochelata group
  - Tallant formation.
  - Barnsdall formation.
    - Unnamed shale member.
    - Okesa sandstone member.
  - *Unconformity.*
  - Wann formation.
  - Iola formation.
    - Avant limestone member.
    - Muncie Creek shale member.
    - Paola limestone member.
  - Chanute formation.
  - *Unconformity.*
- Skiatook group.

Chanute Formation

The name Chanute formation is applied in Kansas to beds lying between the Drum (Dewey) limestone, below, and the Iola formation, above. In southern Washington County[91] the

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90. Gould, Charles N., "Index to the Stratigraphy of Oklahoma": *Okla. Geol. Survey Bull.* 35, p. 75, 1925.

91. Oakes, Malcolm C., "Geology and Mineral Resources of Washington County, Oklahoma": *Okla. Geol. Survey Bull.* 62, pp. 57-65, 1940.

Oakes, Malcolm C., "Results of Recent Field Studies in Osage, Washington, and Nowata Counties, Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, pp. 716-730, 1940.

Chanute is composed of: a lower shale member, resting on the Dewey limestone; the Thayer coal member, generally only a few tenths of a foot thick; the Cottage Grove sandstone member; and a coaly shale member, generally less than 1 foot thick. The lower shale member and the Cottage Grove sandstone member can be recognized in this area, in the north part of T. 22 N., R. 12E., northwest of Skiatook, Osage County.

The Thayer coal has not been seen in place south of sec. 12, T. 21 N., R. 11 E. In sec. 28, T. 21 N., R. 11 E., the Chanute is generally thin, as are the underlying Dewey and overlying Iola formations, and, owing to poor outcrops, it is not certain that the Cottage Grove sandstone member is present. Farther south the formation is progressively thicker and sandstone beds occupy the position of the Cottage Grove sandstone member.

First Reference, Nomenclator, Type locality, Original description, and History of usage are discussed in Oklahoma Geological Survey Bulletin 62, pp. 57 and 58, 1940.

Distribution. The Chanute formation enters Oklahoma from Kansas in the northwestern part of Nowata County, crosses Washington County, and enters this area northwest of Skiatook, Osage County. It crosses this area in a direction somewhat west of south to the south side of T. 19 N., R. 10 E., the southern boundary of the western extension or "panhandle" of Tulsa County. It generally occupies a narrow band on steep hillsides and generally is poorly exposed. The Chanute has been mapped as far south as North Canadian River, the south boundary of Okfuskee County.

Thickness. The Chanute formation is about 35 feet thick from sec. 4, T. 22 N., R. 12 E., northwest of Skiatook, southward to sec. 14, T. 21 N., R. 11 E. It is thinner southward being only 13 feet thick in sec. 33, T. 21 N., R. 11 E. Farther south it is progressively thicker, and is 36 feet thick in sec. 19, T. 20 N., R. 11 E., and 60 feet thick along the south side of T. 19 N., R. 10 E., Tulsa County.

Character. In southern Washington County the Chanute consists of three members: a basal unnamed shale member; the Thayer coal member; a sandstone member, correlated with the Cottage Grove sandstone of Kansas; and an upper coaly shale member, generally only a few inches thick.

In this area the Chanute is composed of shale and nonresistant sandstone. It crops out in hillsides or steep escarpments where it in largely covered by debris so that it is not easy to distinguish the various members or, at some places, to find the limits of the formation. The lower shale member seems to be present across the entire area, immediately above the Dewey formation. The Thayer coal is identified as far south as sec. 14, T. 21 N., R. 11 E. The Cottage Grove sandstone member extends southward to the same locality but it may be absent, at least locally, from there southward to T. 19 N., R. 10 E., Tulsa County, where several sandstone beds with intervening sandy shale occupy the same stratigraphic position. Throughout its occurrence in Oklahoma, the Cottage Grove sandstone is very irregular in thickness and character, as if the materials were contributed by several streams draining diverse areas and emptying simultaneously but separately into the sea. The upper part of the Chanute formation in this area is shale, probably equivalent to the upper coaly shale member in Washington County, but it is known to contain a coaly streak in but one locality, one-fourth mile south of the N¼ cor. sec. 12, T. 21 N., R. 11 E. In that part of the area where the Cottage Grove sandstone member is not recognizable the entire formation may consist of shale. The following localities are worthy of special mention.

T. 22 N., R. 12 E. About one-eighth mile south of the E¼ cor. sec. 4, in the loading pit of a quarry, coal thought to be Thayer was found (1942) a few feet above the Dewey. This exposure is probably not open now.

On the east end of the outlying hill in sec. 31, all three members of the Chanute are represented. The lower shale member is about 23 feet thick, the Cottage Grove sandstone member about 3 feet thick, and the upper shale member about 4 feet thick.

T. 21 N., R. 11 E. On the spur of the hill about one-fourth mile south of the N¼ cor. sec. 12 (see No. 126, Appendix B), the lower shale member is about 3 feet thick, the Thayer coal is represented by two coal streaks and 1 foot of intervening shale, and the Cottage Grove sandstone member is about 7 feet thick. The upper shale member is about 27 feet thick, and has a coaly or smutty streak at the base, which seems to indicate that the southward increase in thickness of this member is above its coaly phase as exposed in Nowata and Washington Counties.

Coal was seen in the stream bed, but not in place, east of the center of sec. 14, at about the horizon of the Thayer coal and it is thought that the Thayer extends at least that far south.

Stratigraphic relations. In northwestern Nowata County the Dewey and part or all of the Nellie Bly formation were removed by pre-Chanute erosion and the Chanute rests unconformably upon the eroded surface. Across a large part of Washington County, the Chanute probably rests unconformably upon the Dewey formation. At most places in southeastern Osage and western Tulsa Counties there is no indubitable evidence of unconformity at the contact of the Dewey with the overlying shale, but the probable absence of the upper limestone member and part of the middle shale member of the Dewey formation in the vicinity of the rock school house, E¼ cor. sec. 28, T. 21 N., R. 11 E., indicates that the unconformity exists, at least locally, that far south.

In the course of field work for the new Geologic Map of Oklahoma, now in preparation, the author found evidence that the upper part of the Dewey equivalents in Tps. 14, 15, and 16 N., R. 9 E., Creek County, were removed by post-Dewey-pre-Chanute erosion. In the area covered by this report the Chanute is overlain conformably by the Iola formation but southward from T. 16 N., R. 9 E., Creek County, it is overlain unconformably by the Okesa sandstone member of the Barnsdall formation.

Correlation. The Chanute formation in Oklahoma is the direct continuation of the Chanute formation of Kansas but in this area it has heretofore been included in the Ochelata formation of former usage. The Ochelata is now considered a group of which the Chanute is the lowermost member.

Detailed sections. For measured outcrop sections of the Chanute formation see sections numbered 55, 56, 58, 63, 65, 96, 97, 99, 102, 103, 105, 124, 126, 127, 128, 129, 130, 133, 153, 154, 155, 157, Appendix A.

Iola Formation

In its type locality, near Iola, Kansas, the Iola formation consists of the lower Paola limestone member; the middle Muncie Creek shale member; and the upper Raytown limestone member. The Raytown is correlated with the Avant limestone member of the Iola formation in Oklahoma. Prior to the present investigation the writer had traced the formation from the Kansas-Oklahoma line southward across Washington County and into the area covered by this report. In northern Oklahoma the Iola formation is conformably underlain by the Chanute formation, and conformably overlain by the Wann formation. The three members extend across this area but they vary some in character and considerably in thickness from place to place and, in some localities, they cannot be differentiated with certainty.

First reference, Nomenclator, Type locality, Original description, and *History of usage* are discussed in Oklahoma Geological Survey Bulletin 62, p. 64, 1940.

Distribution. The Iola formation is known to extend northeastward from its type locality at Iola, Kansas, to south-central Iowa and is present in the Platte Valley in Nebraska.[92] It extends southward into northwestern Nowata County, Oklahoma, follows a southwesterly course across Washington County, and enters the area covered by this report over the north line of sec. 4, T. 22 N., R. 12 E., northwest of Skiatook, Osage County. In this area the formation crops out in steep escarpments so that it occupies a narrow band which follows a course west of south, enters Creek County over the south line of sec. 34, T. 19 N., R. 10 E., and extends southward across T. 16 N., R. 9 E., Creek County. Farther south it was removed by pre-Barnsdall erosion.

Thickness. The Iola formation is very irregular in thickness, mostly in the Muncie Creek shale member and the Avant limestone member. Moore[93] says that the Iola formation is 30 feet thick near Iola, Kansas, and that the average thickness of the formation in northeastern Kansas is 7.5 feet. Across the northern part of

92. Moore, Raymond C., "Divisions of the Pennsylvanian System in Kansas": *State Geological Survey of Kansas Bull.* 83, pp. 102-104, 1949.
93. *Idem.*

Washington County it is 4 to 8 feet thick and only 2.2 feet thick near the N¼ cor. sec. 1, T. 25 N., R. 12 E., Washington County,[94] where all three members are recognizable. South of that point it is progressively thicker, reaching a maximum of about 70 feet in the vicinity of Avant, Osage County.

The following table gives the thickness of the Iola formation in several localities in this area.

TABLE IX

THICKNESS OF IOLA FORMATION

Sec.	T. N.	R. E.	Approximate thickness, ft.
4	22	12	70
18	22	12	90
31	22	12	75
12	21	11	70
14	21	11	65
28	21	11	50
33	21	11	40
19	20	11	80
36	20	10	100
10	19	10	85
14	19	10	75

Paola limestone member. The Paola limestone member is said to extend northward as far as the Iola formation is known, at least to the Platte Valley in Nebraska, but nowhere does it have a thickness of more than a few feet. In Kansas it occurs as a single massive limestone bed 1 to 2 feet thick, but across Washington County, Oklahoma, it consists of 3 to 5 feet of massive, calcareous sandstone with relatively pure limestone at the top, locally. In this area the Paola ranges from a relatively pure limestone to a sandstone, as illustrated by the following examples:

T. 23 N., R. 12 E. In sec. 33, limestone, marly, fossiliferous, "crumby" or granular appearance, 1 foot thick rests upon the Cottage Grove sandstone member of the Chanute formation, the upper shale member of the Chanute being absent.

T. 22 N., R. 12 E. A few hundred feet north of the SE cor. sec. 18, is limestone, about 1 foot thick.

94. Oakes, Malcolm C., "Geology and Mineral Resources of Washington County, Oklahoma": *Okla. Geol. Survey Bull.* 62, p. 185, 1940.

On the east end of the outlying hill in SW¼ sec. 31, limestone sandy, yellow to white, fossiliferous, not well exposed, is about 3 feet thick.

T. 21 N., R. 11 E. On the spur of the hill one-fourth mile south of the N¼ cor. sec. 12, a bench growing persimmon trees but no hard bed crops out, probably a soft limestone or marl representing the Paola limestone.

A short distance west of the SE cor. sec. 14, a sandstone, not well exposed, forms a bench, probably about 5 feet thick.

T. 20 N., R. 11 E. About one-fourth mile south of the NE cor. sec. 19, the second bench from the base of the hill, probably limy sandstone about 2 feet thick.

T. 19 N., R. 10 E. In SW¼SW¼ sec. 10, immediately south of U. S. Highway 64, south of Arkansas River in Tulsa County, a sandstone a few feet thick forms a bench. Thin limestone plates, not in place, were found along the top of the sandstone. Phosphatic nodules similar to those so prevalent in the base of the Muncie Creek shale in Washington County and northward were found above this sandstone, near by, and at one place in T. 18 N., R. 10 E., beyond the limits of this area to the south.

Muncie Creek shale member. The Muncie Creek shale is represented northward in the Iola formation, being reported as far north as south-central Iowa and the Platte Valley in Nebraska. In Kansas it ranges in thickness from less than 1 foot to a maximum of about 3 feet. Jewett and Newell[95] say that a zone of black, phosphatic concretions is the most constant feature of the Iola formation in Kansas, and that it was observed by Newell as far south as the Kansas-Oklahoma line. This zone of phosphatic nodules extends across Washington County, Oklahoma. It is less conspicuous in this area but has been observed locally as far south as sec. 2, T. 18 N., R. 10 E., Creek County, beyond the southern limit of this area.

The Muncie Creek shale is present entirely across this area. Its observed thickness ranges from about 15 to 30 feet or more.

95. Jewett, John M., and Newell, Norman D., "The Geology of Wyandotte County, Kansas": *State Geol. Survey of Kansas Bull.* 21, p. 175, 1935.

Generally, it is not well exposed but is covered by debris that accumulates on the scarp slopes in which it crops out. The upper part of the Muncie Creek shale member locally interfingers with the overlying Avant limestone member so that it is difficult or impossible to fix its upper limit.

Avant (Raytown) limestone member. The Avant limestone member of the Iola formation is notable for its great variation in thickness. It is about 5 feet across Wyandotte and Johnson Counties, Kansas; 28 feet thick in the vicinity of Iola, Kansas; locally thin or absent in southern Kansas and across Nowata and Washington Counties, Oklahoma; and 55 or more feet thick in the vicinity of Avant, Osage County, Oklahoma, a short distance north of this area.

In Nowata and Washington Counties, Oklahoma, and probably in southern Kansas, only the lower few feet of the Avant is present as limestone. Shale and lenticular limestone beds included in the lower part of the Wann formation of Washington County are probably time equivalents of most of the Avant of the type locality.

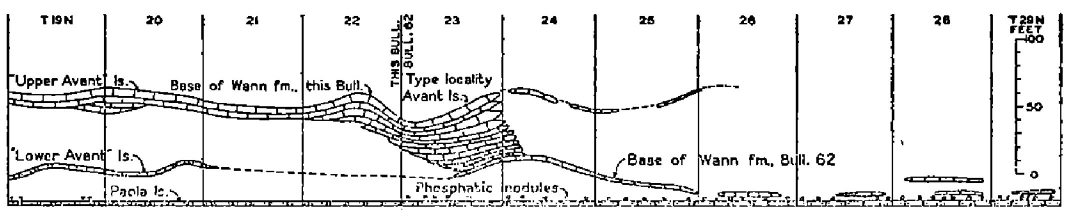

FIG. 9. Generalized outcrop section, from western Tulsa County to the Kansas-Oklahoma line, showing the thickness and character of the Iola formation and its gradational stratigraphic relation to the overlying Wann formation.

Northwest of Skiatook, Osage County, the Avant is about 30 feet thick but southward the lower parts of the member seem to grade into calcareous shale which in turn, grades into clay shale so that only the upper part is recognizable and traceable as limestone. Because of this Emery[96] thought there was an unconformity at the base of the Avant. Locally, this upper part is markedly sandy especially in T. 19 N., R. 10 E., Tulsa County, where it is little more than a limy sandstone in many localities.

96. White, David, and others, "Structure and Oil and Gas Resources of the Osage Reservation, Oklahoma": *U. S. Geol. Survey Bull.* 686, p. 2, 1922.

There are sandy limestone beds in secs. 4 and 9, T. 20 N., R. 11 E., that occupy a stratigraphic position corresponding to the base of the Avant in the vicinity of Avant. South of Arkansas River, where the persistent upper beds are little more than sandstones, these lower beds are very limy, and the two sets of limy beds have been called colloquially the upper and lower Avant limestones. They are here considered to mark the upper and lower limits of the member which contains more shale than limestone and also contains sandstone beds in the south part of T. 19 N., R. 10 E., Tulsa County. East and southeast of Bristow, Creek County, the Avant consists of limy, sandy siltstone which, in surface exposures, is light-weight and porous, owing to leaching of the lime content; and it contains wheat grain-like impressions that probably are fusulinid molds.

Stratigraphic relations. The Iola formation is underlain conformably by the Chanute formation. In this area and northward in Oklahoma, it is overlain conformably by the Wann formation. In the south part of T. 16 N., R. 9 E., Creek County, it is overlain unconformably by the Okesa sandstone member of the Barnsdall formation. Farther south it was removed by pre-Barnsdall erosion.

Detailed sections. For measured outcrop sections of the Iola formation, see sections numbered 52, 53, 54, 55, 56, 58, 60, 61, 62, 63, 93, 94, 95, 96, 97, 98, 99, 102, 103, 105, 124, 126, 127, 128, 129, 130, 132, 133, 152, 153, 154, 156, 157, Appendix A.

Wann Formation

The name, Wann Formation, as restricted and redefined by the author,[97] applies to all strata between the top of the Iola formation, below, and the base of the Torpedo sandstone, above, or to the base of the Birch Creek limestone member of the Barnsdall formation, in areas where the Torpedo sandstone was removed by pre-Birch Creek erosion. In this area the Wann is overlain unconformably by the Okesa sandstone member of the Barnsdall formation.

97. Oakes, Malcolm C., "Results of Recent Field Studies in Osage, Washington, and Nowata Counties, Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, pp. 726-727, 1940.

The Wann formation is notable for its heterogeneous rock types which intergrade both laterally and vertically. In this area the Wann consists dominantly of shale and sandstone with limestone and limy sandstone present in small amount and only locally. The thickness of the Wann increases from about 225 feet on the north side of this area to 265 feet on the south side. Thick sandstones are prominent in Tps. 20 and 21 N., but they split into thinner sandstones and intercallated maroon shales in T. 19 N., R. 10 E., Tulsa County.

First Reference, Nomenclator, Type locality, Original description, and *History of usage* are discussed in Oklahoma Geological Survey Bulletin 62, p. 73, 1940.

Distribution. The Wann crops out over a wide area in northern Washington County, covers a band less than 2 miles wide south of Bartlesville, and is again wide-spread in the vicinity of Avant, Osage County. The outcrop is about 9 miles wide along the north line of T. 22 N., Rs. 10, 11, and 12 E., Osage County, several miles wide in Tps. 20 and 21 N., Rs. 10 and 11 E., and 1.5 miles wide where it enters Creek County over the south line of T. 19 N., R. 10 E. Owing to pre-Barnsdall erosion, the Wann extends little south of the latitude of Bristow, Creek County.

Thickness. The Wann is about 225 feet thick along the north side of this area, T. 22 N., Rs. 10, 11, and 12 E., Osage County, and is thicker southward at a surprisingly uniform rate to about 265 feet along the south side of T. 19 N., R. 10 E., Tulsa County. Progressive southward truncation at the top, by pre-Barnsdall erosion, and interfingering of the lower part into the Avant limestone member of the Iola formation are more than offset by the progressive southward increase in thickness of remaining parts of the formation.

Character. Beyond the limits of this area to the north, in T. 25 N., R. 12 E. and northward, the Wann formation has been subdivided into four lithologic zones for purpose of description.[98]

98. It is desired to call attention here to an error in the preparation of Fig. 8 on page 76 of Oklahoma Geological Survey Bull. 62. The dotted line between the zone of shale and thin platy limestone, below, and the zone of limestone and calcareous fossiliferous shale, above, should have been drawn at the base of the massive limestone in Tps. 23, 34, and 25 ., to accord with the text on p. 77.

From the base upward they are: Zone 1, the basal zone, shale; zone 2, shale and thin, platy limestones; zone 3, limestone and calcareous, fossiliferous shale; zone 4, sandstone and shale. These

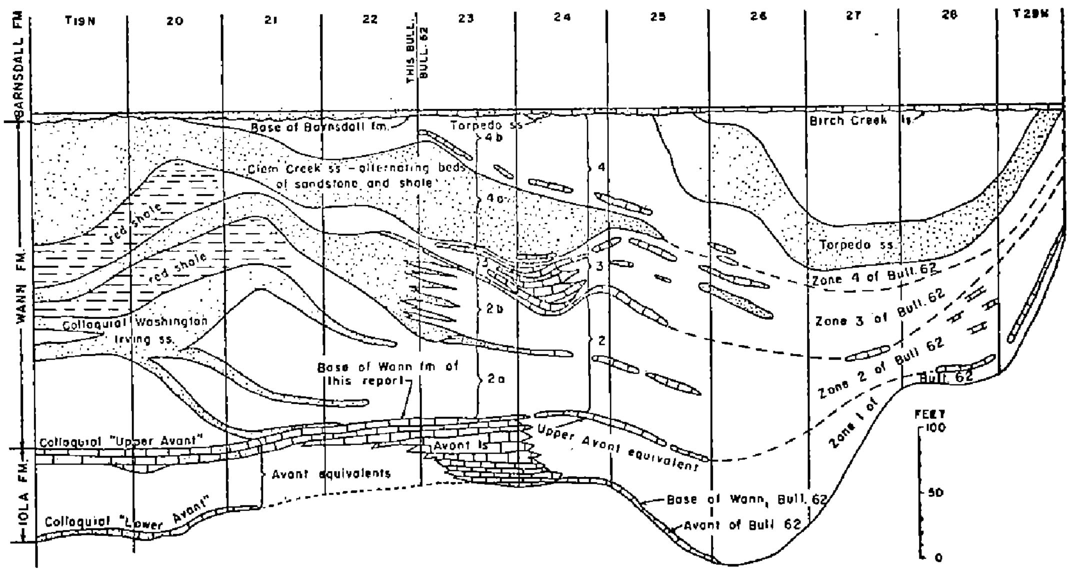

FIG. 10. Generalized outcrop section, from western Tulsa County to the Kansas-Oklahoma line, showing the heterogeneous character of the Wann formation and its gradational stratigraphic relation to the Iola formation, below, and the unconformity at the base of the Barnsdall formation, above.

zones are continuous laterally but they are gradational vertically and their boundaries probably transgress bedding.

In the road up the escarpment 3 miles west of Ramona, Washington County, the four zones are as follows: Zone 1 extends from the top of the Avant limestone member of the Iola formation at the E¼ cor. sec. 25, T. 24 N., R. 12 E. up the hill about 62 feet to the top of a yellow, fossiliferous limestone about 2.5 feet thick. Zone 2 extends from the top of this limestone upward about 67 feet to the base of the massive limestone. A thin limestone about 30 feet above the base of zone 2 is now thought to be the "shelly" limestone of Emery.[99] Zone 3 includes the practically continuous limestone section, about 42 feet thick, and the overlying shale, about 10 feet thick. It thus extends up to the base of the Clem Creek sandstone of Emery. The "Fusulina-bearing gray" limestone of Emery is believed to be at the base of the 42 feet of limestone and his "red" limestone at the top. Zone 4 extends from the base of

99. White, David, and others, "Structures and Oil and Gas Resources of the Osage Reservation, Oklahoma": *U. S. Geol. Survey Bull.* 686, p. 3, 1922.

the Clem Creek sandstone of Emery to the top of the Wann formation, and includes the Clem Creek sandstone and its overlying shale. An attempt was made to trace the yellow, fossiliferous limestone at the top of zone 1 southward across T. 24 N., R. 12 E. Although there are considerable gaps between exposures, this limestone seems to converge with the underlying and conspicuously thickening Avant limestone, and to merge with it about one-fourth mile north of the S¼ cor. sec. 33, T. 24 N., R. 12 E. It thus seems probable that all of zone 1 grades and interfingers laterally into the greatly thickened Avant limestone, as indicated in Fig. 10.

Southward, the lower limit of zone 2 is thus fixed at the top of the Avant limestone, that is at the top of the Iola formation. In sec. 25, T. 23 N., R. 12 E. the upper half of zone 2 contains some thin sandstone beds and in sec. 33, T. 23 N., R. 12 E. it consists of a lower shale division 2a, and an upper sandstone division, 2b. The lower division, 2a, continues southward into the south part of T. 22 N., R. 11 E. where it contains several thin sandstone beds which coalesce farther south in T. 20 N., to form a thick, massive sandstone, known colloquially as the "Washington Irving" sandstone, so called because its conspicuous outcrop rims Washington Irving glen[100] at the NW cor. sec. 29, T. 20 N., R. 10 E. In T. 19 N., R. 10 E. there are at least two divisions of the "Washington Irving" sandstone with intervening shale. The sandstone division, 2b, is composed of sandstone and silty shale beds and in the cliff on the north side of Hominy Creek in sec. 20, T. 22 N., R. 11 E., it contains limy sandstone beds in the upper part. Division 2b extends to the south side of western Tulsa County.

The upper limit of Zone 3 is the base of the Clem Creek sandstone. Emery[101] says that the Clem Creek sandstone is limited below by the "red" limestone but actually in sec. 25, T. 24 N., R. 12 E., the "red" limestone is separated from the Clem Creek by about 10 feet of shale. Southward the "red" limestone grades first into sandstone and then into shale and equivalents are not distinguished south of sec. 6, T. 22 N., R. 12 E. The base of the Clem

100. This glen is so named because it is thought to be one of the camp sights occupied by the party of which Washington Irving was a member in the autumn of 1832. He was then making the journey on which he based his "Tour of the Prairies."
101. White, David, and others, *op. cit.*

Creek sandstone, the upper limit of zone 3, can be readily traced southward across Bird Creek to the hills south of Avant where the "shelly" limestone of Emery, the base of which is considered to be the lower limit of zone 3, is only 10 to 15 feet below the Clem Creek. There is thus considerable thinning of zone 3 southward from sec. 25, T. 24 N., R. 12 E., where it is about 52 feet thick. At many places in the area covered by this report zone 3 is represented by only 10 to 20 feet of shale, and at some places it is so sandy as to be nearly undistinguishable.

Zone 4 extends upward from the base of the Clem Creek sandstone of Emery to the top of the Wann formation and consists of the Clem Creek, 4a, and its overlying shale, 4b. The Clem Creek sandstone is composed of sandstone and silty shale beds. All of the shale, 4b, seems to have been removed by pre-Barnsdall erosion south of sec. 19, T. 20 N., R. 10 E. and from that locality to the south limit of western Tulsa County the Okesa sandstone member of the Barnsdall formation rests unconformably upon the Clem Creek sandstone.

Stratigraphic relations. The Wann formation is underlain conformably by the Iola formation. In this area it is overlain unconformably by the Okesa sandstone member of the Barnsdall formation. Southward in Creek County, pre-Barnsdall erosion cut progressively deeper into the Wann formation and it is doubtful if there are any representatives of the Wann south of T. 16 N., R. 9 E., Creek County.

In the south part of T. 24 N., R. 12 E., Osage County, the underlying Avant limestone member of the Iola formation is greatly thicker than it is farther north, and this increase in thickness is thought to be at the expense of an equal thickness of shale constituting zone 1 of the Wann formation. Thus the contact between the Wann and Iola formations in this locality is gradational.

Correlation. The Wann formation corresponds to that part of the southern Kansas section that lies between the Iola formation, below, and the uppermost limestone member of the Stanton formation, above, probably the South Bend limestone member.[102]

102. For further discussion of the correlation of the Wann formation with the Kansas section, see *Okla. Geol. Survey Bull.* 62, p. 80, 1940.

Detailed sections. For measured outcrop sections of the Wann formation see outcrop sections numbered 50, 51, 53, 54, 59, 60, 61, 62, 89, 90, 91, 92, 93, 98, 105, 117, 120, 121, 122, 123, 124, 126, 127, 131, 132, 133, 149, 151, 152, 156, 157, Appendix A.

Barnsdall Formation

Subsequent to the completion of the field work for this report, the author has done extensive field mapping in northeastern Oklahoma for the new Geologic Map of Oklahoma, now in preparation, and in the course of that work it was found expedient to set up a new geologic unit of formation rank to include the rocks that crop out between the base of the Birch Creek limestone of Bowen,[103] below, and the base of the Bigheart sandstone member of the Tallant formation, above. The name Barnsdall formation has been applied to these rocks. The name is from the town of Barnsdall in T. 24 N., R. 11 E., Osage County, situated on the outcrop of the upper part of the formation. Immediately west of the town is a high escarpment capped by the basal part of the Bigheart sandstone member of the overlying Tallant formation. There is a good exposure of the Birch Creek limestone, the basal member of the Barnsdall formation, in the road near the E¼ cor. sec. 25, T. 24 N., R. 11 E. about a mile south and a little east from Wolco, Osage County.

First reference. Oakes, 1951.

Nomenclator. Oakes, 1951.

Type locality. Barnsdall, Osage County, Oklahoma. Barnsdall was originally called Bigheart, and the type locality of the Bigheart sandstone is in the hills west of the town. Another town in sec. 3, T. 27 N., R. 10 E. is now called Bigheart.

Original description.

> At the state (Kansas-Oklahoma) line the Barnsdall consists of Birch Creek limestone, at the base and two unnamed shale members that are separated by inconspicuous, unnamed sandy limestone less than 2 feet thick. Southward this

103. White, David, and others, "Structure and Oil and Gas Resources of the Osage Reservation, Oklahoma": *U. S. Geol. Survey Bull.* 686, pp. 17-19, 1922.

unnamed, sandy limestone grades into sandstone continuous with the Okesa sandstone member. Farther south the Okesa is much thicker, at the expense of the two shale members, and includes as its basal bed, limy sandstone that is equivalent to the Birch Creek limestone. Other sandstone beds of the Okesa member are limy locally, and contain fossils in the form of casts and molds. The upper shale member contains the Wildhorse dolomite bed, only a few feet below the top of the Barnsdall formation.[104]

Distribution. The Barnsdall formation extends from the Kansas-Oklahoma line southward through western Washington County, eastern Osage County, western Tulsa County, and Creek and Okfuskee Counties. Its southern limit is not definitely known. Patches of red shale below the base of the Virgil series in Seminole County may represent the Barnsdall formation. If so, they are only remnants left by pre-Virgil erosion.

Thickness. The Barnsdall formation is about 100 feet thick at the Kansas-Oklahoma line, 110 feet in T. 23 N., 145 feet in T. 22 N., 120 feet in T. 21 N., and 120 feet in T. 19 N.

Character. The Barnsdall formation is heterogeneous and contains shale, sandstone, dolomitic limestone, and dolomite. It has several members, probably none of which is coextensive with the formation, unless it is the shale member at the top which apparently is present all along the outcrop.

Birch Creek limestone member. The Birch Creek limestone member is discussed at length in Oklahoma Geological Survey Bulletin 62. It is at best only an argillaceous to sandy limestone, and at many places is hardly more than a limy sandstone. South of T. 23 N. it grades into sandstone that is the basal bed of the Okesa sandstone member.

Okesa sandstone member. The Okesa sandstone member was named by Clark[105] from the town of Okesa in sec. 20, T. 26 N., R. 11 E., Osage County. In that locality a thick shale member underlies the Okesa and separates it from the Birch Creek limestone member. Northward along the outcrop the Okesa sandstone is

104. Oakes, Malcolm C., "The Proposed Barnsdall and Tallant Formations in Oklahoma": *Tulsa Geol. Soc. Digest,* pp. 119-122, 1951.
105. White, David, and others, "Structures and Oil and Gas Resources of the Osage Reservation, Oklahoma": *U. S. Geol. Survey Bull.* 686, p. 95, 1922.

irregular in thickness, because of the lenticular nature of the upper and lower sandstone beds. Apparently neither the top nor the base of the Okesa sandstone is a stratigraphic surface, except locally. For some miles south of the Kansas-Oklahoma line the Okesa sandstone is represented by a single bed of sandy limestone that is more and more sandy southward. Southward from the type locality the Okesa sandstone contains progressively less shale and is progressively thicker at the expense of the overlying and under-

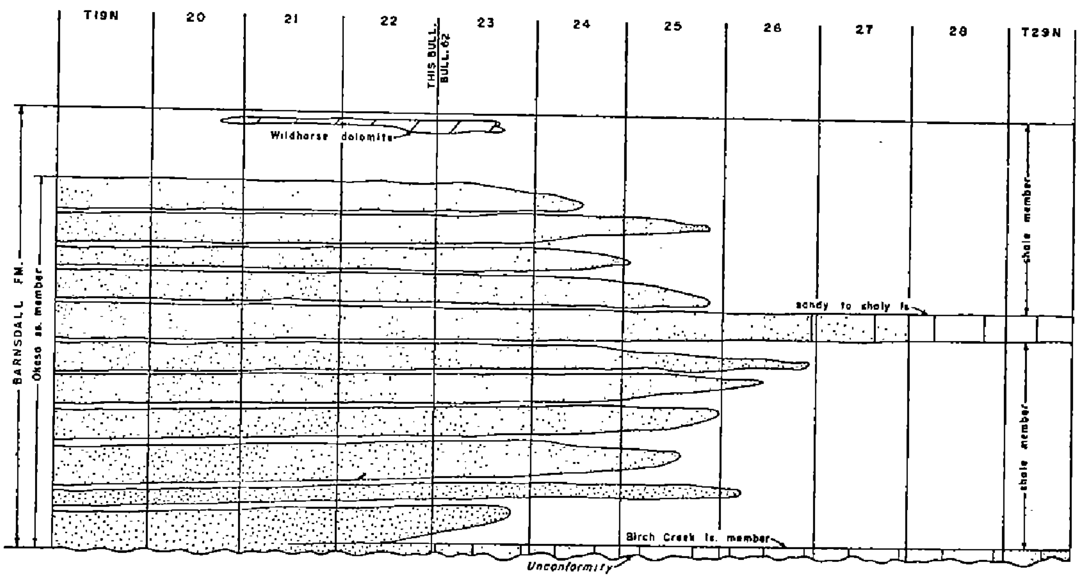

FIG. 11. Diagram, not to scale, showing the character and subdivisions of the Barnsdall formation from western Tulsa County to the Kansas-Oklahoma line.

lying shales, especially the latter. South of T. 23 N., the Okesa sandstone member includes the limy sandstone equivalent of the Birch Creek limestone member. As far south as the southern border of western Tulsa County, at least, the sandstone beds of the Okesa are characterized by their limy cement and by fossils, the latter often found in the form of molds and casts. Immediately west of the outcrop many drillers of oil wells have logged the Okesa sandstone as limestone. Individual sandstone beds are generally separated by sandy to silty shale of varying thickness, from inches to feet.

Shale members. For some miles south of the Kansas-Oklahoma line there are two silty to calcareous shale members, one above and one below the attenuated, silty, limy Okesa sandstone member. The lower of these two shale members grades southward into sandstone beds included in the Okesa sandstone member.

The shale above the Okesa sandstone member is varied in character. It has not been studied in detail north of the vicinity of Barnsdall, sec. 18, T. 24 N., R. 11 E. Southward from Barnsdall it consists of clay shale, is locally calcareous, and contains some limestone beds.

In the south part of T. 23 N., R. 10 E., it is markedly calcareous, and contains the Wildhorse dolomite bed near the top, noticeable as a thin bed in the north part of sec. 27. Near the SW cor. sec. 34 the Wildhorse is 16 feet thick, fossiliferous, crystalline, and gray to brown or pink. In sec. 21, T. 22 N., R. 10 E. the shale is calcareous, 70 to 80 feet thick, and the included Wildhorse dolomite bed near the top caps outlying hills, is gray, crystalline, and 17 feet thick. Farther south the Wildhorse is thinner, silty to sandy, and is not present south of the Arkansas River.

In addition to the Wildhorse, there are thin limestone and dolomite beds from place to place in the shale above the Okesa sandstone member. These beds are particularly noticeable near the middle of sec. 18, T. 21 N., R. 10 E.

Stratigraphic relations. In the area covered by this report the Barnsdall formation overlies the Wann formation unconformably, and is overlain conformably by the Tallant formation.

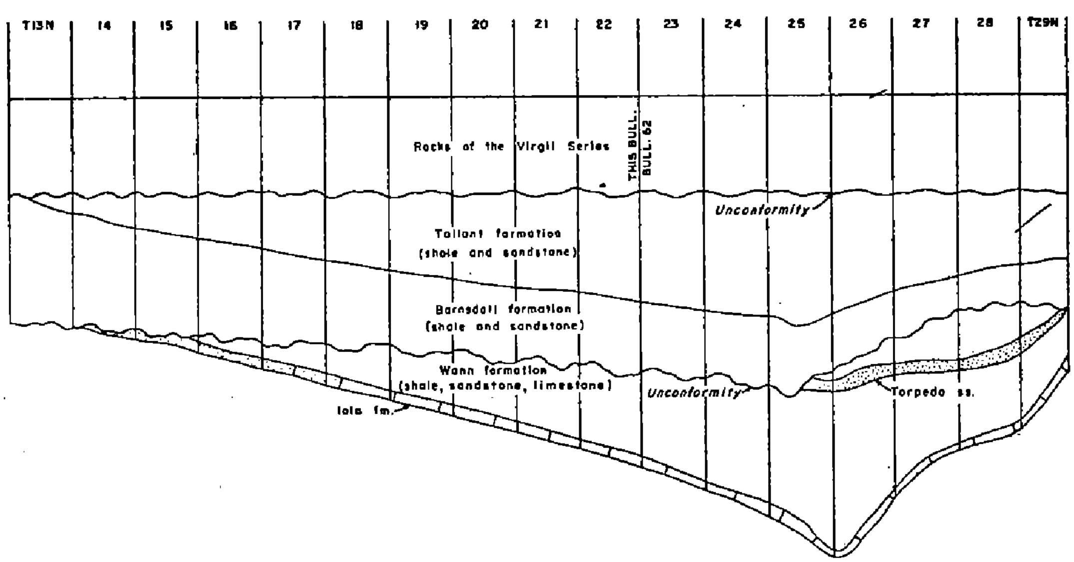

Fig. 12. Diagram, not to scale, showing the stratigraphic relations of the Iola formation, the Torpedo sandstone and overlying shale, the Barnsdall formation, the Tallant formation, and basal rocks of the Virgil series from northern Okfuskee County to the Kansas-Oklahoma line.

As in Washington County,[106] the unconformity at the base of the Barnsdall is not evident from local observations, but is apparent only if the study is extended over a considerable area. The Okesa sandstone and the underlying Wann formation were studied by means of measured outcrop sections, by tracing outcrops in the field, and by stereoscopic study of aerial photographs, much of the latter being done in the field, in conjunction with other field work, and it was found that the shale above the Clem Creek sandstone member of the Wann is thinner over structurally high areas and in general thinner southward, and is overlapped in sec. 19, T. 20 N., R. 10 E., where the Okesa rests on the Clem Creek sandstone. The author finds, as a result of his recent mapping for the new Geologic Map of Oklahoma, now in preparation, that southward in Creek County the Okesa sandstone member of the Barnsdall formation overlaps all of the Wann formation and the Iola formation and rests on the Chanute formation in the northeast part of T. 15 N., R. 9 E.

Correlation. The Birch Creek limestone member at the base of the Barnsdall formation, north of the area covered by this report, is probably equivalent to the South Bend limestone of Kansas and Nebraska, and southward it grades into the basal bed of the Okesa sandstone member. Aside from this thin bed, the Barnsdall is equivalent to the lower part of the Weston shale of southern Kansas. Excepting doubtful patches, the Barnsdall was probably removed by pre-Virgil erosion in Seminole County, Oklahoma, and farther south.

Measured sections. For measured outcrop sections of the Barnsdall formation see sections numbered 50, 59, 89, 90, 117, 118,

The base of the Virgil series in southern Kansas has been

119, 120, 121, 122, 150, Appendix A.

106. Oakes, Malcolm C., "Geology and Mineral Resources of Washington County, Oklahoma": *Okla. Geol. Survey Bull.* 62, pp. 86-91, 1940.

Oakes, Malcolm C., "Results of Recent Field Studies in Osage, Washington and Nowata Counties, Oklahoma": *Bull. Amer. Assoc. Petrol, Geol.*, Vol. 24, pp. 728-730, 1940.

Tallant Formation

drawn at the base of the Tonganoxie sandstone,[107] and has been thought to be marked by the base of the Bigheart sandstone, in northern Oklahoma.

Subsequent to completion of field work for this report the author did extensive mapping for the new Geologic Map of Oklahoma, now in preparation, and in the course of that work found that Oklahoma equivalents of the Tonganoxie are 100 to 200 feet higher than the Bigheart. The Tonganoxie equivalents in Oklahoma are the Cheshewalla sandstone of northern Osage County, Oklahoma, the Cheshewalla sandstone of the type locality, in the vicinity of Tallant, Osage County, and conglomeratic sandstone beds in the lower part of the Vamoosa formation in the area north of the Arbuckle Mountains. The conglomeratic sandstone beds in the lower part of the Vamoosa rest on an eroded surface that has considerable relief. The base of the Virgil series in Oklahoma, north of the Arbuckle Mountains, is drawn at the base of the Tonganoxie equivalents.

It was found expedient to set up a new geologic unit of formation rank to include the rocks that crop out between the base of the Bigheart sandstone, below, and the Missouri-Virgil boundary, above. The name Tallant formation has been applied to these rocks. The name is from the town of Tallant in the SE cor. sec. 35, T. 25 N., R. 10 E., Osage County, north of the area covered by this report. Tallant is on the outcrop of the formation, near the base, where the narrow valley of Bird Creek is cut through the Bigheart sandstone, the basal member of the formation. Basal beds of the Bigheart sandstone member cap the prominent escarpment northeast of the town. The top of the Tallant formation is at the base of the Cheshewalla sandstone, the second sandstone bench below the top of the hill along the road west from the town. The higher sandstone caps the hill, and above that is a westward sloping prairie.

107. Moore, Raymond C., "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas": *Kansas Geol. Survey Bull.* 22, pp. 142-150, 1935.
Moore, Raymond C., "Divisions of the Pennsylvanian System in Kansas": *Kansas Geol. Survey Bull*, 83, pp. 122-131, 1949.
Moore, Raymond C., and others, "The Kansas Rock Column": *Kansas Geol. Survey Bull.* 89, p. 73, 1951.

First reference. Oakes, 1951.

Nomenclator. Oakes, 1951.

Type locality. Tallant, Osage County, Oklahoma.

Original description.

> It consists of sandstone and shale. In Osage County... there are two principal, named sandstone members, the Bigheart and Revard, in ascending order. . . . In addition to the Bigheart and Revard there are other sandstone units and some of these may be extensive enough to be mapped, eventually, as members.[108]

Distribution. The Tallant formation extends in a strip only a few miles wide from the Kansas-Oklahoma line southward across eastern Osage County, southeastern Pawnee County, Creek County, and into Okfuskee County as far as sec. 28, T. 13 N. R. 8 E., where it is overlapped by basal Virgil beds in the Vamoosa formation.

Thickness. The Tallant formation has not been studied in detail but it is about 100 feet thick at the Kansas-Oklahoma line, reaches a maximum of 250 feet thick in T. 25 N., and is thinner farther south.

Character. The Tallant formation consists of sandstone and shale. In Osage County, the only area in which the Tallant rocks have been much scrutinized, there are two principal sandstone members, previously named the Bigheart and Revard, in ascending order. Geologists[109] who have written of them are not in agreement as to the limits of the Revard or the upper limit of the Bigheart. Fortunately, all agree as to the lower limit of the Bigheart sandstone member, the basal member of the Tallant formation. In addition to the Bigheart and Revard sandstone members there are other sandstone units, some of which may be extensive enough to be mapped as members.

Many of the sandstone beds of the Tallant in Osage County are fine-grained, but locally others are moderately coarse-grained,

108. Oakes, Malcolm C., "The Proposed Barnsdall and Tallant Formations in Oklahoma": *Tulsa Geol. Soc. Digest*, pp. 119-122, 1951.
109. White, David, and others, "Structures and Oil and Gas Resources of the Osage Reservation, Oklahoma": *U. S. Geol. Survey Bull.* 686, 1922.

and in spite of being poorly sorted, are porous and permeable and produce oil in areas west of the outcrop.

Stratigraphic relations. The Tallant formation is conformably underlain by the Barnsdall formation and unconformably overlain by basal Virgil rocks. Across Osage County the Tallant is overlain by the Cheshewalla sandstone, the basal member of the Vamoosa formation in this area. Clear evidence of unconformity at the base of the Cheshewalla is lacking at most places in the area covered by this report, and the rocks above and below are so similar in appearance that it is only by continuous tracing of several other beds, above and below, that the Cheshewalla can be mapped with assurance. It is doubtful that the base of the Virgil series can be recognized in local subsurface studies in this latitude.

Correlation. The Tallant formation is equivalent to shale containing sandstone lenses in the upper part of the Weston shale of southern Kansas, and to part, at least, of the Tonkawa sand of subsurface usage.

Measured sections. For measured outcrop sections of the Tallant formation in this area see sections numbered 50, 89, 118, 119, Appendix A.

Virgil Rocks

Rocks of Virgil age, consisting for the greater part of sandstones and shales, crop out in the extreme northwestern part of the area covered by this report. The author has not studied them and does not know enough about them to justify their discussion at this time.

QUATERNARY (?) SYSTEM

A deposit of sand, silt, and clay forms a mantle that covers the older rocks in a belt up to 2 miles wide, along the north side of the Arkansas River along most of its course across this area. Part of this material, was, no doubt, deposited by the Arkansas River at a time when it flowed at a higher level, but much of it, especially the finer material, seems to have been deposited by the prevailing wind from the southwest, and probably was blown up out of the river bed during times of low water and high winds. Indeed, such deposition is still in progress.

These deposits are now much disected by tributary streams that flow into the Arkansas from the north, and part of both the water-deposited and the wind-deposited material has been reworked and redeposited by water at various levels. The greatest thickness of the deposit is not known but is probably 100 feet or more. It grades northward imperceptibly into material of local origin, and finally, into strictly residual soil. The age of the oldest of this deposit is not definitely known but it is presumed to be Quaternary.

The soil in much of this belt is suitable for orchards and there is some gardening and general farming. Locally, the deposit yields considerable supplies of ground water.

QUATERNARY SYSTEM

Flood plain deposits along the Arkansas, Verdigris, and Caney Rivers and their tributaries are composed of clay, silt, and sand. Their maximum thickness is not known but it is probably on the order of 100 feet. The streams still overflow from time to time and add material to these deposits.

Some of the most fertile agricultural land of the county is on these flood plains. The land is especially prized for alfalfa, fruits, vegetables, and pecan groves. Coarser material in the lower parts of these flood plain deposits yield considerable amounts of ground water at some places.

SUBSURFACE STRATIGRAPHY

From pre-Cambrian time to the present, northeastern Oklahoma, of which Tulsa County is a part, has been repeatedly uplifted and eroded, and repeatedly submerged beneath the sea and covered by sediments. As a result there are numerous unconformities and the eroded edges of some beds have been covered by overlapping, higher beds. The extent, thickness, character, and correlation of formations encountered in drilling for oil and gas in Tulsa County are discussed here briefly.

PRE-CAMBRIAN

The Spavinaw granite probably underlies all of Tulsa County at comparatively shallow depths. It is reported that the granite was encountered at about 1,100 feet below sea level in a well on the Owasso dome in the south part of T. 21 N., R. 13 E.; and it is progressively deeper southwestward to about 3,600 feet below sea level in the northwest part of T. 17 N., R. 10 E., Creek County. Evidence obtained from deep wells indicates that in lower and middle Cambrian time a large area, of which Tulsa County was a part, was a rather rugged, granitic terrane and that part of this area remained above the sea throughout most of lower Ordovician time. The highest granite peaks remained islands in the Ordovician sea and if they were ever covered by Ordovician sediments they were uncovered by erosion prior to deposition of the Chattanooga shale, of Devonian and Mississippian age, which now surrounds and overlies them.[110]

ORDOVICIAN SYSTEM

Southwestward, in the Arbuckle Mountain area, and northeastward, in Missouri and adjacent parts of Oklahoma, the pre-Cambrian granite was covered by Cambrian sediments, but in a large intervening area, that included Tulsa County, the oldest sedimentary rocks now known to be present are Ordovician in age. If Cambrian rocks were ever deposited in this area, they were re-

110. Ireland, H. Andrew, and Warren, John H., "Maps of Northeastern Oklahoma and Parts of Adjacent States Showing the Thickness and Subsurface Distribution of Lower Ordovician and Upper Cambrian Rocks Below the Simpson Group": *U. S. Geol. Survey Oil and Gas Investigations, Preliminary Map* 52, 1946.

moved by erosion. The area was subjected to erosion several times during the Ordovician period, and there are several corresponding unconformities. Two groups of Ordovician rocks are recognized in this area, the Arbuckle group, below, and the Simpson group, above.

ARBUCKLE GROUP

Rocks of the Arbuckle group, "Siliceous" lime, of lower Ordovician age, overlie the pre-Cambrian beneath the greater part of Tulsa County. The group is divided into formations by unconformities, which mark times of uplift and erosion.

In his studies of these rocks, Ireland[111] has applied to them the nomenclature established for equivalent rocks in southwestern Missouri, basing his correlation largely on characteristics of their insoluble residues.

SIMPSON GROUP

In southern Tulsa County and adjoining parts of Creek and Okmulgee Counties about 300 feet of dolomite, sandy dolomite, shale and sandstone beds of the Simpson group overlie the Arbuckle group unconformably and are unconformably overlain, locally, by the Fernvale limestone, also of Ordovician age, and generally by the Chattanooga shale, of Devonian and Mississippian age. In this area the Simpson group consists of the Burgen sandstone at the base, the Tyner formation in the middle, and the "Wilcox" sandstone at the top, but post-Simpson erosion cut progressively deeper northeastward and the Simpson does not extend far northeast of Tulsa County.[112]

Burgen Sandstone.

The Burgen sandstone consists of a heterogeneous mixture of large and small quartz grains, both rounded and angular, and at many places it is quartzitic. In color, it ranges from very light gray to yellowish brown. It rests upon the unevenly eroded surface of the Arbuckle rocks, and may not have covered the highest hills. Also, it was exposed to post-Simpson erosion along its northeastern

111. *Idem.*
112. White, Luther H., "Subsurface Distribution and Correlation of the Pre-Chattanooga ("Wilcox" Sand) Series of Northeastern Oklahoma": *Okla. Geol. Survey Bull.* 40, Vol. I, pp. 21-40, 1928.

edge. For these reasons the Burgen is absent locally and ranges in thickness from a knife edge to about 75 feet. It extends little beyond the northeast limits of Tulsa County.

Tyner Formation

According to descriptions by White[113] and by Cloud,[114] the Tyner formation beneath Tulsa County consists of clay shale and sandy shale, with upper and lower sandstone zones and, near the middle, some thin beds of red shale. Owing in part, at least, to post-Simpson erosion, the Tyner ranges from a knife edge to about 40 feet thick. The Tyner is not generally present beneath the northeast part of Tulsa County.

"Wilcox" Sand.

The "Wilcox" sand constitutes the upper part of the Simpson group in Tulsa County but farther south and west the "Wilcox" is overlain by higher Simpson strata. The "Wilcox" is composed of both angular and rounded fine-grained quartz sand, generally loosely cemented. The larger rounded grains are frosted and are a conspicuous but not a unique characteristic of the formation. Owing to post-Simpson erosion the "Wilcox" sand has a wide range of thickness and is not present everywhere beneath Tulsa County.

Fernvale Limestone

The Fernvale limestone overlies the Simpson group unconformably in Creek, Okmulgee, and southern Tulsa Counties. It is usually considered to be of Richmond Age, and according to usage of the United States Geological Survey, the Richmond is upper Ordovician. The Fernvale is characteristically coarsely crystalline and so light in color that it has been called the "White" limestone and the "Buttermilk" limestone by oil well drillers. It is overlain conformably by the Sylvan shale or unconformably by the Chattanooga shale.

Sylvan Shale

The Sylvan shale is light-colored and calcareous. It rests conformably on the Fernvale limestone. In Tulsa County the Sylvan

113. *Idem.*
114. Cloud, W. F., "Tulsa County" in "Oil and Gas in Oklahoma": *Okla. Geol. Survey Bull.* 40, Vol. 3, pp. 627-651, 1930.

is overlain unconformably by the Chattanooga shale, of Devonian and Mississippian age. Owing to pre-Chattanooga erosion the Sylvan is of patchy occurrence beneath Tulsa County.

DEVONIAN AND MISSISSIPPIAN SYSTEMS

Rocks of Devonian and Mississippian age beneath Tulsa County are, in ascending order, the Chattanooga shale and the "Mississippi" lime. Correlation of the "Mississippi" lime and the overlying "Cherokee" shale, Pennsylvanian, with surface outcrops to the east is not certain.

Chattanooga Shale

The Chattanooga shale is present beneath most of Tulsa County. It ranges in thickness from a knife-edge to about 100 feet, and generally is from 30 to 60 feet thick. Characteristically it is brown to black, slaty and bituminous. The Chattanooga rests unconformably on older rocks ranging from the Sylvan shale to the pre-Cambrian granite, and is overlain by limestone of Mississippian age with at least local unconformity.

The Chattanooga is correlated with the Woodford formation of the Arbuckle Mountain area, and with the middle part of the Arkansas novaculite of the Ouachita Mountains. General usage of mid-continent geologists classes the Chattanooga of Oklahoma as Mississippian (Kinderhook). The Woodford has long been thought to be Devonian in its lower part and Mississippian (Kinderhook) in its upper part, and recent work by Hass,[115] based on conodonts, substantiates this idea, and shows that the middle division of the Arkansas novaculite also is Devonian and Mississippian. On this basis, it is probable that the Chattanooga shale of Oklahoma also is of Devonian and Mississippian age.

"Mississippi" Lime

The "Mississippi" lime underlies all of Tulsa County and is from less than 100 feet thick to about 400 feet thick. The following description is adapted from Cloud,[116] omitting his correlations: The upper part of the "Mississippi" lime, 60 to 80 feet thick, is gray

115. Hass, Wilbert H., "Age of Arkansas Novaculite": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 35, pp. 2526-2541, 1951.
116. Cloud, W. F., *op. cit.*

limestone and chert, coarsely crystalline, platy, granular, and locally micaceous. The middle part consists of dark gray to black, finely granular, platy, siliceous, argillaceous limestone and contains thin beds of black shale, locally. The lower part consists of 40 to 50 feet of light gray, massive chert and finely crystalline, buff limestone.

The "Mississippi" lime overlies the Chattanooga shale with at least local unconformity, and is overlain unconformably by the "Cherokee" shale of Pennsylvanian age. At the outcrops of these rocks in Delaware and Mayes Counties the Boone limestone, equivalent to at least the lower part of the "Mississippi" lime, overlies the Chattanooga unconformably, and is succeeded in ascending order by the Moorefield shale, the Batesville sandstone, the Fayetteville shale, and the Pitkin limestone, all of Mississippian age. The Pitkin is overlain unconformably by rocks of the Morrow series, of Pennsylvanian age, and the Morrow rocks are, in turn, overlain unconformably by the "Cherokee" shale.

The "Mississippi" lime beneath Tulsa County may possibly contain representatives of all the Mississippian formations of the outcrop and, in addition, representatives of the Pennsylvanian Morrow series as well. However, it is more probable that the "Mississippi" lime is equivalent to the Boone limestone and more or less of the higher Mississippian rocks and that the Morrow rocks are either included in the "Cherokee" shale of Tulsa County, or do not extend that far west because of post-Morrow-pre-"Cherokee" erosion.

PENNSYLVANIAN SYSTEM

All of the rocks that crop out in Tulsa County belong to the Pennsylvanian system. Rocks equivalent to the Cherokee shale of Kansas usage crop out east of Tulsa County and rest unconformably on rocks of the Mississippian system. Representatives of the Cherokee are present beneath Tulsa County, but subsurface workers call the rocks immediately above the "Mississippi" lime the "Cherokee" shale because correlation of the lower part in some areas is uncertain.

"Cherokee" Shale

The "Cherokee" shale rests unconformably on the "Mississippi" lime under all of Tulsa County and has been the source of most of its shallow oil production. It is about 1,700 feet thick in the southeast part of the county, where the upper part crops out, but it is progressively thinner toward the northwest, and is only about 700 feet thick in the northwest part of the county. Some of the strata in the lower part, in some areas, may actually be equivalent to upper Morrow beds of the surface.

The "Cherokee" is composed dominantly of dark shale, but contains several sandstone units and several limestone units. Some of these have been given subsurface names and a few can be assigned places in named surface formations south of Arkansas River. The Dutcher sand is thought by some geologists to be basal Atoka in age. The sand variously known as Booch, Tucker, or Taneha is probably equivalent to the Little Cabin or Warner sandstone of the surface, in the lower part of the McAlester formation. The Bartlesville sand is the approximate equivalent of the Bluejacket sandstone in the lower part of the Boggy formation. An unnamed lime just above the Bartlesville is apparently the same as the Inola limestone just above the Bluejacket. The Red Fork sand may very well be equivalent to the Taft sandstone of the Boggy formation. The "Pink" lime is equivalent to the Tiawah limestone and is middle Senora in age. The Skinner sand is the Chelsea sandstone of the surface and the Chelsea has been mapped into the middle Senora south of the Arkansas River. The little Oswego or Verdigris lime is the same as the Verdigris (Ardmore) limestone. The Prue sand is in the upper part of the Senora formation. The Oswego lime, in the light of the work of Howe and Warren,[117] comprises the lower limestone member of the Fort Scott limestone and the Breezy Hill limestone together with the intervening black shale.

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117. Howe, Wallace B., of the Missouri Geological Survey, and Warren, John H., of the Oklahoma Geological Survey, verbal communications, 1951.

STRUCTURE

The surface structure of Tulsa County was not mapped in detail, but it is generally known that the rocks form a regional monocline that dips westward. Dillé prepared the subsurface structure map, Plate III as part of his chapter "Oil and Gas in Tulsa County," published in this Bulletin. The structure is indicated by 50 foot contours drawn on the top of the "Mississippi" lime, which is admittedly an erosional surface and not a true stratigraphic surface. However, it is the most easily recognized datum in most wells and indicates pre-Pennsylvanian folding adequately for practical purposes. The map shows that the major feature of pre-Pennsylvanian structure is southwestward trending anticlinal and synclinal folds with some local closures. The structure of the Pennsylvanian rocks, overlying the "Mississippi" lime, does not correspond very closely to the structure of pre-Pennsylvanian rocks.

ECONOMIC GEOLOGY

OIL AND GAS IN TULSA COUNTY

By

Glen S. Dillé

Introduction

Tulsa County has produced oil and gas for a long time. In fact, some authorities believe that a well at Red Fork was the earliest commercial well in what is now Tulsa County, if not the earliest in the present limits of the state of Oklahoma. Yet, with all its long-time record of production, probably less has been published about the general geology of this county than of any other county in Oklahoma which has a similar long-time record. This lack of published information is believed to be due to the fact that in the early days of development there were few if any geologists in Tulsa County and, if there were any, they were occupied by other interests than writing and publishing papers. Operators in those early days were concerned only with the problems of drilling and producing. Poor records were kept, for many wells only depths to tops of producing sands were recorded, and in many instances even these scanty records were inexact.

With such scanty and untrustworthy information available it has been an unsatisfying chore for a geologist to attempt to write about oil and gas development in Tulsa County. No doubt there is an abundance of information available if all operators could have been contacted, but now many details have been forgotten, many of the operators are dead, and many others are widely scattered. However, some drilling has been done in recent years, and good logs have been kept and they provide a better knowledge of subsurface conditions than was possible from the earlier information.

The following discussion is given for the purpose of preserving and making available to the public something of what is known about conditions in this county. The existing literature on Tulsa County is not exhaustive, but does, however, give details about portions of the county, and a general outline of the subsurface geology.

Of the available publications, Bulletin 19, pt. 2, gives a resume of development in Tulsa County as of the date, 1917, and contains a production map, but no subsurface information, nor any surface, or subsurface maps. Bulletin 19 is now out of print. The other publications are, either confined to some one portion of the county, or are too generalized for present-day requirements.

Trade journals of the early days carried some general information which, so far as can be determined, was confined to drilling depths, sand tops, and initial production of wells.

HISTORY OF DEVELOPMENT

The first commercial oil production in Tulsa County, Oklahoma was found at Red Fork in June, 1901. The initial well produced about 100 barrels per day and is still (1952) producing 1 barrel per day. By 1903, very active development was under way, chiefly in T. 19 N., R. 13 E.

The greater part of the oil found in Tulsa County has come from structures that are now classified as stratigraphic traps. Nearly all of the early drilling found sand lenses. Most of the early production was from sand lenses, but later these lenses were found to be lying across structural folds in the older rocks where deeper drilling found production from traps of the closed structure type. Among the more prominent closed structures which produced oil are Turkey Mountain, Bruner, Sand Springs, Jenks, Tulsa, and Sperry. Most of these pools are small in areal extent, but have been prolific in the deeper sands. Reference to the sand map will show the wide-spread distribution of the Pennsylvanian sands in Tulsa County. The stratigraphic traps in the Pennsylvanian beds are so widespread and so numerous that today, more than 50 years after the initial discovery of oil in them, there is some prospecting, some deepening, and some plugging back still going on throughout the county. Today water-flooding is expected to recover as much oil from these sands as was produced by primary methods.

The first period of active development came to an end shortly after the first World War, but from 1925 through 1930 renewed activity developed the western part of the county. Deeper drilling was extended westward.

It is not known how much oil the Pennsylvanian sands have produced per acre. The figure is not a particularly large one. Nevertheless, the sands are so numerous and so widespread that in the aggregate they have supplied most of the oil which has been produced in Tulsa County. In some areas there are as many as 10 producing sands. In pools producing from deeper beds, the Ordovician, the production has been about 6,000 barrels per acre, but the productive areas have been small.

It is not known how much oil has been produced in Tulsa County since the initial discovery in 1901.

PRESENT CONDITIONS

Producing wells in Tulsa County are now strippers, making from 1 to 20 barrels per day. The cost of development has long since been repaid and daily expenses of operation are small so that such oil as is now produced costs little.

The Mid-Continent Oil and Gas Association oil field nomenclature committee has in recent years consolidated individual pools into districts and some of the Tulsa County districts include small areas of adjoining counties. Current production is reported by districts. Consequently there are no reports for individual pools and the total reported production from Tulsa County is slightly greater than the actual production. Production figures are available for many individual leases so that it should be possible to compute the production of the individual pools by leases as originally defined. Perhaps the true total production from Tulsa County could be computed by this method.

TABLE X

Production for 1950 by Districts		
Airport Pool	(20 N-13 E)	1,825 bbls.
Alsuma	(19 N-13 and 14 E)	1,095
Bird Creek	(21 N-12 and 13 E) (22 N-12 and 13 E)	290,905
Bixby	(17 N-13 E)	22,265
Broken Arrow	(18 N-14 and 15 E) (17 N-14 and 15 E)	3,285
Bruner-Vern	(19 N-12 E)	24,820
Collinsville	(22 N-14 E)	4,380
Dawson	(20 N-13 E) (20 N-14 E)	6,570
Fisher	(19 N-11 E)	6,205
Jenks	(18 N-12 and 13 E)	62,050
Leonard	(17 N-14 E and Secs. 2, 3,-16 N-14 E)	10,220
Owasso	(21 N-13 and 14 E)	8,760
Perryman	(19 N-13 E)	1,095
Red Fork	(19 N-11 and 12 E)	15,330
Sand Springs	(19 N-11 E)	13,505
Tulsa	(19 N-13 E)	None
Turkey Mountain	(18 N-12 E)	29,930
Turley	(20 N-12 and 13 E)	61,685
Wicey	(16 N-13 E, 17 N-13 E) (Sec. 18-16 N-14 E)	86,140

FUTURE POSSIBILITIES

The sedimentary deposits beneath Tulsa County have been thoroughly explored and it is probable that little new production will be found. The future of oil production in the county is dependent on stripping and secondary recovery, that is, the further slow recovery of the oil which naturally drains into the present wells or to others which may be drilled, and in the application of means for increasing that flow. Among the means that may be employed for increasing the flow are water flooding and repressuring with gas. Most of the wells that produce from the Pennsylvanian are 1,000 to 2,000 feet deep. This is well within the depths at which secondary methods are used today. The deeper wells, that produce from the Ordovician, are from 1,800 to 3,000 feet deep.

In recent years many operators have thought that the "exhausted" Pennsylvanian sands beneath Tulsa County constitute a huge reserve of ultimately recoverable oil. The Gulf Oil Corporation and the Texas Company have tried repressuring and water-flooding in the Flat Rock area at the edge of Tulsa with favorable results.

Many of the sands of Tulsa County have been cored and analyses of the cores show that the sands still contain large amounts of oil and it is believed that there are many areas in the county in which water-flooding will be successful. However, it will require systematic appraisal to identify the favorable areas.

In considering any program of secondary recovery an operator should consider the possibility of by-passing, and also bear in mind that the sands may not be as thick, or so completely saturated, as they have been reported to be. Old driller's logs indicate that in some wells the producing sand is as much as 100 feet thick and completely saturated. This probably is not true.

Water-flooding as of today, 1952, in the Flat Rock and Glenn Pool is a successful project. This is the result of 10 years of study of waterflooding and repressuring. Today Glenn Pool is producing again the more or less fabulous amount of oil it originally produced.

Correlation and Description of Oil Sands

Turkey Mountain sand. The oldest producing zone found in Tulsa County is known as the Turkey Mountain sand. It is not a sand, in the true sense of the word, but consists of the weathered upper rocks of the dolomitic Arbuckle group together with local accumulations of detrital or residual sand resting upon these rocks. This detrital sand is not to be confused with the overlying Burgen sandstone, which may or may not be present in areas where the Turkey Mountain produces. Generally there is a great amount of chert in this weathered zone.

Production is found on the top, or flanks, of closed anticlinal structures. The best accumulations occur where the dolomitic lime is most deeply weathered and most porous. Perhaps the best known of these structures is in the Turkey Mountain pool from which the sand takes its name. Others which produce from the Turkey Mountain sand are the Bruner, Incho, Country Club, Oakhurst, and Fisher pools.

The closed structures are small and the Turkey Mountain production is generally confined to about 40 acres on or near the crest of the structure. Two of these pools have been described in some detail by Ruedeman and Redmon.[118]

Burgen and Hominy sands. In general usages there has been confusion in the application of these names. They have been used interchangeably by many people. As used herein, the term Burgen refers to the Burgen sandstone which in this area is the lowest member of the Simpson group and overlies the weathered dolomitic limestones of the Arbuckle group. The term Hominy refers to sand in the upper part of the Tyner formation. The Hominy sand generally lies immediately below the Chattanooga shale in areas north of the city of Tulsa where there is no "Wilcox" sand. Production from the Burgen and Hominy sands is found at Sperry, Owasso, Leonard, Fisher, Sand Springs, and on small structures scattered over the county.

"Wilcox" sand. The "Wilcox" sand of Tulsa County is in the Simpson group. Locally, in the southern part, it is overlain by the Fernvale limestone. At most places where the "Wilcox" sand is present, it lies immediately below the Chattanooga shale. It is not found north of the city of Tulsa. The "Wilcox" is the most prolific oil-producing sand in the pre-Pennsylvanian section. The original discovery of "Wilcox" sand in the Tulsa County was made by the H. F. Wilcox Oil and Gas Company in the No. 1 Call, Sec. 3, T. 16 N., R. 13 E. This sand has also been called the "Mounds" sand because of production found in it near the town of Mounds in T. 16 N., R. 12 E. The sand is almost pure quartz with well rounded and frosted grains. The "Wilcox" sand produces at Jenks, Glen Pool area, Mounds, Tulsa, Sand Springs, Bixby, and Turkey Mountain.

"Mississippi" lime. The "Mississippi" lime produces oil and gas from the upper part at many places in Tulsa County, and has been important for gas production in the northern part. Where the "Mississippi" lime produced oil it was well weathered during

118. Ruedemann, Paul, and Redmon, H. E., "Turkey Mountain Lime Pools, Oklahoma": *Amer. Assoc. Petrol. Geol.*, in "Structure of Typical American Oil Fields," Vol. I, pp. 211-219, 1929.

the pre-Pennsylvanian erosion. These weathered zones in the "Mississippi" lime are closely associated with the overlying Burgess sand and at many places production from the lime has been mistaken for Burgess production and vice versa. The "Mississippi" lime has been productive at Bixby, Jenks, Sperry, Owasso, and Sand Springs. Wells averaged about 40 barrels per day initially where the upper part of the lime is well weathered.

Burgess sand. The Burgess sand occurs in scattered discontinuous sand bodies, and generally rests directly on the eroded "Mississippi" lime. At some places a bed of black or vari-colored shale intervenes. The Burgess produces more gas than oil. It is present over much of Tulsa County but seems to be most prolific in the northern and eastern parts. Many of the gas wells in the Owasso-Collinsville area are Burgess sand wells. The sand is composed entirely of weathered material, generally chert and quartz grains. Much of the chert is devitrified. Some well sorted beds of coarse sand are encountered. Initial daily production of oil wells in the Burgess sand ranged from 20 barrels, commonly, to 500 barrels. The Burgess produces only on the top of structures where there was pre-Mississippian erosion.

Dutcher sand. The Dutcher sand is 50 to 200 feet above the Mississippi lime and may rest unconformably on limestone in the Morrow group. If so, it is probably basal Atoka in age and is overlapped by younger rocks not far north of southern Tulsa County. The term Dutcher was introduced into the subsurface nomenclature of Tulsa County when operators recognized a hitherto unknown sand in the Pennsylvanian at Jenks. They were considerably perplexed because of its apparent disappearance northward. It was frequently mistaken for the Taneha sand, and for the Burgess sand. The distribution of the Dutcher is shown on the accompanying sand map, Plate IV. It may be even more widely distributed. The Dutcher sand is generally a coarse, mixed sand but in many places it is well sorted and well bedded. In some places it is very limy and fossiliferous. The initial daily production of Dutcher wells was commonly about 10 barrels, but there have been some very large wells which were flashy and quickly settled down to small production, and the offsets of some of them were dry.

Taneha (Tucker, Booch) sand. The Taneha sand is also known as the Tucker and Booch. It is generally medium-grained, well sorted, angular, and micaceous. It has a wide distribution and is a good producing sand over much of the county. In many wells it is as long-lived as the Red Fork and Bartlesville sands. Both the Flat Rock and the Bird Creek areas produce from the Taneha. Initial production of Taneha sand wells ranged from 10 barrels to 100 barrels per day, with an occasional larger producer.

Bartlesville sand. The Bartlesville sand of the subsurface is approximately equivalent to the Bluejacket sandstone of surface terminology, which is continuous with the lowermost sandstone zone of the Boggy formation and lies just below the middle of the "Cherokee" shale. Where productive of oil, the Bartlesville is a uniformly sorted, angular, micaceous sand which at many places contains thin shale partings. It is lenticular and locally grades into shale. For this reason the cleaner parts constitute very productive stratigraphic traps. The sand also produces on top of closed structures. The Bartlesville attains a thickness of 120 feet in some localities but probably does not average more than 40 feet over much of the county. It is wide-spread but has a hit-and-miss occurrence in the eastern part, and is entirely absent along the east side of the county.

The Bartlesville probably has produced more oil in Tulsa County than all other sands taken together. The average recovery per acre is not known for Tulsa County, but is probably not far from 3500 barrels which is the known recovery in adjacent parts of Osage County. This is not a high recovery per acre, but the productive area is large and in the aggregate a great amount of oil has been produced from the Bartlesville sand of Tulsa County.

Red Fork sand. The Red Fork sand is somewhat higher in the "Cherokee" section than the Bartlesville. It is similar to the Bartlesville in its general texture, but seems to be a bar or shore deposit. It affords good stratigraphic traps because the sand pinches out up dip. Generally the wells have not been large but some have made as much as 200 barrels per day, initially. The Red Fork has produced over much of the county. Although the wells are small they have been long-lived and the Red Fork has, in the aggregate, produced much oil. Today, 1952, a redevelopment of Red Fork sand has been brought about through the development of the hydrafrac process. This new method of treatment has caused a great increase in drilling for Red Fork production.

Skinner sand. The Skinner sand has angular grains and contains much fine mica. It grades into micaceous shale and thus forms stratigraphic traps like other sands of the "Cherokee" shale. It is not a heavy producer and is not present everywhere. Initial production of Skinner wells ranged from 10 to 100 barrels and such production as has been found in this sand in Tulsa County is confined to the southern and western parts. It is probably thickest and most productive in the Jenks district. It is presently being sought for additional production by the hydrafrac process.

Prue sand. The Prue sand is made up of sand lenses lying between the Oswego lime (Fort Scott) and the Verdigris limestone. The productive Prue sand has angular grains, is finely micaceous, and grades laterally into shale. Throughout large areas it is not present. The more permeable parts form stratigraphic traps in which the wells are small but long-lived. The Prue is productive in the Tulsa and Jenks districts and its shallow depth makes it possible to operate the small wells at a profit. Hydrafrac treatment in 1951 and 1952 has given excellent results in the Prue sand.

Oswego lime (Fort Scott limestone). The Oswego produces oil in the Owasso, Bird Creek, and Collinsville areas. In general it produces more gas than oil especially in the north part of the county where at one time there was an active gas development in the Oswego lime. The wells are small and production is found only where there is porosity within the lime section.

The Peru sand. The productive phase of the Peru sand is composed of uniformly sorted angular sand which grades laterally into shale and thus forms stratigraphic traps of erratic distribution. The wells are small but relatively long-lived.

Big lime (Oologah limestone). The surface equivalent of the Big lime is the Oologah formation. It crops out along the east side of the county where it has a maximum thickness of about 100 feet. It is equivalent to the Pawnee limestone, Bandera shale, and Altamont limestone of Kansas. It has not been identified at the surface south of Broken Arrow but underground farther west it extends at least as far south as the vicinity of Red Fork where the first producing oil well in Tulsa County produced from the Big lime. The initial production of the first well was about 100 barrels per day and it is still producing about 1 barrel per day. In general, the Big lime is coarse-grained and uniformly textured. It is very porous in some localities. Production is confined to the southern, western, and central parts of the county. Initial daily production of the wells has ranged from 10 barrels to 100 barrels. but the larger wells are not common.

Other sands. Other shallower sands which have produced oil locally in Tulsa County are the Cleveland sand in the lower part of the Seminole formation and the Layton sand in the upper part of the Coffeyville formation.

Subsurface Geology

(With special reference to oil and gas)

The formations containing some of the producing zones crop out within the county and have been described under "Surface Stratigraphy" and the formations containing others have been described under "Subsurface Stratigraphy." Plate III is a subsurface structure map with contours drawn on top of the "Mississippi" lime.

About 4,500 feet of sedimentary rocks overly the Pre-Cambrian granite in Tulsa County. Limestones of the Arbuckle group make up about 1,500 feet in the Simpson group, about 250 feet is the Skiatook group, and the remainder is the Ochelata group. These figures indicate orders of magnitude only. The Pennsylvanian sediments, especially, have a great range of thickness, being considerably thicker in the southern part of the county than in the northern part. Farther south in the McAlester basin, equivalent beds are much thicker than in Tulsa County.

Certain beds are easily recognized in drilling. They have characteristics which make their identification from samples (drill cuttings) easy. These beds are the Avant and Dewey limestones, the Hogshooter limestone, the Checkerboard limestone, the "Big" lime, the "Oswego" lime, the Verdigris limestone and the "Pink" lime. Other limestones of importance are the Pitkin limestone in the southern part of the county and the "Mississippi" lime, and the Arbuckle limestone ("Arbuckle group"), under the whole county.

On the subsurface Structure Map (Plate III) the contours are drawn on the top of the "Mississippi" lime. In general it shows a series of trends crossing the county from northeast to southwest. Along the axes of these trends are many closed structures. The impression is gained from a study of the structure map, and the sand map, that the Cherokee sands were deposited across these trends in such a manner that stratigraphic traps were formed. The map does not show many favorable areas for further prospecting, but the contour interval is 50 feet and a smaller interval might disclose additional favorable areas. In general, the structure shown by the contours drawn on top of the "Mississippi" lime is the same, or very similar, to that shown by contours on top of the "Siliceous" lime (Arbuckle group). Owing to pre-Pennsylvanian unconformity, the structure of the surface rocks does not correspond closely to the structure on the "Mississippi" lime and the "Siliceous" lime.

PRINCIPAL PRODUCING AREAS

The names used in the following discussion of oil pools are those designated by the Committee on Oil Field Nomenclature, Kansas-Oklahoma Division, Mid-Continent Oil and Gas Association, list of October, 1941 and later decisions.

A difficulty encountered in describing individual pools and their characteristics is that as individuals they have lost their identity in the new grouping of such pools into districts, such as Bird Creek, which now includes Flat Rock and Skiatook, as well as many other small pools. Sand Springs, now covers a multitude of small producing areas, all in T. 19 N., R. 11 E.

As a result of this grouping no reliable figures can be obtained concerning production from individual pools, however, it can be obtained for individual leases in the districts. Defining limits of pools has become a problem. Early development of many pools circumscribed them, but in later years discovery of flanking sands increased their area of production. Whether or not this increase in area should be called by a new name or just added to the old is troublesome. The Committee on Nomenclature has avoided this by grouping all pools in a certain area as one, and calling it a district. Hence, names which were once singularly fitted to the oil business are lost, and with them a part of the romance of the business. Any attempt today to preserve the names would mean a long and difficult problem of interviewing pumpers and drillers over the whole county.

The following names are the accepted present day nomenclature for the producing areas of Tulsa County:

Airport Pool

Location. Secs. 26, 34, and 35, T. 20 N., R. 13 E.

Surface Stratigraphy. Nowata shale, Lenapah limestone, Holdenville (Memorial) shale, and Seminole formation.

Structure. Stratigraphic trap.

Depth to sand. Bartlesville sand found locally at 1,000 feet.

Development and production. The pool was opened in 1937. Initial production ranged from 10 to 100 barrels. All wells quickly settled to small pumpers making from 1 to 10 barrels per day. Total production to end of 1950—152,760 barrels. During 1950—1,825 barrels.

Alsuma District

Location. All production in T. 19 N., R. 14 E., and small areas in T. 19 N., Rs. 13 and 15 E.

Surface Stratigraphy. Labette shale, Holdenville (Memorial) shale, Oologah limestone, Nowata shale, Lenapah limestone, Seminole formation, High terrace deposits, and Recent alluvium.

Structure. Small stratigraphic traps, and small closures on the "Mississippi" lime.

Depth to sands. The depths to the sands increases from northeast to southwest across the township. Numerous sands produce, ranging from the Prue at 500 feet to the Tyner at 1,500 feet.

Development and production. All wells were small. Most production found was gas. The first development took place in 1906, with the most active drilling from 1915-1917 and again from 1920-1925. Even today, 1952, there are scattered wells drilling.

Present production. During 1950 this district produced 1,095 barrels.

Bird Creek District

Location. This district now includes most of Tps. 21 and 22 N., R. 13 E., and adjacent parts of T. 20 N., Rs. 12 and 13 E. and T. 22 N., R. 12 E.

Surface Stratigraphy. Most of the area embraced has the Coffeyville formation at the surface. Checkerboard limestone crops out across the east side and the Nellie Bly formation covers the western part.

Structure. Stratigraphic traps. Anticlinal noses and terraces, with several small closed structures.

Depth to sands. Several sands produce, from the Oswego at 700 feet to the "Wilcox" at 1,700 feet. The prolific Bartlesville sand occurs at about 1,100 feet and the Burgess at 1,350 feet.

Development and Production. First development occurred in 1906. The most active period covered the following 10 years. It is now a quiet area with only water-flooding prospects remaining. Wells ranged in size from a few barrels to some of 500 barrels initially. All have settled to a few barrels per day.

Present production. During the year 1950 the Bird Creek district produced 290,905 barrels of oil.

Bixby District

Location. This area now embraces all of T. 17 N., R. 13 E.

Surface stratigraphy. Wewoka formation, Lenapah limestone, Holdenville shale, Seminole formation, and recent Alluvium.

Structure. Small stratigraphic traps lying across well developed anticlinal trends, upon which local closures are found.

Depth to sands. Various sands produce at different depths, hence production is found from 950 feet to 2,100 feet, with the Bartlesville at about 1,000 feet, the Taneha at about 1,200 feet, the Dutcher at 1,700 feet and the "Wilcox" at 2,100 feet.

Development and Production. The first development took place in the Bixby area in 1914. The most active period was the 10 years following discovery. Some exploration still goes on. Initial production ranged from a few barrels in many wells to some which exceeded 1,000 barrels.

Present production. The Bixby district in 1950 produced 22,265 barrels.

Broken Arrow District

Location. This district embraces all of T. 18 N., R. 14 E., and parts of adjacent townships.

Surface Stratigraphy. Surface formations are the Senora formation, Fort Scott limestone, Labette shale, Oologah limestone, Nowata shale, High terrace deposits, and Recent Alluvium.

Structure. Stratigraphic traps and small anticlinal folds.

Depth to sands. Producing sands range from 1,300 feet to 2,500. The Taneha, Dutcher, and Burgess all produce in some parts of the district.

Development and Production. The first exploration which resulted in finding oil and gas occurred in 1904. Active development occurred during 1914, 1917, and again in 1923 and 1925. Since then sporadic drilling has uncovered small pools in the township. Wells ranged in size from 5 barrels to as much as 500.

Present production. During 1950 this district produced 3,285 barrels.

Bruner-Vern District

Location. Secs. 4, 5, 6, 7, and 8, of T. 19 N., R. 12 E.

Surface Stratigraphy. Coffeyville formation, Hogshooter formation, Nellie Bly formation, High terrace deposits and Recent alluvium.

Structure. Well developed anticline.

Depth to sands. This pool, in common with many others in Tulsa County, produces from several formations. The depth ranges from 1,200 feet to 2,100 feet. Perhaps the most important production in this pool is from the Tyner and Arbuckle formations. Wells ranged in size from 100 to 1,000 barrels.

Development and production. The first development occurred in this area in 1912, but the more important Bruner pool was not drilled until 1923.

Present production. During 1950 the Bruner-Vern district produced 24,820 barrels.

Collinsville District

Location. This area now embraces T. 22 N., Rs. 13 and 14 E., except that part of T. 22 N., R. 13 E. included in Bird Creek.

Surface Stratigraphy. Oologah limestone, Nowata shale, and Seminole formation, also Recent alluvium.

Structure. Small anticlinal folds and small stratigraphic traps.

Depth of sands. The producing sands occur from 700 feet to 1,600 feet, with the Burgess sand the most prolific and widespread producer.

Development and production. The first production from the Collinsville pool was in 1916. However, some parts of what is now the Collinsville district produced as early as 1910. Most of the production from this area was gas and occasioned the erection and operation of zinc smelters at the town of Collinsville. These are now abandoned and the gas production is small.

Present production. During 1950 the Collinsville area produced 4,380 barrels of oil.

Dawson Area

Location. All of Secs. 25 and 36, T. 20 N., R. 13 E. and Secs. 18-20 and 28-33, T. 20 N., R. 14 E.

Surface Stratigraphy. Oologah formation, Nowata shale, Lenapah limestone, Holdenville (Memorial) shale, Seminole formation, and Recent alluvium.

Structure. Stratigraphic traps, with some small local folds.

Depth to sands. Oil and gas both occur in the Bartlesville sand at depths ranging from 850 to 950 feet, the Taneha sand at about 1,050 feet, the Burgess sand at 1,400 feet, and the "Mississippi" lime at about 1,500 feet.

Development and production. The first development occurred in 1906 as a part of the Bird Creek-Flat Rock drilling. The wells were small and more gas than oil was found. Today the prospects seem limited to water flooding.

Present production. During 1950 the Dawson area produced 6,570 barrels.

Fisher District

Location. This district covers the southwest part of T. 19 N., R. 11 E. except that included in the Sand Springs area.

Surface stratigraphy. Nellie Bly formation, Dewey formation, Chanute formation, Iola formation, Wann formation, and Barnsdall formation.

Structure. Local folds and stratigraphic traps.

Depth to sands. Production ranges in depth from 1,100 feet to 2,800 feet. Sands which are at depths of 1,500 feet in the eastern part of this district are found at depths of 2,200 feet along the west side of T. 19 N., R. 10 E., and other sands are at similarly greater depths.

Development and production. The first development in this district followed by some 10 years the discovery of oil at Red Fork. During the period of 1917 to 1919, much activity developed, with the original Fisher pool discovery in 1918. Again from 1925 to

1928 greater activity occurred. Some sporadic drilling continues to the present time. Wells ranged in size from 10 to 500 barrels, with the Turkey Mountain furnishing the largest producers.

Present production. During 1950 this district produced 6,205 barrels of oil.

Jenks District

Location. This district now includes east part of T. 17 N., R. 12 E., northwest T. 17 N., R. 13 E., southeast part of T. 18 N., R. 12 E., T. 18 N., R. 13 E., and adjacent parts of T. 18 N., R. 14 E. and T. 19 N., R. 13 E.

Surface stratigraphy. Nowata shale, Lenapah limestone, Holdenville (Memorial) shale, Seminole formation, Checkerboard limestone, and Coffeyville formation.

Structure. Local anticlinal folds and stratigraphic traps in the form of sand lenses.

Depth to sands. Producing sands range in depth from 700 feet to 2,400 feet, and include sands from the Peru to the "Wilcox".

Development and production. First active development in the Jenks area followed the Red Fork discovery in 1901. Many sands produced. The largest wells produced not more than 500 barrels per day, but many of the early producers are still pumping small daily yields. This area has excellent water-flooding possibilities.

Present production. During 1950 this district produced 62,050 barrels.

Leonard District

Location. As now defined the Leonard district includes the south part of T. 17 N., R. 14 E. and Secs. 2-4, T. 16 N., R. 14 E.

Surface stratigraphy. Senora formation, Fort Scott limestone, Calvin sandstone, Wetumka shale, and Wewoka formation.

Structure. Stratigraphic traps, and small local folds.

Depth to sands. Numerous sands produce from depths of 1,000 feet to 2,400 feet. Perhaps the most important producing sand in the Leonard district is the Bartlesville. However the Red Fork and Tyner produce well.

Development and production. Development in this district started as early as 1916. Production in general was not large, but a few wells in excess of 1,000 barrels were brought in. Activity has continued for many years with some development still under way.

Present production. During 1950 the Leonard District produced 10,220 barrels of oil.

Owasso District

Location. This district embraces southeast part of T. 21 N., R. 13 E., south part of T. 21 N., R. 14 E., and adjacent parts of T. 20 N., Rs. 13 and 14 E.

Surface stratigraphy. Oologah limestone, Nowata shale, Seminole formation, and Coffeyville formation.

Structure. Stratigraphic traps and local folds. One of the most pronounced structures in Tulsa County, known as the Owasso dome, is in this district.

Depth to sands. Numerous sands produce. They range in depth from 500 feet to 1,800 feet. The best producing sands are the Bartlesville at about 1,150 feet, and the Burgess at 1,350 feet.

Development and production. Much of the production in the Owasso district was gas, though considerable oil was found in the Red Fork, Bartlesville, and Burgess sands. First development in parts of this district occurred as early as 1910. During 1913 the Owasso pool was opened.

Present production. During 1950 the Owasso district produced 8,760 barrels of oil.

Perryman District

Location. This district includes Secs. 30 and 31, T. 19 N., R. 13 E., and the E½ of Sec. 25 and E½ of Sec. 36, T. 19 N., R. 12 E.

Surface stratigraphy. High terrace deposits and Recent alluvium.

Structure. Stratigraphic traps and local folds.

Depth to sands. Sands are at the following depths in the Perryman district: Red Fork, 1,450; Bartlesville, 1,550; Taneha, 1,725; Burgess, 1,890; Wilcox, 2,150; Turkey Mountain, 2,260.

Development and production. Most drilling was during the years 1916 to 1925. The wells were generally small with the sands found in the Pennsylvanian furnishing the most oil.

Present production. During 1950 the Perryman district produced 1,095 barrels of oil.

Red Fork District

Location. All that part of T. 19 N., R. 12 E., lying south of the Arkansas River, and the E½ of Sec. 25 and NE¼ of Sec. 36, T. 19 N., R. 11 E.

Surface stratigraphy. Seminole formation, Checkerboard limestone, Coffeyville formation, Hogshooter formation, Nellie Bly formation.

Structure. Anticlinal folds and stratigraphic traps.

Depth to sands. Producing sands range in depth from 450 feet to 2,200 feet.

Development and production. The first drilling took place in 1901 when Big Lime production was found near the town of Red Fork. Wells in general have been small but there are some wells now included in this district which initially produced 500 barrels.

Present production. During 1950 the Red Fork district produced 15,330 barrels of oil.

Sand Springs District

Location. That portion of T. 19 N., R. 11 E., lying south of the Arkansas River. In general the east half of T. 19 N., R. 11 E.

Surface stratigraphy. Coffeyville formation, Hogshooter formation, and Nellie Bly formation.

Structure. Local anticlinal folds and stratigraphic traps.

Depth to sands. Numerous producing sands are found at depths ranging from 1,000 feet to 2,200 feet. Probably the most important zone of production is the Turkey Mountain sand found at about 2,200 feet.

Development and production. Active development first took place about 1916 and continued through the first world war to

1919. Later activity in 1925 and 1926 discovered some additional pools. Some drilling is still going on, but it is a minor activity. Many sands produced in this area with wells ranging in size from 10 to 1,500 barrels per day initially. The large wells were from the Arbuckle limestone.

Present production. During 1950 the Sand Springs district produced 13,505 barrels of oil.

Tulsa District

Location. This district is adjacent to the southeast edge of the city of Tulsa, and includes Secs. 9, 10, 11, 13, 14, 15, 16, 17, 20, 21, 22, 23, T. 19 N., R. 13 E.

Surface stratigraphy. Nowata shale, Lenapah limestone, Holdenville (Memorial) shale, Seminole formation, and High terrace deposits.

Structure. Stratigraphic traps and small local folds.

Depth to sands. Production is found in sands ranging in depth from 450 feet to 2,000 feet.

Development and production. This district was first tested in 1901 following the discovery of oil at Red Fork. All production was small, wells of 100 barrels being the maximum. The wells were long lived, and some are still producing. There is no present new activity.

Present production. Production during 1950 from the Tulsa district is not reported.

Turkey Mountain District

Location. The area comprising the Turkey Mountain district includes Secs. 1, 2, 3, 10, 11, 12, of T. 18 N., R. 12 E., and S½ and NE¼ Sec. 34, Sec. 35, and W½ Sec. 36, T. 19 N., R. 12 E.

Surface stratigraphy. Seminole formation, Checkerboard limestone, Coffeyville formation, and Recent alluvium.

Structure. Anticline, with many lenticular, flanking sands.

Depth to sands. Production is from sands ranging in depth from 450 feet to 2,200 feet. "Wilcox" sand production was found at about 2,000 feet.

Development and production. The Turkey Mountain pool was opened in 1922. Since then activity in the area has been chiefly that of producing the shallow sands flanking the structure. Wells ranged in size from 1 to 2 barrels to as much as 1,000 barrels initially in the deeper beds.

Present production. During 1950 the Turkey Mountain District produced 29,990 barrels of oil.

Turley District

Location. The Turley district now includes Secs. 17, 18, 19, 20, and 21 of T. 20 N., R. 13 E. and Secs. 10, 13, 14, 15, 22, 23, 24, 25, 26, and 27 of T. 20 N., R. 12 E.

Surface stratigraphy. Seminole formation, Checkerboard limestone, and Coffeyville formation.

Structure. Stratigraphic traps lying across well developed anticlinal trends and small local folds.

Depth to sands. Production is found in many sands ranging in depth from 800 feet to 2,000 feet with the Bartlesville at about 1,250 feet, the Burgess at 1,600 feet, and the Turkey Mountain at about 2,000 feet.

Development and production. Drilling in this district started about 1914 and saw its greatest activity during the war years of 1917 and 1918. Initial production ranged from 10 to 500 barrels, with the Bartlesville sand the most prolific. At present this area has important water-flooding prospects.

Present production. During 1950 the Turley District produced 61,685 barrels.

Wicey District

Location. This district includes that portion of Tulsa County lying in T. 16 N., R. 13 E. except Sec. 18, and Sec. 18, T. 16 N., R. 14 E.

Surface stratigraphy. Holdenville (Memorial) shale, Coffeyville formation, and Checkerboard limestone.

Structure. Local anticlinal folds.

Depth to sands. Sands range in depth from 1,000 feet to 2,000 feet.

Development and production. First drilling in this district followed the Glenn Pool discovery. The most active period was 1915 to 1918. Wells ranged in size from 10 barrels to 300 barrels with most of the oil coming from the Bartlesville and Dutcher sands, the Dutcher sand being the most prolific producer.

Present production. During 1950 the Wicey District produced 86,140 barrels of oil.

COAL

Tulsa County has been one of the minor coal producing counties of Oklahoma. There are many exposures of coal in the county in several formations, but there are only two seams that have been of commercial importance, the Broken Arrow and the Dawson. Both have yielded considerable amounts of coal from strip mines, and the Dawson has been mined underground. Neither is thick enough to be attractive for large scale underground mining under present economic conditions. Table XII gives the chemical analyses of mine samples of coal from Tulsa County.

TABLE XI

REPORTED THICKNESS OF DAWSON COAL[1]

Location	Remarks	Thickness, inches Min.—Max.
Sec. 3, T. 16 N., R. 12 E.	Strip pit	12 to 26
Sec. 2, T. 17 N., R. 12 E.	Exposures in coal creek	2 to ? Average 16
Sec. 15, T. 18 N., R. 12 E.	Strip mine	16 to 20
Sec. 35, T. 18 N., R. 12 E.	Strip mine	up to 26
Sec. 16, T. 19 N., R. 13 E.	Shaft mine	30
Sec. 3, T. 19 N., R. 13 E.	Shaft mine	28
Sec. 33, T. 20 N., R. 13 E.	Slope mine	26
Sec. 21, T. 20 N., R. 13 E.	Strip mine	Approximately 26
Sec. 27, T. 21 N., R. 13 E.	Strip mine	16 to 21
Sec. 17, T. 22 N., R. 14 E.	Strip mine	26
Sec. 3, T. 22 N., R. 14 E.	Small strip mine or prospect in bank of Caney River at north line of Tulsa County.	22 to 24

1. Compiled from descriptions supplied by miners, operators, land owners, and records of the State Mineral Survey, WPA Project 65-65-538, sponsored and directed by the Oklahoma Geological Survey, 1936.

TABLE XII
CHEMICAL ANALYSES OF MINE SAMPLES OF COAL FROM TULSA COUNTY

	Sample			Proximate					Ultimate					Calorific value				
	Laboratory No.[1]	Kind[2]	Condition[3]	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Air-drying loss	Calories	B. t. u.	Softening temperature[4]	Bulletin No.[5]	Date of sampling
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
ANALYZED BY THE U. S. BUREAU OF MINES																		
Dawson, ½ mile west of; Southwestern No. 1 mine, Dawson bed (500 feet north of slope mouth).	20712	B	1	6.7	36.3	48.3	8.7	3.4					3.3	6,967	12,540	1,920	123	1914
			2	...	38.9	51.7	9.4	3.6					...	7,472	13,450	...	...	...
Tulsa, south of; SW.¼ SE.¼ sec. 30, T. 18 N., R. 12 E.; drill hole, bed unnamed (material found while drilling an oil well).	18247	A	1	1.6	39.9	49.3	9.2	3.8	5.3	74.2	1.8	5.7	...	7,595	13,670	...	123	1913
			2	...	40.5	50.2	9.3	3.8	5.2	75.3	1.8	4.8	...	7,717	13,890	...	...	...
			3	...	44.6	55.4	...	4.2	5.7	83.0	2.0	5.1	...	8,506	15,310	...	...	...
4 miles southeast of; Hickory No. 2 mine, Dawson bed (300 feet southeast of shaft).	20713	B	1	6.3	37.7	47.8	8.2	3.8	5.6	69.5	1.7	11.2	2.9	7,050	12,690	1,970	123	1914
			2	...	40.2	51.0	8.8	4.0	5.2	74.2	1.9	5.9	...	7,528	13,550	...	...	...
			3	...	44.1	55.9	...	4.4	5.7	81.3	2.0	6.6	...	8,250	14,850	...	...	...
5 miles east of; Liberty Coal Co. mine, Tulsa bed(?) (20 feet from face of 1 north entry).	A23793	B	1	6.4	36.5	49.1	8.0	3.7	5.8	67.4	1.6	13.5	1.3	6,950	12,510	2,160	411	1926
			2	...	39.0	52.4	8.6	4.0	5.4	72.1	1.7	8.2	...	7,428	13,370	...	...	...
			3	...	42.7	57.3	...	4.4	5.9	78.8	1.9	9.0	...	8,122	14,620	...	...	...
NE. edge of; sec. 33, T. 20 N., R. 13 E.; Consumers Coal Co., shaft mine, Dawson bed (No. 1 room, north, first west entry, 600 feet north, 600 feet west from shaft).	B84160	A	1	5.7	35.7	48.5	10.1	4.5	...	...	...	...	1.7	...	12,320	2,010	U	1942
			2	...	37.8	51.5	10.7	4.7	...	...	...	...	...	...	13,070	...	...	...
			3	...	42.4	57.6	...	5.3	...	...	...	...	...	...	14,630	...	...	...
Same (No. 2 room, south, first west entry, 600 feet north, 500 feet west from shaft).	B84161	A	1	6.3	35.4	49.2	9.1	3.8	...	...	...	...	2.3	...	12,410	2,010	U	1942
			2	...	37.8	52.5	9.7	4.0	...	...	...	...	...	...	13,240	...	...	...
			3	...	41.9	58.1	...	4.4	...	...	...	...	...	...	14,660	...	...	...
Same (face of west entry, first, 600 feet north, 900 feet west of shaft).	B64162	A	1	6.0	35.8	48.1	10.1	4.8	...	...	...	...	2.1	...	12,260	2,030	U	1942
			2	...	38.1	51.2	10.7	5.1	...	...	...	...	...	...	13,050	...	...	...
			3	...	42.7	57.3	...	5.7	...	...	...	...	...	...	14,610	...	...	...
Same (composite of samples Nos. B84160, B84161, & B84162).	B84163	A	1	6.1	35.5	48.7	9.7	4.3	5.5	67.7	1.6	11.2	2.0	...	12,330	...	U	1942
			2	...	37.8	51.8	10.4	4.6	5.1	72.0	1.7	6.2	...	...	13,130	...	...	...
			3	...	42.1	57.9	...	5.1	5.7	80.3	1.9	7.0	...	...	14,640	...	...	...

TABLE XII (Continued)
CHEMICAL ANALYSES OF MINE SAMPLES OF COAL FROM TULSA COUNTY

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FROM OKLAHOMA GEOLOGICAL SURVEY BULL. 51[6]																		
Collinsville, 1½ miles southwest of; Tulsa County Coal Co., strip pit, Dawson bed, composite of: Face near middle of pit. Face 200 yards north of middle of pit.	176	....	1	4.2	37.5	46.6	11.7	4.7	......	......	......	......	1.4	6,995	12,590	......	......	1928
			2	......	39.1	48.7	12.2	4.9	......	......	......	......	......	7,300	13,140	......	......	......
Tulsa, 4½ miles east of; Henry Adamson No. 1 mine, Dawson bed, composite of: Face of room 13 off 5 west entry, 3,000 feet from bottom of shaft. Face of main west entry, 3,050 feet from bottom of shaft.	172	....	1	6.4	36.0	49.1	8.5	3.8	......	......	......	......	2.8	6,930	12,480	......	......	1928
			2	......	38.5	52.4	9.1	4.1	......	......	......	......	......	7,400	13,320	......	......	......
4½ miles east of, on 15th St.; Pauline No. 1 mine, Dawson bed, composite of: Face of room 14 off 2 west entry, 2,000 feet from bottom of shaft. Face of main south entry, 2,500 feet from bottom of shaft. Face of room 6 off 2 east entry, 2,500 feet from bottom of shaft.	173	....	1	6.6	35.8	45.5	12.1	4.5	......	......	......	......	2.9	6,685	12,030	......	......	1928
			2	......	38.3	48.7	13.0	4.8	......	......	......	......	......	7,160	12,890	......	......	......
4½ miles southeast of; Leavell Coal Co. No. 1 mine, Dawson bed, composite of: Face of stripped seam near middle of pit. Face of stripped seam 150 yards northwest of middle of pit. Face of main entry in drift mine, 1,200 feet from opening.	174	....	1	5.8	35.5	50.1	8.6	3.9	......	......	......	......	1.7	7,015	12,620	......	......	1928
			2	......	37.7	53.2	9.1	4.1	......	......	......	......	......	7,385	13,300	......	......	......

[1] All Bureau of Mines samples in this table were analyzed at the Pittsburgh laboratory.
[2] A, mine sample collected by an engineer of the Bureau of Mines; B, mine sample collected by a geologist of the U. S. Geological Survey.
[3] 1, sample as received; 2, dried at 105° C.; 3, moisture and ash free.
[4] Figures in this column represent the temperature in degrees F. at which the cone of ash fused to a spherical lump when heated in the furnace in a slightly reducing atmosphere.
[5] Figures in column 18 represent the Bureau of Mines Bulletin (or Technical Paper 411) in which may be found the description of the section of the bed from which the sample was taken. U indicates an unpublished analysis by the Bureau.
[6] Samples were collected by J. E. Moose and W. R. Rutherford, July 3 to 11, 1928. The analytical work was done in the laboratory of the Department of Chemistry, University of Oklahoma.

The Broken Arrow coal crops out in a small area in the southeast part of the county, where it is about 21 inches thick. However, the greater part of the Broken Arrow coal in Tulsa County that was suitable for strip mining has been stripped. The Broken Arrow is a relatively hard, black, bituminous coal. It is probably the same as the Croweburg coal of Kansas.

The Dawson coal is a black bituminous coal, comparable to the Broken Arrow coal. It has been used for domestic coal and for steam coal. The outcrop of the Dawson coal extends across Tulsa County from the south side, southeast of Mounds, through the east side of the city of Tulsa, through Dawson, from which the coal takes its name, west of Owasso, through the east side of Collinsville, and into Rogers County along the channel of Caney River over the north line of sec. 3, T. 22 N., R. 14 E.

There are strip mines, slope mines, and shaft mines along the line of outcrop across the county. At the time the field work for this report was done most of these mines were abandoned, and others were closed. There was no opportunity to see fresh exposures of a full thickness of the coal, and the author is obliged to rely on descriptions supplied by miners, operators, land owners, and records of the State Mineral Survey, WPA Project 65-65-538, sponsored and directed by the Oklahoma Geological Survey, 1936. From these data, thought to be substantially correct, Table XI was prepared.

Available data indicate that the Dawson coal in the latitude of Tulsa is dependably 18 to 30 inches thick, but that northward and southward it is irregular in thickness and in general thinner.

Logs of wells drilled for oil and gas indicate that the Broken Arrow coal and the Dawson coal are present underground at many places in Tulsa County at depths suitable for underground mining, as far as technical difficulties are concerned, but these logs afford little more than rough indications as to thickness of the coal beds.

The fact that the Dawson coal has been profitably mined underground in the past indicates that, given suitable economic conditions, underground coal mining in Tulsa County could be an important industry of considerable magnitude, but so long as there is an abundance of cheap gas and fuel oil large scale underground coal mining will not be attractive.

LIMESTONE

Good limestone is a valuable resource in any community. It is used for crushed stone and for building stone; for making lime; in portland cement, rock wool, and glass; and in chemical manufacturing processes. Tulsa County is fortunate in being well supplied with limestone suitable for most of these uses.

Fort Scott and Breezy Hill limestones.

The Fort Scott limestone crops out in the southeastern part of Tulsa County. According to Howe and Warren,[119] only the lower limestone member extends this far south. It is generally less than 10 feet thick. Below the Fort Scott and separated from it by only a few feet of shale is another limestone mapped by Howe and Warren as the Breezy Hill. It is very similar to the Fort Scott and also generally less than 10 feet thick. Generally these limestone ledges are so thin in Tulsa County that they will probably never be an important source of commercial stone, but they supply stone for use in the immediate vicinity of their outcrops, as from the quarry in sec. 7, T. 19 N., R. 15 E., Wagoner County.

Chemical analyses of the Fort Scott and Breezy Hill are available from but four places in Tulsa County, but these analyses and field observations indicate that they are so impure that they would serve few if any chemical uses. However, a sample from near the E¼ cor. sec. 32, T. 17 N., R. 14 E., made good rock wool when blown in the Survey laboratory at 1440° C.

In T. 18 N., R. 15 E., Wagoner County, immediately east of Tulsa County, the combined Breezy Hill and Fort Scott is about 20 feet thick and would serve for crushed stone, and possibly for building stone. No analyses of the limestone from these localities are available.

Oologah limestone.

The Oologah in eastern Tulsa County ranges from about 40 feet thick north of Broken Arrow, where it grades abruptly into calcareous shale, to about 100 feet thick in T. 20 N., R. 14 E., northeast of Tulsa. Immediately north of Broken Arrow the lower

119. Howe, Wallace B., of the Missouri Geological Survey, and Warren, John H., of the Oklahoma Geological Survey, verbal communications, 1951.

TABLE XIII

Selected Analysis of Limestones, Tulsa County [1]

LIMESTONES WITH CALCIUM CARBONATE GREATER THAN 95 PERCENT [2]

Lab. No.	Location	Ins.	R_2O_3	CaO	MgO	CO_2	Total	Th. Ft.	Ovb. Ft.	Formation
307	22-19N-10E	3.20	1.46	53.76	0.10	42.29	100.81	1	2	Iola
315*	24-19N-10E	2.32	1.32	53.24	0.30	42.10	99.28	5	4	Dewey
291*	24-19N-11E	3.70	1.60	53.40	none	41.90	100.92	12	1-14	Lost City Q
296*	24-19N-11E	2.30	2.03	53.30	none	41.82	99.45	12	1-14	Lost City Q
328*	6-19N-12E	2.20	3.27	53.70	0.40	42.57	102.14	2	10	Lost City
325*	6-19N-12E	2.60	2.00	53.80	none	42.21	101.01	1	4	Lost City
324*	6-19N-12E	3.00	2.12	53.60	none	42.05	101.57	1	0	Lost City
1725*	3-19N-14E	1.94	0.64	54.37	none	43.16	100.11	25	5	Oologah
1602	17-19N-14E	3.24	1.14	54.10	trace	42.45	100.93	35	5-10	upper Oologah
1099*	28-19N-14E	1.50	0.59	53.62	1.10	43.27	100.08	15		Oologah
346*	34-19N-14E	3.46	1.30	53.72	none	42.15	100.63	12		Oologah
1701*	19-20N-14E	1.02	1.00	55.44	none	43.50	100.96	20	1	upper Oologah

WITH CALCIUM CARBONATE PLUS MAGNESIUM CARBONATE GREATER THAN 90 PERCENT
MAGNESIUM CARBONATE LESS THAN 10 PERCENT

Lab. No.	Location	Ins.	R_2O_3	CaO	MgO	CO_2	Total	Th. Ft.	Ovb. Ft.	Formation
327*	6-19N-12E	2.76	2.15	52.74	0.20	41.60	99.45	2.5	6	Lost City
362*	6-19N-12E	3.60	3.23	49.30	2.76	41.69	100.58	24?	14	Lost City
288*	18-19N-12E	1.60	4.87	52.00	none	40.80	99.27	12	8	Lost City
289	26-19N-12E	4.00	3.91	46.86	3.50	40.59	98.86	3.5	0-3	Checkerboard
1148*	10-19N-14E	6.72	1.72	50.70	0.60	40.43	100.17			Oologah Q
1371*	14-19N-14E	7.04	1.44	50.76	0.28	40.14	99.66	20		Oologah
1155*	15-19N-14E	6.92	1.55	50.90	0.54	40.53	100.44	11	10-30	Oologah
1094*	23-19N-14E	6.24	1.33	51.16	1.10	41.34	101.17	25	0-30	Oologah
1603	17-19N-14E	3.50	1.60	53.14	none	41.69	99.93	35	5-10	Oologah Q
363*	27-18N-14E	6.60	3.02	47.00	3.40	40.59	100.61	4	3	Fort Scott
329*	11-19N-10E	5.00	2.52	51.20	none	40.17	98.89	2	1	Iola
292*	24-19N-11E	2.80	2.08	52.90	none	41.51	99.43	4	2	Lost City
293*	24-19N-11E	2.60	2.66	52.60	none	41.27	99.38	4	2	Lost City Q
294*	24-19N-11E	2.20	1.92	53.00	none	41.58	99.98	4	2	Lost City Q
326*	6-19N-12E	2.30	2.54	52.82	0.40	41.88	99.94	2.5	6	Lost City
1095*	23-19N-14E	2.96	1.19	53.08	0.48	42.17	99.88	25	0-20	Oologah
349*	27-19N-14E	3.30	4.01	47.10	4.10	41.42	99.93	10	10	Oologah
1097*	27-19N-14E	4.76	1.14	52.02	0.40	41.25	99.57	15		Oologah
1098*	27-19N-14E	4.00	1.14	52.02	0.76	41.64	99.56	12		Oologah
2449*	4-20N-14E	2.76	0.80	52.20	none	41.62	97.38	8		Oologah
2253*	28-20N-14E	4.00	1.80	52.00	1.06	41.96	100.82	6.5		Oologah
2263*	28-20N-14E	4.86	0.80	52.12	0.90	41.87	100.55	23.5		Oologah
2265*	28-20N-14E	7.74	1.00	49.60	1.42	40.47	100.23	23.5		Oologah
2273*	28-20N-14E	6.64	1.22	51.14	0.46	40.62	100.08	23.5		Oologah

[1] Taken from Oklahoma Geological Survey Mineral Report No. 5, LIMESTONE ANALYSES, compiled by S. G. English, Robert H. Dott, and J. O. Beach.
[2] To obtain percent of calcium carbonate Multiply (CaO) by 1.7846.
[3] To obtain percent of magnesium carbonate multiply (MgO) by 2.0913.
Ins.: Insoluble residue, chiefly silica. Th.: thickness in feet.
R_2O_3: Al_2O_3, Fe_2O_3, and MnO_2 combined. Ovb.: Overburden in feet. Q: Quarry.
*** Phosphate (P_2O_5), less than 0.5 percent.**

two-thirds or more is extremely cherty and the upper part is not high grade limestone. Both field observations and chemical analyses indicate that the percentage of calcium carbonate is progressively greater northward from Broken Arrow, and that it is about 95 percent at some places in T. 20 N., R. 14 E., northeast of Tulsa. Farther northward along the outcrop, in Rogers County, the proportion of calcium carbonate is probably less than 95 percent. The Oologah of some localities makes excellent crushed stone for construction and road work and has been used to a limited extent for building stone, but in many localities it is too shaly or cherty for many purposes.

Some of the cherty parts of the Oologah may prove suitable for making rock wool, but it will be necessary to investigate all quarry sites proposed for this purpose, particularly with reference to uniformity of the rock. The Oologah is not a high grade limestone at most places but selected sites may provide stone suitable even for some chemical uses.

Lenapah limestone.

Wherever it crops out in Tulsa County the Lenapah limestone is only a few feet thick at most. At many places it is soft and marly and at others it is extremely sandy. Such a thin, impure limestone, so non-uniform in composition, will probably never find any economic use, except very locally as building stone.

Checkerboard limestone

The Checkerboard limestone in Tulsa County is a single bed of limestone about 2½ feet thick. It is dark blue, dense, hard, and fossiliferous. Conspicuous joint cracks divide it into nearly rectangular blocks as large as 3 feet by 5 feet. Its massive character recommends it for some purposes, and the Checkerboard should never be overlooked whenever there is need for moderate amounts of heavy stone near its outcrop.

Chemical analyses of the Checkerboard from Tulsa to the north limits of the county indicate that the calcium carbonate ranges from about 84 percent to 89 percent and that much of it is 85 percent or better. There may very well be localities where the Checkerboard would be a more economical source of agricultural limestone than thicker, higher grade beds farther away. It will probably never serve as a source of chemical limestone.

Hogshooter limestone

The upper or Winterset limestone member is the only part of the Hogshooter formation found north of sec. 20, T. 20 N., R. 12 E., Osage County. It is generally less than 5 feet thick and at some places is less than 1 foot thick.

The Winterset is too thin to be of more than possibly local economic importance. It would serve for crushed stone and for building stone. Possibly it would serve for agricultural stone in localities where the short haul would offset the low quality. The calcium carbonate content ranges from about 70 to about 90 percent. The lower 1 foot contains phosphatic nodules but they are not plentiful enough to make the Winterset particularly desirable for its phosphate content.

The Lost City limestone member is a broad lens that underlies the Winterset member from sec. 20, T. 20 N., R. 12 E., Osage County, to the south side of T. 19 N., R. 11 E., and extends into Creek County. It is about 50 feet thick, maximum, and over a considerable area south of Arkansas River it is 40 feet or more thick.

The Lost City is gray, massive, and fossiliferous. It makes excellent crushed stone and has been used for building stone. It contains some well preserved fossils and a great amount of finely broken fossil shells and other fossil material, including some structures thought to be of algal origin. Because these fossil remains result in pleasing patterns on polished surfaces, the Lost City has possibilities as decorative stone.

Chemical analyses in the files of the Oklahoma Geological Survey show that much of the Lost City member of the Hogshooter limestone is more than 95 percent calcium carbonate. Magnesia is reported low to absent. This stone should be suitable for many chemical purposes.

In areas where the Lost City has been exposed to weathering for a long time the joint cracks have been greatly enlarged by solution and there are other, generally smaller, solution cavities. All of these are commonly invaded by red clay that is troublesome to separate, especially if the product is crushed stone.

Dewey limestone

The Dewey formation in Tulsa County consists of upper and lower limestone members, each less than 5 feet thick, and an intervening shale member about 50 feet thick. The limestones are so thin and impure that they probably will never be of any economic importance. At a few places they might be used locally for building stone and for agricultural limestone.

Iola limestone

The Paola limestone member at the base of the Iola formation is too thin everywhere in the area covered by this report to be of economic value.

The Avant limestone member crops out in Tulsa County as thin, sandy beds and will probably never be of economic value, but northwest of Skiatook, Osage County, the Avant is about 30 feet thick and has been used for crushed stone and might be used for building stone. No chemical analyses of samples from that part of the area are available.

Wildhorse dolomite

The Wildhorse dolomite bed crops out in Osage County along the western edge of the area covered by this report. It is thin and unimportant in the north part of sec. 27, T. 23 N., R. 10 E. It is abruptly thicker southward and is 16 feet thick in sec. 34, of the same township where it is fossiliferous, crystalline, and gray to brown or pink. In sec. 21, T. 22 N., R. 10 E. the Wildhorse is gray, fossiliferous, crystalline, and 17 feet thick. Farther south it is brown, sandy, and progressively thinner. It is not found south of Arkansas River.

The Wildhorse in Tps. 22 and 23 N., could probably be used for crushed stone and for building stone. It contains about 90 percent calcium carbonate and magnesium carbonate combined; the magnesium carbonate content, on an impurities free basis, is generally less than 40 percent. It should make good agricultural limestone, especially for soils deficient in magnesium. It would also be excellent as a filler in commercial fertilizers. Its use in chemical processes will depend on establishment of near-by operations where the short haul would offset its low quality.

SAND AND GRAVEL

There are no good gravel deposits in Tulsa County, but that deficiency is offset by the abundance of limestone suitable for making crushed stone.

Sand is an important mineral resource, and an abundance of good building sand is available from the bed of the Arkansas River. Dredging building sand from the river is an important local industry.

CLAY AND SHALE

Other than brick and tile, there is no clay products industry in Tulsa County. Brick and tile have been made in the vicinity of Tulsa since early Indian Territory days, and several plants are now active in the area.

No special attention was paid to clays and shales in the course of this investigation, and no samples were taken for laboratory tests. However, both clay and shale were seen at many places and from cursory examinations it seems that material suitable for making brick and tile are plentiful, but are by no means present everywhere. Sampling and testing adequate to insure a sufficient supply of suitable material should precede any new venture in this industry.

BUILDING STONE

There are many places in Tulsa County where stone suitable for ordinary building purposes can be obtained with a minimum of effort, and certain limestone and sandstone ledges may yield blocks suitable for dimension stone.

Some common structures in which building stone may be used are, outlets for ponds and terraces, culverts, bridges, barns and other outbuildings on farms, school houses, rural residences, and foundations in general. Stone in layers 3 to 6 inches thick serves as veneer in the construction or reconditioning of private residences. The various relief agencies that operated throughout the

TABLE XIV
Building Stone

A register of localities, compiled from the files of the State Mineral Survey, Works Progress Administration Project No. 65-65-538, sponsored and directed by the Oklahoma Geological Survey, 1936-37.

Field Sheet No.	Location	Formation	Thickness of layers, inches	Remarks
	T. 16 N., R. 12 E.			
382	Secs. 3, 10, and 15	Holdenville	6 to 8	Limestone flags possibly suitable for veneer stone.
	T. 16 N., R. 14 E.			
332	South part, Secs. 7, 8	Wewoka	2 to 6	At least 40 acres covered by hard sandstone flags 2 to 6 inches thick.
385	Secs. 17, 18	Wewoka	2 to 6	A great deal of good building stone is available in these two sections.
	T. 17 N., R. 12 E.			
59	Line between Secs. 3, 4, 9, 10	Checkerboard	30	Good exposures of Checkerboard limestone.
60	SE¼ Sec. 13	Seminole	6 to 24	Sandstone 15 feet or more thick; makes cliffs along the roads.
	T. 17 N., R. 13 E.			
58	¼ mile east of S¼ cor. Sec. 19	Seminole	6 to 24	Sandstone in massive beds 15 to 20 feet thick, forms cliffs on each side of road.
	T. 17 N., R. 14 E.			
122	South part of Sec. 26	Wewoka	Not known	Exposures of sandstone which might be used for building stone.
390	South part, Secs. 34, 35	Wewoka	Not known	Area is well covered by loose sandstone boulders and flags suitable for building stone. Limestone 5 feet thick along north side of Sec. 35.
	T. 18 N., R. 12 E.			
124	SE¼ Sec. 14	Seminole	6 to 18	Exposure of sandstone 18 feet thick and 300 feet long.
392	SW¼ Sec. 34	Checkerboard	30	Checkerboard limestone, massive, overburden 0 to 10 feet.
	T. 19 N., R. 10 E.			
602	Secs. 9, 10	Iola	Not known	Limestone and sandstone outcrops. May have some use as construction material.
607	Secs. 11, 12	Nellie Bly, Dewey, Chanute	Not known	Sandstone and limestone outcrops. Quality not known.
601	Secs. 15, 16, 21, 22	Chanute, Iola Dewey, Wann	Not known	Many exposures of sandstone and limestone, suitability for building unknown.
701	Secs. 25, 26, 35, 36	Iola, Dewey	Not known	Several outcrops of limestone, especially in the NE¼ Sec. 25; quality unknown.

TABLE XIV (Continued)
BUILDING STONE

Field Sheet No.	Location	Formation	Thickness of layers, inches	Remarks
88	Secs. 29, 30, 31, 32	Wann, Barnsdall	Thin to massive	This is rough country, there are many outcrops of sandstone, some of which may be suitable for building stone.
	T. 19 N., R. 11 E.			
309	SE NE Sec. 1	Hogshooter, Lost City member	Massive	Outcrop of Lost City limestone about 25 feet thick.
67	Center, Sec. 2	Nellie Bly	3 to 18	Sandstone quarry, stone used by Sand Springs Home and for houses in Sand Springs.
410	Sec. 2	Nellie Bly	Thin to massive	A great deal of stone available, but too soft for some kinds of building stone.
408	Secs. 3, 4	Nellie Bly	Thin to massive	A great deal of sandstone available but too soft for some kinds of building stone.
406	Secs. 5, 6	Nellie Bly	Thin to massive	A great deal of stone is available, but it is too soft for some kinds of building stone.
40	SE NW Sec. 29	Nellie Bly	6 to 24	Ove burden 15 feet, sandstone 30 feet thick.
	T. 19 N., R. 12 E.			
805	SW NW NE Sec. 1 In Tulsa	Checkerboard	30	Exposure of Checkerboard limestone, a single bed, 30 inches thick.
430	Sec. 5	Coffeyville	8 to 12	Sandstone 20 feet thick, overburden 3 feet, exposure 500 feet east to west by 1,320 north to south.
Report by M.C. Oakes	SE SE Sec. 34	Coffeyville	6 to 24	Sandstone 10 feet thick, maximum, little overburden. W.P.A. quarry, supplied stone for National Guard Armory in Tulsa, Oklahoma.
	T. 19 N., R. 13 E.			
419	East side Sec. 20	Seminole	14	Sandstone, may be useful for some purposes.
	T. 20 N., R. 14 E.			
	Sec. 6	Oologah limestone	Not known	Outcrops of Oologah limestone good for crushed stone and possibly for building stone. Maximum thickness exposed 40 feet.
323	Secs. 18, 19	Oologah limestone	Not known	Exposure of Oologah. Maximum thickness exposed 45 feet.
	T. 21 N., R. 13 E.			
520	R. R. cut SE¼ Sec. 24	Seminole	6 to 12	Sandstone, 6 feet thick, overburden 4 feet thick.

TABLE XIV (Continued)
BUILDING STONE

Field Sheet No.	Location	Formation	Thickness of layers, inches	Remarks
	T. 21 N., R. 14 E.			
711	Sec. 33	Oologah		Limestone exposures numerous.
	T. 22 N., R. 13 E.			
225	E side Sec. 11	Checkerboard	30	Outcrops of Checkerboard limestone.
224	NW cor. Sec. 13	Checkerboard	30	Outcrops of Checkerboard limestone.
118	Secs. 16, 21	Coffeyville	Not known	State Highway Dept. has used stone from these sections for culverts.

country about 15 years ago demonstrated that good, serviceable buildings can be constructed of stone theretofore thought to be unsuitable. Even unskilled workmen can construct an outbuilding such as a pig sty, poultry house, or cow shed. With more experience they can erect a barn, milkhouse, or dwelling. The finer sorts of stone work are rightly classed as skilled trades, but so is carpentry. Farmers have long done their rougher sorts of building in wood, in their off seasons, and they can do likewise with stone.

The virgin forests are gone; wood is no longer cheap and is bound to be more dear with the passing years. Soon we must replace wood with stone wherever stone can be made to serve. On farms that have stone close at hand and if the building can be done when other work is not pressing the cash outlay for stone is often less than for wood, especially if service to be expected is considered.

Formerly, stone buildings constructed of somewhat porous stone were damp and it was thought that selected stone from only a few sources could be used. But dampness can now be avoided even though the stone is somewhat porous, and without excessive expense. A simple method is to apply cement stucco, or even a wash of portland cement, to the exterior. Sandstone, in particular, has impervious laminae parallel to the bedding that alternate with the pervious laminae. If such stone is laid in the wall with the bedding horizontal, as was almost universally done in the past, moisture seeps through along the pervious laminae, but if at least the outer course is laid with the bedding vertical, and if due attention is paid to the mortar joints the wall will stay dry in wet weather.

The accompanying table lists numerous exposures of both sandstone and limestone, many of which will, no doubt, yield stone suitable for various purposes.

OIL FIELD BRINES

In Tulsa County, as in many other counties of Oklahoma, large quantities of oil field brine go to waste annually. Indeed, disposing of oil field brine, usually by returning it underground, to the sands from which it came, is a source of considerable expense to the oil industry. Oil field brine has been used in a few places for stabilizing the base in gravel road construction and to alleviate dust on gravel roads. The hygroscopic chlorides hold moisture and tend to prevent dust from blowing.

The main constituent of oil field brine is common salt or sodium chloride, and salt is an important raw material in some chemical manufacturing. Oklahoma brines also contain magnesium chloride, and in 1934-35 a plant in the vicinity of Tulsa operating on similar brine gave Oklahoma second place in the nation in the production of natural magnesium salts.[120]

PHOSPHATE

As in other states large quantities of phosphate are needed in Oklahoma for rebuilding the soil, and Tulsa County is not different in this respect from other counties in Oklahoma. In all of their field work members of the Survey staff are conscious of the need of phosphate and are on the alert for local supplies. All rocks that seem to offer any hope are tested and evaluated. It would not be necessary that phosphatic material be particularly high grade if the quantity available were sufficient and if the effort required to mine and apply it to the land were not too great.

However, the only phosphatic material that has been found in Tulsa County to date is phosphatic nodules, in shale and in limestone, and at no place are they plentiful enough to be useful. Phosphatic nodules are found in black shale both above and below the lower Fort Scott limestone; in black shale at the base of the Coffeyville formation, immediately above the Checkerboard limestone; in black shale of the Seminole formation, immediately overlying the Dawson coal; in the lower 1 foot of the Winterset limestone member of the Hogshooter formation; and in the lower part of the Muncie Creek shale member of the Iola formation, immediately above the Paola limestone member.

120. *U. S. Bureau of Mines, Minerals Year Book,* p. 63, 1937.

WATER RESOURCES

BY JOHN H. WARREN

INTRODUCTION

In the area covered by this report, farmers generally rely on ground water from wells. They also use surface water from creeks and rivers, and conserve runoff by impounding it behind small dams. Some towns depend on wells or springs for their public water supplies, but as the ground-water resources are not adequate for larger city and industrial requirements, the city of Tulsa and some of the towns have had to resort to surface-water sources.

A comprehensive analysis of the water resources of Tulsa County and adjacent area is beyond the scope of this report, but it is appropriate to summarize the information that is available. In 1936 the State Mineral Survey collected information on rural wells throughout the area as part of Works Progress Administration Project 65-65-538, which was sponsored and directed by the Oklahoma Geological Survey. The depth of each well, the static water level, the estimated yield, the performance during drought, nature of the water-bearing rocks, and the approximate character of the water were reported by farm occupants to field men. Direct measurements in wells were not made, nor were water samples collected for analysis. Although the data obtained in this survey are not precise with respect to individual wells, they are helpful with respect to groups of wells. Thus for a township they indicate about how deep most wells have been sunk and about how far the water table is below the surface, but they do not serve as a reliable guide to the ground-water conditions under abnormal situations, for example, the well to be drilled high on a hill or low in a valley, which will not be "average" in depth for position of water table. As 1936 was a very dry year near the middle of the drought of the 1930's, the reports are probably a good index to the dependability of the ground-water supplies in different aquifers and in different parts of the area. The well records of the State Mineral Survey are given in Appendix C.

The writer spent about a month in 1948 measuring depth and water levels in 41 wells representing the more important water-bearing formations of the area. Records of these wells are given in Appendix C. Chemical analyses of 28 samples of water collected at the same time were made in the laboratory of the Quality of Water Branch of the United States Geological Survey,[121] at Stillwater, Oklahoma, and are given in Table XV. Hundreds of wells have been drilled for oil and gas in the area of this report, but only 24 of the well logs filed with the Oklahoma Corporation Commission are sufficiently detailed to be of value in locating supplies of fresh ground water. They are summarized in Appendix B.

Chemical analyses of water from all parts of Oklahoma, including analyses from 12 wells in the area of this report, were published in 1942.[122]

The Surface Water Branch of the United States Geological Survey has gauged the flow of the Arkansas River at the bridge on U. S. Highway 66 in Tulsa since March, 1938. During the period of record through September 30, 1949, the discharge varied from 147 cubic feet per second daily (January 20, 1940) to 173,000 (May 20, 1943) and averaged 7,714. Detailed records of the river discharge will be found in annual Water Supply Papers of the United States Geological Survey under the title "Surface Water Supplies of the United States, Pt. 7, Lower Mississippi River Basin." Analyses of water samples collected from the Arkansas River at the bridge in Sand Springs and at Bixby are summarized by Walling, Schoff, and Dover.[123] They also give three analyses each of water from Bird Creek near Skiatook, Hominy Creek near Skiatook, and Bird Creek near Owasso.

Acknowledgments: The writer is indebted to the water well drillers and to the residents of Tulsa County from whom information was obtained. Appreciation is here expressed for the many aids rendered to this work by S. L. Schoff, U. S. Geological Survey, and to Robert H. Dott, J. O. Beach and M. C. Oakes, all of the Oklahoma Geological Survey.

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121. Cooperative project of Oklahoma Agricultural and Mechanical College, Oklahoma State Department of Health, Engineering Experiment Station, Oklahoma Geological Survey, Oklahoma Planning and Resources Board, and U. S. Geological Survey.

122. Smith, O. M., "The Chemical Analyses of the Waters of Oklahoma": *Oklahoma A. and M. College, Engineering Experiment Station, Publication* 52, 1942.

123. Walling, I. W., Schoff, S. L., and Dover, T. B., "Chemical Character of Surface Waters in Oklahoma, 1946-49": *Oklahoma Planning and Resources Board Bulletin* 5, 1951.

TABLE XV.

ANALYSES, IN PARTS PER MILLION, OF WATER FROM WELLS IN TULSA COUNTY AND ADJACENT PARTS OF ROGERS AND OSAGE COUNTIES, OKLA.
[MADE IN THE QUALITY OF WATER LABORATORY OF THE U. S. GEOLOGICAL SURVEY, STILLWATER, OKLA.]

Well no.	Depth (feet)	Probable aquifer	Date collected	Specific conductance (micromhos at 25° C.)	Temperature (°F.)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na+K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness as $CaCO_3$
2	40	Seminole (lower)	6-20-48	8,740	63	508	362	1,970	0	956	4,850	850	0.4	2.0	958	2,760
20	59	Seminole (upper)	6-24-48	1,650	67	25	16	363	....	742	35	192	.4	.2	974	128
36	18	Alluvium	6-24-48	616	67	75	18	13	12	247	32	9	.1	25	366	261
103	18	Alluvium	7-18-48	867	65	94	18	26	0	318	5	70	....	.2	326	308
130	60	Terrace deposit	6-25-48	105	68	9	3	13	....	44	8	3	....	15	105	34
178	96	Nelly Bly (middle)	6-27-48	872	....	32	10	147	....	341	84	36	1.4	22	586	120
193	29	Terrace deposit	7- 7-48	422	68	52	10	21	....	157	33	24	0	25	270	171
203	20	Alluvium	7-14-48	2,340	....	178	46	215	0	261	130	530	0	3	1,340	633
207	244	Seminole (lower)	7-14-48	1,050	67	29	7	205	30	465	2	115	.2	3	600	102
209	34	Alluvium	7-13-48	885	61	126	32	19	0	265	220	24	.2	8	642	446
215	130	Seminole (lower)	7-14-48	576	....	74	12	57	31	270	67	11	.2	.2	308	234
246	65	Oologah	6-25-48	1,490	71	17	7	295	10	405	24	222	3.0	25	823	73
253	20	Alluvium	7- 8-48	953	62	116	38	8	0	346	81	62	.6	8	442	446
254	136	Wann (upper)	7- 8-48	1,710	66	148	83	98	0	216	400	105	.2	225	1,250	711
259	74	Nelly Bly	7- 9-48	305	66	14	12	16	0	16	17	51	.2	20	194	84
291	28	Nowata	7-10-48	1,500	74	146	24	115	0	207	23	312	0	100	980	463
303	63	Seminole (lower)	7-10-48	694	62	43	20	80	24	194	90	46	0	8	458	190
310	186	Wann (upper)	7-13-48	1,030	64	22	26	185	17	253	41	200	1	2	618	162
322	74	Nelly Bly	7-13-48	1,680	64	54	123	216	0	381	658	52	.2	50	1,340	641
324	61	Coffeyville	7-13-48	2,890	....	101	61	414	10	266	281	618	....	6	1,740	503
335	83	Seminole (upper)	7-13-48	3,330	69	31	59	641	46	470	271	685	.2	6	1,960	322
355	41	Oologah	7-21-48	2,810	63	110	86	306	6	140	282	502	2	200	1,680	504
358	184	Wann (upper)	7-12-48	449	68	25	18	43	6	192	34	19	.2	1	242	136
365	56	Wann (lower)	7-12-48	171	64	16	6	10	0	70	7	11	.2	6	134	6
377	28	Alluvium	7-14-48	1,570	61	86	32	185	0	444	5	265	.4	5	741	346
379	50	Wann	7-13-48	643	....	48	19	62	30	85	63	61	....	75	431	198
390	81	Seminole (upper)	7-14-48	2,620	64	36	16	525	24	422	5	642	.4	.2	1,440	156
404	30	Seminole (middle)	7-13-48	2,580	68	126	85	382	0	452	345	200	0	600	1,910	664
*	....	Terrace deposit	9- 5-51	146	....	11	3	14*	0	42	5	9	0	20	119	41

* Sample taken from Broken Arrow water supply. Additional determinations: silica (SiO_2) 22 and iron (Fe) 0.02 parts per million. Sodium and potassium were determined separately as follows: Sodium (Na) 13 and potassium (K) 1 parts per million.

Ground Water

The rocks within reach of drilling machines contain many open spaces, called voids, pores, or interstices. These open spaces are the receptacles for the water found below the land surface and recovered in part through wells and springs. Rocks differ greatly in the number, size, and arrangement of their interstices, and hence in their properties as containers of water. The quantity and quality of ground water, therefore, is determined by the character, distribution, and structure of the rocks, together with the climate and topography.

The amount of water that can be stored in a rock depends on the volume of pore spaces in the rock, that is, the porosity which is expressed as a percentage of the total volume of the rock. Well sorted deposits of unconsolidated silt, sand, or gravel have high porosity regardless of the size of the constituent mineral grains. Poorly sorted deposits have lower porosities because small grains fill the openings between the large grains, reducing the amount of open space. The voids in some well sorted deposits of sand and gravel may be partly filled with cementing material, reducing the porosity. Hence sandstone and conglomerate, which are consolidated rocks, are likely to have less porosity than sand and gravel which are unconsolidated. Solution openings and fractures may be large and numerous enough to give an otherwise dense rock a fairly high porosity.

Although the capacity of a rock to contain water is determined by its porosity, its capacity to yield water is determined by its permeability, which is defined as its ability to transmit water under hydraulic head. Impermeable rocks will not transmit water. Silt, clay, or shale may be well sorted and have a high porosity but because of the minute size of the pores will transmit water only very slowly. If shale is fractured, however, the fractures may transmit water in moderate quantities. Well sorted gravel or sand containing relatively large openings that communicate freely with one another will transmit water readily. Sandstone will also transmit water readily if its openings have not been obstructed by cementing material. Part of the water in any deposit is not available to wells because it is held against the force of gravity by molecular attraction.

The amount of water available to wells depends on the saturated thickness, the lateral extent, the porosity, and the permeability of the water-bearing material. It also depends on how much of the water will be held in the rock by molecular attraction. The amount of water that can be pumped perennially without progressive depletion of ground water in storage depends on the amount of replenishment. The replenishment comes mainly from precipitation on the outcrop and from influent seepage from streams crossing the outcrop area.

Most of the bedrock formations in the area of this report are fine grained. Their permeabilities and their ability to yield water, therefore, are likely to be low. The largest yields are to be expected in the unconsolidated sediments along the streams, the most important of which is the Arkansas River.

COMPOSITION OF GROUND WATERS

All ground waters contain mineral matter dissolved from the rocks and soils with which they have come in contact. The quantity of dissolved mineral matter in the water depends primarily on the type of rock or soil through which the water has passed, the length of time of contact, and the pressure and temperature conditions. In addition to these natural factors are others connected with human activities, such as use of streams and wells for disposal of sewage and industrial waste, diversion and use of water for many purposes, and disposal of mine and oil field wastes.

The mineral constituents and physical properties of ground waters reported in the analyses are those having a practical bearing on the value of the waters for most purposes: silica, iron, calcium, magnesium, sodium and potassium carbonate, bi-carbonate, sulfate, chloride, fluoride, nitrate, dissolved solids, hardness, total hardness, pH, specific conductance, and temperature (table XV). The source and significance of these constituents are discussed in the following paragraphs, which are adapted from publications of the Quality of Water Branch of the U. S. Geological Survey.

Silica (SiO_2)—Silica is dissolved from practically all rocks. Some ground waters contain less than 5 parts per million of silica and a few contain more than 50 parts. Silica affects the usefulness of a water because it contributes to the formation of boiler scales. It is usually removed from feed water for high-pressure boilers. Silica also forms troublesome deposits on the blades of steam turbines.

Iron (*Fe*)—Iron is dissolved from many rocks and soils. On exposure to the air, normal basic waters that contain more than a few tenths of a part per million of iron soon become turbid with the insoluble reddish ferric oxide produced by oxidation. Iron causes reddish-brown stains on white porcelain or enameled ware and fixtures and on clothing or other fabrics washed in the water.

Magnesium (*Mg*)—Magnesium is dissolved primarily from dolomitic rocks. Dissolved magnesium, like calcium, makes water hard. Its effects are similar to those of calcium. Generally water containing more than 100 parts per million magnesium sulphate should not be used for drinking purposes, according to standards set by U. S. Public Health Service.

Sodium and potassium (*Na*) *and* (*K*)—Sodium and potassium are dissolved from practically all rocks. Natural waters that contain only 3 or 4 parts per million of the two together are likely to carry almost as much potassium as sodium. As the total quantity of these minerals increases, the proportion of sodium generally is much greater than potassium. Moderate quantities of sodium and potassium have little effect on the usefulness of the water for most purposes, but water that carries more than 50 or 100 parts per million of the two may require careful operation of steam boilers to prevent foaming. More highly mineralized waters in which the proportion of sodium is high in relation to all the other basic constituents may be unsatisfactory for irrigation.

Carbonate and Bicarbonate (CO_3) and (HCO_3)—Carbonate as such is not present in appreciable quantities in most natural waters. Bicarbonate occurs in waters largely through the action of carbon dioxide, which enables the water to dissolve carbonates of calcium and magnesium. Bicarbonate in moderate concentrations in water has no effect on its value for most uses.

Sulfate (SO_4)—Sulfate is dissolved from many rocks and soils and in especially large quantities from gypsum and beds of shale. It is also formed by the oxidation of sulfides of iron. Sulfate in water that contains much calcium and magnesium causes the formation of hard scale in steam boilers and may increase the cost of softening the water.

Chloride (*Cl*)—Chlorides are present in practically all waters, being dissolved from rocks or from natural salt deposits. Sodium chloride is a common constituent in sewage, and any appreciable pollution is marked by an increase of chlorides. Chlorides in excessive quantities in water for processing foodstuffs or beverages tend to give a salty taste, and excessive concentrations must be avoided. In some ground waters sodium chloride is the principal chemical constituent and occurs in such concentrations as to cause the water to be unsatisfactory for most industrial, agricultural, and domestic uses.

Fluoride (*F*)—The importance of fluorides in water for domestic use is becoming more widely recognized.[124] In concentrations up to about 1 part per million, fluoride in drinking water has proved beneficial in the prevention of dental caries in growing children. As the concentration increases above 1 part per million, fluoride may cause children's teeth to become mottled, stained, and disfigured.

Nitrate (NO_3)—Nitrate in water is considered a final oxidation product of nitrogenous material and, in some instances, may indicate previous contamination by sewage or other organic matter. It has been reported that as much as 2 parts per million of nitrate in boiler water tends to decrease intercrystalline cracking of boiler steel.

Water containing an excessive amount of nitrates has been suspected of causing a form of cyanosis (blue babies) when used in the preparation of formulas for feeding infants. The Oklahoma State Health Department now considers water containing less than 10 parts per million nitrogen (approximately 45 parts per million when reported as nitrate) as safe for use. There still are many uncertaintities regarding the danger of using water containing large

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124. Burwell, A. L., Case, L. C., and Goodnight, C. H., "Fluoride Removal from Drinking Water": *Okla. Geol. Survey Circ.* 25, 1945.

Warkentin, E. C., "Fluorides in Oklahoma Waters" in "The Chemical Analyses of the Waters of Oklahoma": *Okla. Agri. and Mech. College, Engineering Experiment Station Pub.* 52, pp. 65-81, 1942.

amounts of nitrates, as there are numerous instances of high-nitrate water being used without apparent ill effects.

One possible explanation offered for the incidence of cyanosis in infants using a high-nitrate water is given in the American Public Health Association Yearbook 1949-50. The authorities quoted in the yearbook believe the less acid gastric juices of infants may permit the nitrate to be altered to nitrite which in turn when absorbed in the blood stream affects the oxygen-carrying capacity of the blood.

Dissolved solids—The residue left on evaporation of water consists primarily of the mineral constituents that were dissolved in the water, and it may also contain some organic matter and water of crystallization. These are reported as dissolved solids. Waters with less than 500 parts per million dissolved solids are generally satisfactory for domestic and some industrial uses.

Hydrogen-ion concentration (pH)—The acidity or alkalinity of water is indicated by the hydrogen-ion concentration expressed as pH. This value is useful in determining the proper treatment for coagulation that may be necessary at water treating plants. A pH value of 7.0 indicates that the water is neutral, being neither acid nor alkaline. Values below 7.0 denote acidity and corrosiveness whereas values above 7.0 denote alkalinity.

Specific conductance—The specific conductance of a water is a measure of its ability to conduct a current of electricity. The conductance varies with the concentration and degree of ionization of the different minerals in solution and with the temperature of the water. The specific conductance is an index to the quality of water, especially for use in irrigation.

Hardness—Hardness is the characteristic of water that receives the most attention with reference to industrial and domestic use. It is usually recognized by the quantity of soap required to produce lather. Hard water is objectionable because of the formation of scale in boilers, water heaters, radiators, and pipes, with a resultant decrease in the rate of heat transfer, the possibility of boiler failure, and reduction of flow. Hardness is caused almost entirely by compounds of calcium and magnesium. Other constituents such as iron, manganese, aluminum, barium, strontium, and free acid also cause hardness, but they are not usually found in appreciable quantities in most natural waters. Water that has a total hardness of less than 50 parts per million is usually rated as soft, and its treatment for removal of hardness is seldom justified. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most household uses, but softening may be profitable for laundries and other industries. When the hardness exceeds 150 parts per million, softening is generally desirable for most uses.

Corrosiveness—The corrosiveness of a water is that property which causes it to attack metal surfaces. Oxygen, carbon dioxide, free acid, and acid-generating salts are the principal corrosive constituents in water. In a general way, very soft waters of low mineral content are more corrosive than hard waters containing appreciable quantities of carbonates and bicarbonates of calcium and magnesium. Corrosiveness is measured roughly by the pH and may result in "red water", which is caused by iron in solution. Corrosion causes the deterioration of water pipes, steam boilers, and water-heating equipment. Many waters that do not appreciably corrode cold-water lines will aggressively attack hot-water lines.

Temperature—With the great expansion in air conditioning and the continued importance of water in industrial cooling processes, the temperature of water supplies has become one of the most important physical characteristics to be considered. The temperature of ground water generally varies only slightly during the year, being likely to be a degree or two higher than the mean annual air temperatures as determined by the Weather Bureau.[125] However, where static water levels are near the surface the water temperature may fluctuate somewhat with the seasonal variations of air temperature, and some temperature change may result from infiltration from streams or artificial recharge of warm air conditioning water to the ground water aquifer. McCutchin[126] found the lowest temperature in a well generally is about 100 feet below

125. Van Orstrand, E. C., "Normal Geothermal Gradient in United States": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 1, pp. 78-115, 1935.

126 McCutchin, J. A., "Determination of Goethermal Gradients in Oil Fields Located on Anticlinal Structures in Oklahoma": *Amer. Petrol. Inst. Production Bull.* 205, pp. 19-61, 1930.

the surface. Below the 100-foot level the temperature of the ground water increases with the depth because the temperature of the rocks of the earth increases downward.

WATER-BEARING FORMATIONS

Beds below the Fort Scott limestone

About 250 feet of shale with thin beds of sandstone and limestone might be encountered in water wells in T. 18 N., R. 14 E., to the south and southeast of Broken Arrow. These beds are below the Fort Scott limestone and are equivalent to the upper part of the Cherokee shale of Kansas and the upper part of the Senora formation of Oklahoma. Hays[127] reports that wells drilled into these strata have yielded 5 to 100 gallons per minute; as follows: sec. 18, T. 17 N., R. 14 E., 80 to 100 gallons per minute; sec. 19, T. 17 N., R. 14 E., 8 to 10 gallons per minute; secs. 1, 5, and 10, T. 17 N., R. 15 E., 5 gallons per minute. Records for these wells are not sufficiently detailed to indicate whether the water comes from the sandstone beds or from crevices in the shale. No waters from the beds below the Fort Scott were analyzed for this report.

Labette Shale

The Labette shale crops out in an area about 2 miles wide extending from the north part of T. 20 N., R. 14 E. into T. 18 N., R. 14 E. It is predominantly shale but includes a few thin lenses of sandstone. The ground water in the formation probably moves more easily through the crevices in the shale than through the sandstones. The State Mineral Survey in 1936 recorded 10 wells that probably tap water in the Labette, all of them yielding water described as hard. Only one was reported to fail during drought. No waters from the Labette shale were analyzed for this report.

Oologah formation

The Oologah formation crops out in this area in T. 22 N., R. 14 E. and southward into T. 18 N., R. 14 E. It is dominantly limestone in the northern part of the county but is shaly southward. It is calcareous shale south of Broken Arrow. The State Mineral Survey in 1936 recorded 15 wells that probably tap water in the

127. Hays, Walter, well driller, Tulsa, Oklahoma, oral communication.

Oologah limestone, all but 3 of them yielding water described as hard. It was reported that 2 wells went dry during drought, 5 declined in yield or water level, and 8 showed no change. Water analyses 246 and 345 representing waters from wells in the Oologah suggest a wide range in chemical character of water from the Oologah in different parts of the area. In parts per million, sulphates are 24 and 282; chlorides, 222 and 502; hardness, 73 and 628; and dissolved solids, 823 and 1,880.

Nowata Shale

The outcrop of the Nowata shale extends from the east-central part of T. 22 N., R. 14 E., about 3 miles northeast of Collinsville, to the terrace deposits of Arkansas River in T. 18 N., Rs. 13 and 14 E. The outcrop is about 0.25 mile wide east of Collinsville but widens southward to about 6 miles near Broken Arrow. Beginning about 3 miles south of that town it is covered for 1 to 2 miles by terrace deposits, and in the valley of the Arkansas River it is covered by alluvium. South and west of Bixby the equivalent shale and limestone flags are mapped as part of the Wewoka formation. Although dominantly shale, the Nowata yields ample water for farm use, most of it probably coming from crevices. The State Mineral Survey in 1936 recorded 64 wells that probably tap water in the Nowata, most of them yielding water described as hard. It was reported that 10 wells went dry during drought, 18 declined in yield or water level, and 36 showed no change. Analysis 278 represents water from a well in the Nowata and shows 23 parts per million of sulphates, 321 of chlorides, 463 of hardness and 980 of dissolved solids.

Holdenville (Memorial) shale

The northernmost outcrop of the Holdenville (Memorial) shale is in T. 20 N., R. 13 E., north of the town of Dawson, where it has a width of about 0.25 mile. The formation extends southward into T. 18 N., Rs. 12 and 13 E. and is covered by alluvium and terrace deposits in and adjacent to the valley of the Arkansas River. Southward it extends from near Jenks to the south line of the county, in T. 16 N., R. 12 E. The Holdenville consists of sandy shale and interbedded layers of sandstone, the thickest of which is 20 feet, and yields only meager supplies of water. The State Mineral

Survey in 1936 recorded 11 wells that probably draw water from this formation. Of these, 2 were said to go dry during drought, 3 to decline in yield or water level, and 6 to show no change. The water from 7 wells was reported as hard and that from 3 as soft. No waters from the Holdenville (Memorial) shale were analyzed for this report.

Seminole formation

The outcrop of the Seminole formation extends diagonally across Tulsa County from the northeast corner to the southwest corner, and has on it the towns of Collinsville, Glenpool, Mounds, and the eastern two-thirds of Tulsa. The formation is composed of shale and sandstone. The sandstone beds are believed to be among the better sources of ground water in the county, and normally yield water in moderate quantities. The shale beds yield little water. The State Mineral Survey in 1936 recorded 74 wells that probably tap water in the Seminole formation. It was reported that 15 had gone dry during drought, 8 had declined in yield or water level, and 51 had shown no change. The 23 wells that went dry or declined during drought probably did so because they penetrated only shale in the zone of saturation or had not been sunk deep enough below the water table.

Many water wells have been drilled to the Seminole formation within the city limits of Tulsa, and these provide the best available information on the yield of wells and quality of the water. According to well drillers B. O. Lee, Charlie Holebrook, and Ed Chastan, all of whom have drilled wells in the city, the initial production of wells in the Seminole ordinarily is 8 to 16 gallons per minute, ultimately decreasing to about 5 gallons per minute. The water-bearing sandstone is from 20 to about 50 feet below the surface and averages about 16 feet thick. A well 255 feet deep at the Sinclair Building, between Main and Boston streets, tapped a deeper sandstone than most wells, and for some years furnished drinking water for 450 employees. The well logs obtained from Lee indicate that some water is derived from beds of shale and clay, but yields in such beds are erratic. Analyses 1, 20, 215, 290, and 325 represent the waters of the Seminole formation and indicate a wide range in concentration of dissolved mineral matter: sulphates, 35 to 4,850 parts per million; chlorides, 11 to 850; hardness, 128 to 2,760; and dissolved solids, 308 to 9,580.

Coffeyville formation

The outcrop of the Coffeyville formation extends from the northern part of Tulsa County southwest through Sperry, the northwestern part of Tulsa, and Red Fork, Kiefer, and Mounds. The formation is composed of shale, silty shale, and sandstone. It seems reasonable that the sandstone beds of this formation should yield water whereas the shale beds should be essentially unproductive, but facts to support this assumption are few. The State Mineral Survey in 1936 recorded 13 wells that probably tap water in the Coffeyville formation. Of these, 2 were said to have gone dry during drought, 3 declined in yield or water level, and 8 showed no change. Water analysis 314 represents a sample from the Coffeyville formation and indicates rather high mineralization. In parts per million, sulphates are 281, chlorides 618, hardness 503, and dissolved solids 1,740.

Hogshooter formation

The Hogshooter formation is thick enough in T. 19 N., R. 11 E., in the panhandle of Tulsa County, to afford some storage capacity for ground water. Many small springs, some of which are dry in summer, issue at its contact with the underlying Coffeyville formation. So few wells have been drilled into the Hogshooter that practically no information is available to indicate how readily the limestone will yield water.

Nellie Bly formation

The Nellie Bly formation crops out along the Osage-Tulsa County line and extends into the panhandle of Tulsa County (T. 19 N., R. 11 E.). At Sand Springs it is concealed by terrace deposits and in the Arkansas Valley it is concealed by alluvium. Shale predominates in the north but grades southward into interbedded shale and sandstone. Of the wells reported in 1936 to the State Mineral Survey, 1 had gone dry during drought, 9 had declined in yield or water level, and 9 had shown no change. The water from 15 wells was described as hard, that from 6 as soft, and that from 1 as salty. Analyses 178 and 255 represent waters from the Nellie Bly and show 17 to 400 parts per million of sulphates, 36 and 105 chlorides, 84 and 534 of hardness, and 194 and 1,250 of dissolved solids.

Wann formation

The Wann formation crops out in T. 22 N., Rs. 10, 11, and 12 E., and extends southwestward to Keystone. It is mostly shale but includes several thick lenticular beds of sandstone. The Shell Pipe Line Corporation has three wells in T. 21 N., R. 10 E. that yield enough water from the Wann formation to cool 12 large engines used in a pipeline booster station. Logs of 2 of these wells show the principal aquifer to be a sandstone 40 feet thick and about 140 feel below the surface. Other sandstone beds, 34 feet and 30 feet thick, occur about 45 to 60 feet and 90 to 100 feet below the surface. Reports obtained by the State Mineral Survey indicate that 2 wells probably tapping water in the Wann formation went dry during drought, 4 declined in yield or water level, and 6 showed no change. It was reported that water from 10 wells was soft and that from 4 wells was hard. Analyses 348, 355, and 369 represent waters from wells in the Wann. In parts per million, sulphates range from 7 to 34, chlorides from 11 to 61, hardness from 6 to 346, and dissolved solids from 134 to 741.

Okesa sandstone

The Okesa sandstone member of the Barnsdall formation crops out in the western part of the area covered in this report. It is logical that this sandstone should be water bearing, in small quantities at least, but no well records are available to give information.

Terrace deposits

Terrace deposits of stream-laid clay and sand, and locally gravel, cover a strip from 0.1 mile to 3 miles wide paralleling the Arkansas River in Tulsa County and the eastern part of Osage County. The thickness of the deposit differs from place to place because of unevenness of the bedrock surface on which it was deposited and because of erosion since deposition. Of the wells recorded in 1936 by the State Mineral Survey, which probably draw water from the terrace deposits, 2 were reported to have gone dry during drought, 1 had declined in yield or water level, and 20 had shown no change. The water of all but 3 of these wells was described as soft. Analyses 130 and 193 represent waters from terrace deposits, and show 105 and 270 parts per million of dissolved solids, including 8 and 33 parts of sulphates, 3 and 25 parts of chloride, and 24 and 171 of hardness.

The town of Broken Arrow obtains its public water supply from wells (originally springs) tapping water in terrace deposits. Several wells in Tulsa that draw water from the terrace deposits have yields that are low compared with those from terrace deposits in some other parts of Oklahoma. Ranging from 0.25 gallon per minute to 6 gallons per minute and averaging about 4.5, they may represent the maximum demand of the owners rather than the maximum yield of which properly constructed wells at the same location might be capable.

Alluvium

Stream-laid sand, gravel, and interbedded clay underlying the bottomlands of the Arkansas River are the most prolific source of ground water in the area of this report. A well at a filling station at 3700 South Peoria, Tulsa, is reported to yield 5 gallons per minute through a 1-inch pump. Another well, owned by the Aero Exploration Company and located at 4140 South Peoria, is reported to yield 25 gallons per minute. C. E. Bliss reported that a well at 2302 Sand Springs Road yielded 50 gallons per minute in a pumping test and showed practically no drawdown. Much larger yields probably could be obtained from wells of better construction. Schoff and Reed[128] reported yields of about 200 gallons per minute from test wells in the Arkansas River valley at Fort Gibson, and estimated that 500 gallons per minute might be obtainable. The same authors (p. 39) report a yield of 1,700 gallons per minute from a well at Ponca City, also in the Arkansas Valley. Of the wells recorded in 1936 by the State Mineral Survey, 5 were said to have gone dry, 5 declined in yield or in water level, and 35 showed no change. The water from 37 wells was described as hard, that from 12 as soft, and that from 1 as sulphurous. Analyses 36, 103, 203, 209, 253, and 369 represent waters from wells in the

128. Schoff, Stuart L. and Reed, Edwin W., "Ground Water Resources of the Arkansas River Flood Plain Near Fort Gibson, Muskogee County, Oklahoma": *Okla. Geol. Survey Circ.* 28, pp. 24-26, 1951.

alluvium deposits. In parts per million the dissolved solids range from 270 to 642; the chlorides from 9 to 62; the sulphates from 5 to 220; and the hardness from 171 to 446.

Bixby. The public water supply of Bixby comes from springs that issue from the alluvium on the north side of the Arkansas River, about 2.5 miles northeast of town. From the springs the water is pumped through a 6-inch pipe line by a pump having a rated capacity of 250 gallons per minute. Storage is afforded by one tank of 55,000 gallons capacity. The water is given no chemical treatment. For emergency use Bixby also has a well within the city limits. The water from it is regarded as too hard for regular use.

Jenks. The town of Jenks obtains its public water supply from a well in alluvium within the town limits. Storage facilities consist of a stand pipe with a capacity of 60,000 gallons. The water, which is reported to be rather hard, is given no chemical treatment.

APPENDIX A

MEASURED STRATIGRAPHIC SECTIONS IN TULSA COUNTY AND PARTS OF ADJACENT COUNTIES

TOWNSHIP 16 NORTH

	Feet
1. SEC. 2, T. 16 N., R. 12 E. FROM STREAM ¼ MILE SOUTH OF NE CORNER, SOUTHWARD TO THE TOP OF THE HILL.	
Seminole formation.	
3. Sandstone: lower sandy part of the Seminole, top eroded, not measured.	
Holdenville (Memorial) shale.	
2. Covered, shale: about	20.0
1. Limestone: dark, weathers yellow; a few fossils	1.0

2. SEC. 13, T. 16 N., R. 12 E. MEASURED FROM THE LIMESTONE FLAGS ABOUT 1/10 MILE WEST OF THE SE CORNER WESTWARD TO THE BASE OF THE SANDSTONE THAT CAPS THE OUTLYING HILL ¼ MILE EAST OF THE S¼ CORNER.

	Feet
Holdenville (Memorial) shale.	
3. Sandstone, poorly exposed, not measured.	
2. Covered: gullies in secs. 13 and 14 indicate silty shale and a few siltstone beds. One mile south a limestone less than 1 foot thick occurs a few feet below this sandstone. West dip allowed 10 feet	120.0
Lenapah (Eleventh Street) limestone.	
The Lenapah limestone is not exposed in this section. Eight miles north it is present as a sandy limestone at the base of a sandstone immediately above the platy limestone and calcareous shale.	
Nowata shale.	
1. Alternating platy limestones and calcareous shale, base not exposed, not measured.	

3. SEC. 15, T. 16 N., R. 12 E. MEASURED FROM THE LIMESTONE FLAGS IN THE NE¼ SW¼ TO THE BASE OF THE SEMINOLE FORMATION IN THE NW¼ SW¼.

	Feet
Seminole formation, lower part.	
6. Sandstone: poorly exposed, top eroded, about	10.0
Holdenville (Memorial) shale.	
5. Covered, probably shale	55.0
4. Alternating flaggy limestone beds and calcareous shale, a bed of fossiliferous limestone at the top 0.5 ft. thick, total thickness	10.0
3. Shale: dark, silty	4.0
2. Sandstone, silty: weathers reddish-brown, thin irregular bedding	2.0
1. Siltstone: limy appearance, thin wavy to ripply marked beds, base not exposed	4.0

4. SEC. 15, T. 16 N., R. 12 E. MEASURED IN THE VICINITY OF THE SE CORNER.

Holdenville (Memorial) shale, somewhat above the middle.

	Feet
4. Sandstone: poorly exposed, fine-grained, thin-bedded; weathers brown, top eroded, exposed in road at section corner	10.0
3. Covered, probably silty shale	20.0
2. Sandstone: fine-grained, weathers reddish-brown, 1/8 mile down stream is about	5.0
1. Siltstone, shaly: base not exposed, measured in stream	6.0

5. SEC. 15, T. 16 N., R. 12 E. FROM BASE OF SANDSTONE IN HILL SOUTH OF STREAM ¼ MILE SOUTH OF NE COR. TO E¼ CORNER.

Holdenville (Memorial) shale, somewhat above the middle.

2. Sandy silty shale and sandstone: covered by sandy soil for the most part, top eroded, thickness 30 feet, presence of limy plates on slope west of E¼ corner leads to estimate that about 10 feet of this member has been eroded giving a total estimated thickness of about	40.0
1. Covered, probably shale.	

6. SEC. 16, T. 16 N., R. 12 E. FROM TOP OF THE MASSIVE SANDSTONE IN THE CREEK BED BELOW THE DAM AT THE OLD MOUNDS WATER WORKS NEAR THE S¼ CORNER TO THE SW CORNER.

Seminole formation.

5. Sandstone: massive at base, top shaly, about	5.0
4. Shale, contains coal: poorly exposed, about	4.0
3. Sandstone: poorly exposed, base of upper sandy member, about	5.0
2. Covered, shale: limestone about 0.5 feet thick about 5 feet from the top indicated by fossiliferous fragments not in place, the Dawson coal should occur near the base, about	55.0
1. Sandstone: lower sandy member, below old dam, fine-grained, massive; weathers brown; base not exposed here, about 15 feet thick across creek to east about 1/8 mile, exposed	5.0

7. SEC. 17, T. 16 N., R. 12 E. FROM THE CREEK BED 200 FEET EAST OF THE NW CORNER OF THE MOUNDS CEMETERY SOUTHWARD TO THE OUTCROP OF THE CHECKERBOARD LIMESTONE 400 FEET WEST OF THE S¼ CORNER. THE CHECKERBOARD CROPS OUT OBSCURELY ON A DIP SLOPE.

Checkerboard limestone.

9. Limestone, not measured.

Seminole formation, upper part.

8. Covered: lower half probably silty shale, upper half probably clay shale	30.0
7. Sandstone: fine-grained, silty and grades upward into silty shale; weathers brown	5.0
6. Shale: gray, laminated, silty	2.0
5. Shale: black; thin-bedded, contains coal streaks 0.5 feet or more thick, not Dawson coal	2.0
4. Sandstone: thin-bedded, weathers brown	3.0
3. Sandstone: massive, fine-grained; weathers brown	3.0
2. Shale: poorly exposed down to bed of creek	30.0
1. Creek bed on dark clay shale.	

TOWNSHIP 17 NORTH

8. SEC. 2, T. 17 N., R. 12 E. MEASURED FROM THE OLD STRIP PIT OR CREEK CHANNEL EAST OF THE ABANDONED RAILROAD GRADE NEAR THE CENTER OF THE SECTION WESTWARD TO THE BASE OF THE UPPER

	Feet
SANDY MEMBER OF THE SEMINOLE IN THE ROAD ALONG THE WEST SIDE OF THE NW OF THE SECTION.	
Seminole formation, upper sandy part and middle shaly part.	
6. Sandstone: thin-bedded, silty, top not exposed	10.0
5. Limestone: weathers reddish-brown, fossiliferous, in part a limonitic siltstone	0.2
4. Shale: dark; weathers yellowish-gray	43.0
3. Shale: black, fissile, contains phosphatic nodules	4.0
2. Shale: dark, efflorescent, contains black sideritic or calcareous concretions	8.0
1. Coal: probably top of the Dawson, thin stringers, covered by water in the pit	0.1

9. SECS. 10 & 15, T. 17 N., R. 12 E. FROM DAWSON COAL IN AN OLD STRIP PIT 300 FEET SOUTHWEST OF NE CORNER SECTION 15 TO CHECKERBOARD LIMESTONE 300 FEET NORTH OF S. ¼ CORNER SECTION 10.

Checkerboard limestone.	
4. Limestone, not measured.	
Seminole formation.	
3. Covered, sandy shale	45.0
2. Sandstone, silty to shaly: poorly exposed, lower part of the upper sandy member	15.0
1. Covered, shale: extends down practically to the Dawson coal which was mined in this pit but is not now exposed	40.0

10. SEC. 13, T. 17 N., R. 12 E. FROM LIMESTONE OUTCROP A SHORT DISTANCE SOUTH OF E¼ CORNER SEC. 13. NORTHWARD ABOUT ¼ MILE TO THE BASE OF THE SEMINOLE FORMATION.

Seminole formation.	
6. Sandstone: not measured.	
Holdenville (Memorial) shale.	
5. Shale: weathers gray	20.0
4. Limestone: dark, dense; weathers brown to yellow; nonfossiliferous	0.8
3. Shale: gray	3.0
2. Limestone: dark; weathers yellow; fossiliferous	0.5
1. Shale: not measured.	

11. SEC. 13, T. 17 N., R. 12 E. FROM THE LIMESTONE OUTCROP NORTH SIDE OF THE ROAD ¼ MILE EAST OF THE NE CORNER WESTWARD ALONG THE ROAD TO THE NORTHWEST CORNER.

Seminole formation, lower sandy part.	
5. Shale: not measured.	
4. Sandstone: medium- to fine-grained; weathers reddish-brown; thin beds of sandy to silty shale, one thin limestone bed about 5 feet from the top	35.0
Holdenville (Memorial) shale.	
3. Shale: weathers grayish-yellow	10.0
2. Limestone: dense, dark-bluish; nonfossiliferous	0.8
1. Shale: not measured.	

12. SEC. 13, T. 17 N., R. 12 E. MEASURED FROM THE BASE OF THE LOWER SANDY MEMBER OF THE SEMINOLE WEST OF THE SOUTHEAST CORNER EASTWARD TO CORNER THENCE SOUTHEASTWARD TO TOP OF HILL.

Seminole formation, lower sandy part.	
3. Covered to top of hill, probably sandstone, about	20.0
2. Sandstone: gray to brown; relatively coarse-grained compared with other sandstones of the region, massive to thin-bedded, cross-bedded in part; some plant fossils	40.0

	Feet
Holdenville (Memorial) shale.	
1. Covered slope, probably dark shale, not measured.	

13. SEC. 15, T. 17 N., R. 12 E. FROM LIMESTONE IN ROAD IMMEDIATELY WEST OF SE CORNER SECTION TO CHECKERBOARD LIMESTONE IN ROAD IMMEDIATELY SOUTH OF S¼ CORNER.

	Feet
Coffeyville formation, basal part.	
7. Shale, not measured.	
Checkerboard limestone.	
6. Limestone: dark; weathers yellow; fossiliferous	1.5
Seminole formation, upper sandy part.	
5. Shale	10.0
4. Covered, shale, silty: dip allowed 20 feet, about	40.0
3. Covered, seems to be silty sandstone: about	10.0
2. Limestone: gray; weathers brown to red; fossiliferous, top of middle shaly part	1.5
1. Shale: poorly exposed, not measured.	

14. SEC. 34, T. 17 N., R. 12 E. FROM THE TOP OF THE LOWER SANDY MEMBER OF THE SEMINOLE ¼ MILE EAST OF SE CORNER TO THE BASE OF THE UPPER SANDY MEMBER AT THE SW CORNER.

	Feet
Seminole formation.	
3. Sandstone: silty and shaly, upper sandy member of the Seminole, not measured.	
2. Covered: middle shale member of the Seminole, west dip allowed 50 feet per mile, the Dawson coal does not crop out but is near the base of this shale	50.0
1. Sandstone, top of the lower sandy member of the Seminole, not measured.	

15. SEC. 34, T. 17 N., R. 12 E. FROM THE CHECKERBOARD LIMESTONE ¼ MILE WEST OF THE NW CORNER TO BASE OF UPPER SANDY MEMBER OF THE SEMINOLE ¼ MILE WEST OF NE CORNER.

	Feet
Coffeyville formation, basal part.	
5. Shale, not measured.	
Checkerboard limestone.	
4. Limestone: poorly exposed, usually	1.5
Seminole formation.	
3. Shale	10.0
2. Covered, silty sandstone and silty shale: base of upper sandy part	50.0
1. Shale: not measured.	

16. SEC. 35, T. 17 N., R. 12 E. FROM THE BASE OF THE LOWER SANDY MEMBER OF THE SEMINOLE ¼ MILE NORTH OF THE SE CORNER TO THE TOP OF THE LOWER SANDY MEMBER ¼ MILE EAST OF THE SW CORNER.

	Feet
Seminole formation.	
3. Shale: not measured.	
2. Sandstone: coarse to medium-grained; weathers brownish-red, good exposure east side of sec. 35, west dip allowed 50 feet per mile, lower sandy part of the Seminole	30.0
Holdenville (Memorial) shale.	
1. Shale, not measured.	

17. SEC. 36, T. 17 N., R. 12 E. FROM SE CORNER WESTWARD ALONG ROAD 5/8 MILE. WEST DIP ALLOWED 50 FEET PER MILE.

Feet

Holdenville (Memorial) shale.

4. Shale: not measured.
3. Limestone: poorly exposed, about 1.5
2. Covered, shale: about 45.0
1. Sandstone: top poorly exposed, not measured.

18. SEC. 4, T. 17 N., R. 13 E. UP THE BLUFF SOUTH OF THE ARKANSAS RIVER NEAR A HOUSE IN THE VICINITY OF THE WEST ¼ CORNER.

Holdenville (Memorial) shale.

6. Limestone: caps hill northwest of house, dark to brown; flaggy, coquinoid, many crinoid stems, top eroded 3.0
5. Covered: probably shale 30.0
4. Bench: probably a thin limy sandstone 2.0
3. Covered: probably shale 10.0

Lenapah (Eleventh Street) limestone.

2. Sandstone, limy: gray to brown; fine-grained, appears massive where fresh; weathers in thin beds, about 10.0

Wewoka formation.

1. Covered talus slope; extends down to the alluvium 40.0

19. SEC. 5, T. 17 N., R. 13 E. MEASURED IN THE SE NE UP HILL EAST OF THE ROAD WHICH FOLLOWS A DRAW IN THE NE¼ OF THE SECTION.

Holdenville (Memorial) shale.

4. Limestone: gray to brown; coquinoid, flaggy, many crinoids; not well exposed 8.0
3. Covered: probably shale 34.0

Lenapah (Eleventh Street) limestone.

2. Sandstone: gray to brown; massive to thin-bedded, fine-grained, lower part limy 5.0

Wewoka formation.

1. Sandy, limy flags, and silty shale: in east bank of road cut, extends down to alluvium by small bridge 17.0

20. SEC. 5, T. 17 N., R. 13 E. MEASURED IN THE SW¼ NE¼ FROM THE STREAM BED UP SPUR OF HILL SOUTHWESTWARD, WEST OF ROAD.

Seminole formation, basal part.

9. A few pieces of reddish-gray, limy sandstone not in place together with badly weathered and shattered brown, medium- to coarse-grained, sandstone further up the slope indicates that the base of the Seminole lies immediately above No. 8.

Holdenville (Memorial) shale.

8. Covered: probably shale 30.0
7. Limestone: brown, weathers yellow; splits and breaks into thin pieces, about 5.0
6. Shale, grayish yellow 25.0
5. Covered: probably shale 15.0
4. Limestone: gray to brown; coquinoid, not well exposed, about 6.0
3. Covered; probably shale 35.0

Lenapah (Eleventh Street) limestone.*

2. Sandstone: brown; fine-grained, lower part limy 5.0

Wewoka formation.

1. Sandy limestone flags and silty shale, base not exposed 20.0

*From the middle of T. 19 N. to the south side of T. 17 N. the Lenapah (Eleventh Street) limestone is underlain by a zone of limy flags and calcareous shale several feet thick.

Feet

At this place the flags are sandy and the shale beds silty. The Lenapah is generally sandy in this latitude, and at most places is overlain by a sandstone into which the limestone grades vertically and probably laterally. This sandstone is, in this work, classified as Lenapah.

21. SECS. 7 & 8, T. 17 N., R. 13 E. FROM WEST BANK OF STREAM ABOUT 1/8 MILE WEST OF SE CORNER SECTION 8, TO LIMESTONE OUTCROP A SHORT DISTANCE WEST OF S¼ CORNER SECTION 7.

Holdenville (Memorial) shale.

4. Shale: not measured.
3. Limestone: dark, dense; nonfossiliferous 0.8
2. Covered: lower part sandy, upper part silty to clay shale, allowing west dip of 50 feet per mile 165.0

Lenapah (Eleventh Street) limestone.

1. Sandstone: basal bed slightly limy in this exposure and is a sandy limestone both northward and southward, about 10.0

22. SEC. 9, T. 17 N., R. 13 E. MEASURED FROM THE STREAM AT THE NORTHEAST CORNER WESTWARD TO THE TOP OF THE HILL.

Holdenville (Memorial) shale.

9. Covered: top eroded, not measured.

Lenapah (Eleventh Street) limestone.

8. Sandstone: deeply weathered, lower part at least is equivalent to the Lenapah 10.0

Wewoka formation.

7. Covered: seems to be a calcareous shale with a few limestone flags 12.0
6. Limestone flags and calcareous shale 6.0
5. Shale: dark, calcareous 17.0
4. Limestone: dark, weathers yellow; few fossils 0.5
3. Shale: calcareous 1.5
2. Limestone: dark, weathers yellow; few fossils 1.0
1. Limestone flags and calcareous shale 25.0

23. SEC. 9, T. 17 N., R. 13 E. MEASURED FROM THE CREEK ¼ MILE NORTH OF THE SOUTHEAST CORNER UP HILL SOUTHWARD THEN WESTWARD TO A HOUSE AT THE TOP OF THE RIDGE.

Wewoka formation.

4. Limestone flags and calcareous shale, top eroded, about 10.0
3. Covered: apparently calcareous shale 10.0
2. Limestone flags and calcareous shale: dark, weathers yellow 49.0
1. Shale: dark clay shale, base not exposed 18.0

24. SEC. 10, T. 17 N., R. 13 E. MEASURED FROM THE SOUTHEAST CORNER WESTWARD TO TOP OF HILL.

Holdenville (Memorial) shale(?)

8. Sandstone: fine-grained, deeply weathered, brown, top eroded 10.0

Lenapah (Eleventh Street) limestone.

7. Limestone, sandy: massive, a few fossils 1.0

Wewoka formation.

6. Limestone flags and calcareous shale 13.0
5. Shale: probably calcareous 20.0
4. Limestone flags and calcareous shale 18.0
3. Covered: probably calcareous shale with a few flags 7.0
2. Limestone flags and calcareous shale 10.0
1. Covered: probably dark shale 18.0

Note: the limestone flags and calcareous shales of this section weather yellow.

Feet

25. SEC. 18, T. 17 N., R. 13 E. MEASURED FROM THE N¼ CORNER WESTWARD TO THE TOP OF THE HILL.

Seminole formation, basal part.

4. Sandstone: medium-grained, thin-bedded; weathers brown.... 10.0

Holdenville (Memorial) shale.

3. Shale: gray 22.0
2. Limestone: weathers buff; fossiliferous, poorly exposed, about 1.0
1. Covered: a few exposures in road ditches indicate dark shale 40.0

26. SEC. 31, T. 17 N., R. 13 E. FROM 200 FEET EAST OF SOUTHEAST CORNER WEST TO SOUTHWEST CORNER. WEST DIP ALLOWED 50 FEET PER MILE.

Holdenville (Memorial) shale.

3. Shale: not measured.
2. Sandstone: medium- to fine-grained; weathers reddish brown, about 15.0
1. Shale: not measured.

27. SEC. 32, T. 17 N., R. 13 E. FROM SOUTHEAST CORNER TO THE BASE OF A SANDSTONE IMMEDIATELY EAST OF THE SOUTHWEST CORNER.

Holdenville (Memorial) shale.

6. Sandstone: not measured.
5. Shale 7.0
4. Limestone: dark, weathers yellow; coquinoid, about 1.0
3. Covered: probably shale 97.0

Lenapah (Eleventh Street) limestone.

2. Covered: sandstone at this horizon in stream ½ mile west, farther north the limy basal portion is equivalent to the Lenapah (Eleventh Street) limestone, about 25.0

Wewoka formation.

1. Limestone flags and shale not measured. Farther north the Lenapah limestone immediately overlies this zone.

28. SEC. 13, T. 17 N., R. 14 E. FROM LIMESTONE OUTCROP A SHORT DISTANCE SOUTH OF E¼ CORNER NORTHWARD ABOUT ¼ MILE TO THE BASE OF THE SEMINOLE FORMATION.

Seminole formation, basal part.

6. Sandstone, not measured.

Holdenville (Memorial) shale.

5. Shale: weathers gray 20.0
4. Limestone: dark, dense; weathers brown to yellow; nonfossiliferous 0.8
3. Shale: gray 3.0
2. Limestone: dark; weathers yellow, fossiliferous 0.5
1. Shale: not measured.

29. SEC. 34, T. 17 N., R. 14 E. MEASURED IN THE VICINITY OF THE CENTER OF THE NE¼ FROM THE EXPOSURE OF LIMESTONE IN THE NORTH-SOUTH ROAD ALONG THE ROAD SOUTHWARD.

Wewoka formation (includes representatives of Calvin sandstone and Wetumka shale).

18. Covered by sandstone rubble: probably similar to Nos. 1 to 17 60.0
17. Shale: weathers red 2.0
16. Sandstone: fine-grained, weathers reddish brown 2.0
15. Shale: dark, weathers red 8.0
14. Sandstone: massive, fine-grained, two layers 2.0
13. Shale: weathers red 9.0

	Feet
12. Sandstone: dense, massive, fine-grained	1.0
11. Shale: dark, weathers red	5.0
10. Sandstone: fine-grained	1.0
9. Shale: dark, weathers red	17.0
8. Sandstone: fine-grained	1.0
7. Shale	4.0
6. Shale and thin sandstone beds	1.0
5. Sandstone	1.0
4. Shale: dark, weathers gray	7.0
3. Sandstone: silty	2.0
Fort Scott limestone.	
Little Osage shale member.	
2. Shale: black, fissile, contains phosphatic nodules	4.0
Higginsville limestone member.	
1. Limestone: about	9.0

TOWNSHIP 18 NORTH

30. SEC. 1, T. 18 N., R. 12 E. MEASURED IN THE NE¼ SW¼, FROM THE ALLUVIUM EAST OF THE SOUTH END OF TURKEY MOUNTAIN TO THE TOP OF THE MOUNTAIN, SUPPLEMENTED BY MEASUREMENTS ¼ MILE NORTH.

Coffeyville formation, lower part.	
19. Covered to the top of the hill: probably thin sandstone and sandy shale beds	12.0
18. Sandstone: fine-grained; weathers gray to brown, a single massive bed	5.0
17. Sandstone: coarse-grained; weathers gray to brown, a single massive bed	4.5
16. Covered: probably shale	20.0
Checkerboard limestone.	
15. Limestone: dark, massive; weathers gray red or yellow; fossiliferous, about	2.5
Seminole formation.	
14. Covered: probably shale	19.0
13. Bench, sandstone, about	5.0
12. Covered: probably shale	15.0
11. Bench, sandstone, about	3.0
10. Covered: probably shale	20.0
9. Sandstone: gray; weathers yellow to red, usually brown; medium-coarse-grained, beds 2 to 6 inches thick	18.0
8. Sandstone: gray; weathers yellow to red, usually brown; medium-coarse-grained, bedding planes almost absent	6.0
7. Covered: probably shale	17.0
6. Sandstone: gray; weathers yellow to red, usually brown; medium-coarse-grained, bedding planes almost absent, base of the upper, sandy member	25.0
5. Covered: probably shale	45.0
4. Coal: Dawson, an abandoned slope mine but coal not exposed, said to be	2.5
3. Covered: probably shale, about	5.0
2. Sandstone: poorly exposed, very coarse quartz sand; weathers yellow to brown; ferruginous cement, occasional soft white flakes are probably weathered chert fragments about	18.0
1. Covered: a sandy slope down to the alluvium of Arkansas River	45.0

31. SEC. 1, T. 18 N., R. 12 E. MEASURED ALONG THE SOUTH LINE OF THE SW¼.

Seminole formation, lower part.	
4. Shale: gray; silty, limonitic streaks, top eroded	10.0

	Feet
3. Sandstone: gray, coarse-grained; weathers reddish-brown to buff; beds 0.2 to 2.0 feet thick, many bands of small cavities, cross bedded	23.0
2. Shale: gray	2.0
1. Covered: down to the alluvium of Arkansas River	55.0

32. SEC. 2, T. 18 N., R. 12 E. MEASURED IN THE ROAD IMMEDIATELY SOUTH OF THE NORTHWEST CORNER.

Coffeyville formation.	
9. Sandstone: beds 6 inches to 1 foot thick, these are the same sandstone beds that were quarried by the W.P.A. for building the armory on the fair grounds in Tulsa. The quarry is in SE¼ section 34, T. 19 N., R. 12 E., not measured.	
8. Shale: gray, contains a few limonitic silty streaks	10.0
7. Sandstone: coarse, weathers brown to red; contains phosphatic nodules	1.0
6. Shale: black, fissile; contains phosphatic nodules	5.0
5. Shale: not well exposed	6.0
Checkerboard limestone.	
4. Limestone: weathers yellow; few fossils, cracks filled with calcite, a lense higher than the main Checkerboard, not more than	1.0
3. Covered: probably shale	5.0
2. Limestone: poorly exposed, the regular, persistent Checkerboard limestone	2.5
Seminole formation.	
1. Covered, shale: not measured.	

33. SEC. 25, T. 18 N., R. 12 E. MEASURED FROM THE SE CORNER WESTWARD UP THE HILL.

Seminole formation.	
9. Covered: probably part of the middle shale	35.0
8. Covered: probably sandstone, upper part of the lower sandstone	10.0
7. Sandstone: yellowish-gray	1.0
6. Shale: gray, poorly exposed, about	1.0
5. Sandstone: gray to brown; medium-grained, massive, about	1.5
4. Covered: probably shale and thin siltstone beds	12.0
3. Limestone: flaggy and packed with fossil fragments, poorly exposed; probably the base of the Seminole formation	1.0
Holdenville (Memorial) shale.	
2. Shale: poorly exposed	15.0
1. Covered	8.0

34. SEC. 26, T. 18 N., R. 12 E. MEASURED AT THE BRIDGE IMMEDIATELY WEST OF THE SE CORNER.

Seminole formation, lower sandy part.	
3. Shale: gray, silty, top eroded	8.0
2. Sandstone: gray to brown; relatively coarse-grained, thin irregular bedding, pockets and little cavities indicate original limy content	22.0
1. Covered	15.0

35. SEC. 33, T. 18 N., R. 12 E. MEASURED IN THE WEST BANK OF THE CREEK IN SE¼ SE¼ SE¼ OF THE SECTION.

Coffeyville formation, basal part.	
3. Covered: not measured.	
Checkerboard limestone.	
2. Limestone: dark, massive; weathers yellow	2.5

Feet

Seminole formation.

1. Shale: dark, occasional limonitic siltstone streaks in lower part; base not exposed 20.0

36. SEC. 34, T. 18 N., R. 12 E. COMPILED FROM A BAROMETRIC PROFILE ALONG THE SOUTH SIDE OF THE SECTION, EXTENDING A LITTLE EAST OF THE SE CORNER. THE WESTWARD COMPONENT OF DIP IS ABOUT 60 FEET PER MILE.

Coffeyville formation, basal part.

4. Covered: not measured.

Checkerboard limestone.

3. Limestone, about 2.5

Seminole formation.

2. Shale with some limonitic siltstone bands in the lower part, about 35.0
1. Sandstone, silty: the base of the upper sandy part, about........ 20.0

37. SEC. 35, T. 18 N., R. 12 E. NOS. 1 AND 2 MEASURED IN THE WEST WALL OF AN OLD STRIP PIT (DAWSON COAL) CENTER OF THE SW¼, NOS. 3, 4, 5, AND 6 MEASURED IN THE EAST-WEST ROAD NEAR THE SW CORNER.

Seminole formation.

6. Sandstone, silty: base of the upper sandy member, not measured, top eroded.
5. Shale, silty, about 2.0
4. Limestone: fossiliferous, weathers yellow, less than 1.0
3. Covered: probably dark shale 35.0
2. Shale: black; fissile, with phosphatic nodules 2.0
1. Shale: dark; in the lower part of the middle shale member.... 12.0
   Note: The Dawson coal is not visible in this old strip pit at the present time but is known to lie only a few feet below the base of this section. Note the difference between this normal section above the Dawson coal and the section in sec. 30, T. 18 N., R. 13 E., which shows a coal thought to be just above the base of the Seminole.

38. SEC. 3, T. 18 N., R. 13 E. FROM THE NW CORNER SOUTHWARD TO THE TOP OF THE HILL.

Seminole formation.

5. Sandstone: fine-grained, thin-bedded, weathers brown, base channeled, top eroded 5.0

Holdenville (Memorial) shale.

4. Siltstone and silty shale 23.0
3. Covered: probably silty shale 57.0
2. Shale: silty 14.0
1. Covered: probably silty shale 3.0

39. SEC. 4, T. 18 N., R. 13 E. MEASURED FROM A POINT 200 FEET SOUTH OF THE SW CORNER NORTHWARD ALONG THE ROAD TO THE TOP OF THE HILL.

Seminole formation, lower sandy part.

9. Sandstone: brown, thin-bedded, top eroded 30.0
8. Shale, silty and sandstone, fine-grained, thin beds: Brown...... 8.0

Holdenville (Memorial) shale.

7. Shale: yellowish-brown clay shale 13.0
6. Limestone: gray, brown, or red; fossiliferous; ¼ mile to the northeast this bed is 5 feet thick and fossiliferous........ 2.0
5. Covered: probably shale 37 0

	Feet
4. Sandstone: exposed at the cross roads; brown, fine-grained, thin-bedded, about	5.0
Lenapah (Eleventh Street) limestone.	
3. Limestone: fossiliferous, well exposed in draw west of house and south of road, generally about	3.0
Nowata shale.	
2. Shale and limestone flags, a few beds of fossiliferous limestone	17.0
1. Shale: weathers yellow; base not exposed, extends down to bed of creek, about	5.0

40. SEC. 9, T. 18 N., R. 13 E. FROM THE BRIDGE ABOUT ½ MILE WEST OF THE NE CORNER UP HILL EASTWARD TO THE CORNER.

Seminole formation, lower sandy part.	
10. Sandstone: fine-grained, massive to rudely laminated	28.0
9. Shale, silty: gray	2.0
8. Sandstone: gray to brown, fine-grained	1.0
7. Shale, silty: weathers gray	5.0
6. Sandstone: gray; fine-grained, rudely laminated	20.0
5. Sandstone: massive	5.0
4. Sandstone: fine-grained to silty, rudely laminated; coal intercalated in lower part	10.0
3. Siltstone to silty sandstone (laterally), rudely laminated, about	4.0
Lenapah (Eleventh Street) limestone.	
2. Sandstone: fine-grained, weathers brown; lower part rudely laminated and limy, upper part massive	2.5
Nowata shale.	
1. Clay shale: dark, base not exposed	5.0

41. SEC. 10, T. 18 N., R. 13 E. FROM NE CORNER WESTWARD TO TOP OF HILL.

Seminole formation.	
9. Sandstone: lower sandy part, gray to brown; fine-grained to silty, roughly laminated, top eroded	10.0
Holdenville (Memorial) shale.	
8. Shale, sandy and silty, micaceous	5.0
7. Sandstone: fine-grained, micaceous, massive with irregular bedding or banding	5.0
6. Shale: weathers dark	26.0
5. Sandstone: fine-grained, weathers brown	3.0
4. Shale: gray, weathers brown	23.0
3. Sandstone: fine-grained to silty, some bands of silty shale, all unevenly laminated	6.0
Lenapah (Eleventh Street) limestone.	
2. Sandstone: limy, fossiliferous, crinoid stems and wood	2.0
Nowata shale.	
1. Silty shale: base not exposed	10.0

42. SEC. 15, T. 18 N., R. 13 E. FROM NW CORNER UP HILL SOUTHWARD.

Seminole formation.	
14. Sandstone: poorly exposed, weathers brown; top eroded, base of the upper sandy part	17.0
13. Partly covered, exposures poor, probably all shale, middle shaly part	28.0
12. Sandstone: gray, fine-grained, unevenly laminated; lower sandy part	40.0

	Feet
Holdenville (Memorial) shale.	
11. Shale: gray, a few silty streaks in the upper part	40.0
Lenapah (Eleventh Street) limestone.	
10. Sandstone: brown, a few fossils	0.2
9. Shale	1.5
8. Sandstone: brown, fossiliferous	0.1
7. Shale: silty, weathers gray	3.0
6. Sandstone: limy, fossiliferous, weathers brown	0.2
5. Shale: weathers gray	3.0
4. Limestone: ferruginous, weathers brown, some fossils like those in No. 2	0.2
3. Shale: dark, weathers gray to brown	8.0
2. Limestone: gray, weathers yellowish brown, ferruginous streaks along partings; contains crinoids, brachiopods, bryozoans, corals	2.0
Nowata shale.	
1. Covered: probably dark shale	26.0

43. SEC. 30, T. 18 N., R. 13 E. MEASURED FROM THE ALLUVIUM EAST OF THE S¼ CORNER UP RAVINE TO OLD COAL MINE THEN CONTINUING NORTHWESTWARD TO TOP OF HILL.

Seminole formation, lower sandy part.	
13. Sandstone: poorly exposed, massive to thin-bedded, top eroded	10.0
12. Sandstone: silty, thin-bedded	8.0
11. Covered: probably shale	3.0
10. Covered to mouth of slope, well exposed near by, shale	12.0
9. Coal: poorly exposed, said to be	1.5
8. Covered: shale	2.0
7. Sandstone: medium-grained, weathers brown	4.0
6. Shale: not well exposed	23.0
5. Siltstone: thin-bedded	8.0
4. Shale: dark, silty	5.0
3. Shale: dark clay	5.0
2. Sandstone: weathers brown, fine-grained, thin-bedded	12.0
Holdenville (Memorial) shale.	
1. Covered: ravine is choked with sandstone debris and a minor amount of coquinoid limestone fragments	45.0

44. SEC. 31, T. 18 N., R. 13 E. MEASURED UP A DRAW AND HILLSIDE ABOUT 1/8 MILE SOUTHEAST OF THE N¼ CORNER. THIS IS SOUTH OF THE CHANNEL OF POLECAT CREEK BUT IS IN THE OLD BLUFF OF THE ARKANSAS RIVER ON THE SOUTH SIDE.

Seminole formation, lower sandy part.	
15. Covered: not measured.	
14. Coal streak in road	0.1
13. Covered: probably shale	6.0
12. Poorly exposed, thin sandstone beds and shale	6.0
11. Covered: probably sandy shale	5.0
10. Sandstone: light gray to reddish-brown; massive, rough, medium-grained, about	2.0
9. Covered: probably shale	23.0
8. Sandstone: medium-grained, weathers reddish-brown, thin wavy beds	15.0
Holdenville (Memorial) shale.	
7. Covered; no doubt shale and thin sandstones, probably some thin limestones	55.0
6. Limestone: dark, crystaline, weathers red, massive; contains crinoids, corals, bryozoa, brachiopods	0.8

	Feet
5. Covered, for most part: a few exposures of dark shale	18.0
Lenapah (Eleventh Street) limestone.	
4. Limestone: dark, weathers red to gray, similar to No. 2, contains crinoids, bryozoans, and unidentified fragments	3.0
Wewoka formation.	
3. Shale: dark, marly; some fossil fragments, thin streaks of limestone	3.0
2. Limestone: dark, thin-bedded to flaggy; extremely fossiliferous, contains many crinoid stems	2.5
1. Covered down to water level in Polecat Creek	6.0

45. SEC. 11, T. 18 N., R. 14 E. LOWER PART OF THE OOLOGAH LIMESTONE IN PIT DUG FOR CITY WATER TANK IN TOP OF OUTLIER NORTHEAST OF THE TOWN OF BROKEN ARROW, NE¼ NE¼ SEC. 11, T. 18 N., R. 14 E.

Oologah formation.	
3. Limestone: gray to dark bluish; siliceous; irregular lenticular beds, 0.1 to 1.0 feet thick	10.0
2. Limestone: dark bluish to pink; massive, siliceous	1.0
1. Limestone: dark bluish; siliceous, no fossils, beds rather even and regular 0.1 to 0.5 feet thick	6.0

46. SEC. 13, T. 18 N., R. 14 E. FROM THE LIMESTONE OUTCROP IN THE DITCH, NORTH SIDE OF THE RAILROAD GRADE, WEST OF THE CREEK, AND ABOUT 600 FEET WEST OF THE EAST LINE OF THE SECTION; WEST AND NORTH TO THE BASE OF THE BREEZY HILL LIMESTONE ON THE HILL SOUTH OF A HOUSE. DISTANCE INVOLVED ABOUT ½ MILE AND THE DIP ALLOWED 15 FEET, NORTHWESTWARD.

Senora formation.	
6. Limestone: Breezy Hill; top eroded, not measured.	
5. Covered: probably shale	40.0
4. Sandstone: fine-grained, thin-bedded	5.0
3. Sandstone and shale: in thin alternating bands, all silty	3.0
2. Limestone: a single massive bed, dark; weathers yellow; fossiliferous, fragments of crinoids, bryozoans, large brachiopods (Spirifer?) and large myalyna-like pelecypods	2.0
1. Sandstone: gray, fine-grained to silty, top only exposed.	

47. SEC. 13, T. 18 N., R. 14 E. IN A DRAW SOUTH OF THE RAILROAD AND NEAR THE CENTER OF THE SECTION.

Labette shale.	
4. Covered: probably shale, not measured.	
Fort Scott limestone.	
3. Limestone: dark, weathers brown to yellow; wavy beds 1 to 6 inches	5.0
Senora formation	
2. Shale: black, fissile; contains phosphatic nodules	2.5
1. Clay shale: dark, extends down to stream, base not exposed	4.0

48. SEC. 27, T. 18 N., R. 14 E. IN A RAVINE WEST OF THE ROAD AND 0.4 MILE NORTH OF THE SOUTHEAST CORNER. TOP OF THE SECTION JUST NORTH OF THE HOUSE AND BASE WEST OF THE HOUSE.

Labette shale.	
4. Covered: probably shale.	
Fort Scott limestone.	
3. Limestone: dark, weathers white to buff, fossiliferous	5.0

	Feet
Senora formation.	
2. Shale: black, fissile; contains phosphatic nodules	2.5
1. Limestone: Breezy Hill, gray, fossiliferous; base not exposed	1.0

49. SEC. 7, T. 18 N., R. 15 E.; SEC. 11, T. 18 N., R. 14 E. MEASUREMENTS ALONG THE NORTH SIDE OF SEC. 18, T. 18 N., R. 15 E. INDICATE THAT THE WESTWARD COMPONENT OF DIP IS 50 FEET PER MILE. AS THERE IS NO EVIDENT INDICATION THAT DIP CHANGES ABRUPTLY THE SAME FIGURE IS USED FOR THIS TRAVERSE. THE SECTION IS MEASURED FROM AN OUTCROP OF FT. SCOTT LIMESTONE NEAR THE N¼ CORNER SEC. 7, T. 18 N., R. 15 E. WESTWARD TO THE BASE OF THE OOLOGAH LIMESTONE IN THE RESERVOIR HILL, NE CORNER SECTION 11, T. 18 N., R. 14 E. DISTANCE 1½ MILES. THE MEASURED DIFFERENCE IN ELEVATION IS 110 FEET TO WHICH IS ADDED 75 FEET FOR DIP, GIVING AN INTERVAL OF 185 FEET.

Oologah formation.	
3. Limestone: poorly exposed, top eroded, about	15.0
Labette Shale.	
2. Covered: probably shale, some sandstone in the upper part	185.0
Ft. Scott limestone.	
1. Limestone: not measured.	

TOWNSHIP 19 NORTH

50. SEC. 11 to 4, T. 19 N., R. 9 E. FROM RAILROAD CUT AND BRIDGE ON SALT CREEK NW¼ SEC. 11, ALONG STATE HIGHWAY NO. 51 TO BASE OF A THICK SANDSTONE AT THE TOP OF THE HILL ¼ MILE WEST OF E¼ CORNER SECTION 4. WEST DIP ALLOWED 50 FEET PER MILE.

Tallant formation.	
8. Sandstone: not measured.	
Barnsdall formation.	
Unnamed shale member.	
7. Covered in part: probably shale with a few thin sandstones	100.0
Okesa sandstone member.	
6. Covered: probably alternating beds of sandstone and silty shale a few inches thick	55.0
5. Alternating beds of sandstone and silty shale a few inches thick	25.0
4. Shale: dark	1.0
3. Limy sandstone or sandy limestone: irregular layers a few inches thick. Fresh material hard and almost white, weathers soft and reddish-brown, contains a few marine fossils and abundant plant impressions, equivalent to the Birch Creek limestone, about	3.0
Wann formation.	
2. Clay shale; dark	6.0
1. Covered: in west bank of creek, probably shale, about	25.0

51. SEC. 6, T. 19 N., R. 10 E. MEASURED IN THE ROAD UP THE HILL SOUTH OF KEYSTONE.

Wann formation.	
5. Shale: not measured.	
4. Sandstone: coarse-grained, weathers brown to red; probably some interbedded shale, poorly exposed	30.0
3. Sandstone and maroon shale	15.0
2. Shale: maroon	51.0
1. Sandstone: thick massive, the colloquial Washington Irving sandstone, not measured but about	20.0

	Feet
52. SEC. 9, T. 19 N., R. 10 E. MEASURED AT THE CENTER.	
Iola formation.	
Avant limestone member.	
3. Sandstone and limestone: the colloquial upper Avant	10.0
2. Shale: gray, partly covered	30.0
1. Limestone: the colloquial lower Avant; reddish-brown; fossiliferous, sandy, from 4 to 8 feet thick	6.0

53. SEC. 9, T. 19 N., R. 10 E. MEASURED NEAR THE CENTER OF THE NW¼.

Wann formation.	
4. Sandstone: the colloquial Washington Irving sandstone; gray to brown; lower half coarse, upper half medium-grained, four massive beds	28.0
3. Covered	85.0
Iola formation.	
Avant limestone member.	
2. Limestone: the colloquial upper Avant; lower 6 feet very sandy; gray to brown; upper part sandy limestone in part fossiliferous, gray to reddish-brown, weathers in wavy plates less than 1 foot thick; probably equivalent to the upper part of the Avant of the type locality	15.0
1. Shale: not measured.	

54. SEC. 9, T. 19 N., R. 10 E. MEASURED FROM OUTCROP OF COLLOQUIAL UPPER AVANT LIMESTONE 1,200 FEET SOUTH OF CENTER, UP HILL SOUTHWARD.

Wann formation.	
9. Sandstone and shale: poorly exposed, top eroded	30.0
8. Covered: shale	30.0
7. Sandstone: brown to red, coarse	10.0
6. Covered: shale, maroon	20.0
5. Sandstone: massive, medium-grained; weathers brownish-red; the colloquial Washington Irving sandstone	20.0
4. Covered: shale	30.0
3. Bench, probably sandstone, about	3.0
2. Covered: shale	50.0
Iola formation.	
Avant limestone member.	
1. Limestone: colloquial upper Avant; gray; fossiliferous, massive, upper part weathers brownish-red	12.0

55. SEC. 10, T. 19 N., R. 10 E. MEASURED IN THE SW¼ SW¼ FROM THE PAVEMENT AT THE STREAM SOUTHEASTWARD UP THE HILL.

Iola formation.	
Avant limestone member.	
10. Sandstone: brown, massive, medium-grained; colloquial upper Avant, equivalent to the upper part of the Avant of the type locality	5.0
9. Covered: shale	10.0
8. Bench: probably sandstone	1.0
7. Covered: shale	15.0
6. Bench: probably sandstone	1.0
5. Covered: shale	14.0
4. Limestone: the colloquial lower Avant; gray to red, sandy; equivalent to basal Avant of the type locality	8.0
Muncie Creek shale member.	
3. Covered: shale	30.0

	Feet
Paola limestone member.	
2. Bench: sandstone; brown; fine-grained, thin-bedded; thin limestone plates found along top of outcrop, phosphatic nodules not in place observed just above this bench ¼ mile southwestward	2.0
Chanute formation.	
1. Covered: shale	30.0

56. SECS. 11 and 12, T. 19 N., R. 10 E. A COMPOSITE OF SEVERAL SECTIONS MEASURED UP THE HILL SOUTH OF U. S. HIGHWAY NO. 64 BETWEEN ROCKY POINT, NW¼ SE¼ SEC. 12, AND A POINT 1/8 MILE WEST OF W¼ COR. SEC. 11.

Iola formation.	
Paola limestone member.	
14. Sandstone: gray to brown; massive, medium-grained, lies at the horizon of the Paola limestone	8.0
Chanute formation.	
13. Covered: shale	17.0
12. Bench: sandstone	2.0
11. Covered: shale	20.0
Dewey formation.	
10. Limestone: the colloquial upper Dewey; gray to reddish-brown, fossiliferous	5.0
9. Covered: shale	20.0
8. Sandstone: weathers brown, about	5.0
7. Shale: partly covered; lower part gray, calcareous, and contains phosphatic nodules	10.0
6. Limestone: fossiliferous, weathers dark to yellow	0.5
5. Shale: gray, calcareous	3.0
4. Limestone: the colloquial lower Dewey; fossiliferous, sandy, weathers gray to brown	2.0
Nellie Bly formation.	
3. Sandstone: gray, speckled or reddish-brown	3.0
2. Shale: dark	9.0
1. Sandstone: gray; massive, medium-grained; weathers yellow to reddish-brown, the colloquial Shell Creek sandstone	30.0

57. SEC. 14, T. 19 N., R. 10 E. MEASURED NEAR THE CENTER.

Dewey formation.	
6. Limestone: colloquial upper Dewey; gray, weathers white, fossiliferous	1.0
5. Limestone, sandy: gray, weathers brownish-red	3.0
4. Covered: probably shale	50.0
3. Limestone: colloquial lower Dewey; sandy and in part sandstone, fossiliferous	3.0
Nellie Bly formation.	
2. Covered: shale, dark	12.0
1. Sandstone: massive, base not exposed, not measured.	

58. SEC. 14, T. 19 N., R. 10 E. MEASURED IN SW¼.

Iola formation.	
Avant limestone member.	
9. Sandstone: massive, medium-grained; weathers yellow to reddish-brown, top eroded; equivalent to top of the Avant of the type locality	5.0
8. Covered; probably shale, equivalent to the main mass of the Avant of the type locality	25.0
7. Limestone: gray, massive; weathers brown or red; equivalent to basal Avant of the type locality, colloquial lower Avant	9.0

	Feet
Muncie Creek shale member.	
6. Covered: probably shale	31.0
Paola limestone member.	
5. Bench: probably limy sandstone	5.0
Chanute formation.	
4. Covered: probably shale, about	12.0
3. Bench: probably sandstone, about	5.0
Chanute formation and Dewey formation.	
2. Covered by sandstone rubble but probably shale	37.0
Dewey formation.	
1. Limestone: gray, weathers brown; sandy, fossiliferous	2.0

59. SECS. 18 AND 19, T. 19 N., R. 10 E. MEASURED FROM CREEK BELOW PUMP STATION NEAR CENTER OF SE¼ SE¼ SEC. 18 UP WINDING ROAD TO TOP OF HILL IN SE¼ NW¼ NE¼ SEC. 19.

Barnsdall formation.	
Okesa sandstone member.	
20. Shale: top eroded, not measured.	
19. Sandstone: brown, medium-grained	2.0
18. Shale: brown	9.0
17. Sandstone: reddish-brown, medium-grained, thin- to massive-bedded	9.0
Wann formation.	
16. Covered: shale	5.0
15. Sandstone: brown, medium-grained, massive	12.0
14. Covered: shale	5.0
13. Sandstone: gray, fine-grained, weathers red	7.0
12. Shale: gray to reddish-brown	27.0
11. Sandstone: gray, medium-grained, massive	2.0
10. Shale: maroon	10.0
9. Sandstone: reddish-brown, medium-grained thin-bedded	10.0
8. Covered: shale	7.0
7. Sandstone: gray to reddish-brown, massive, medium-grained	7.0
6. Shale: maroon	31.0
5. Sandstones: gray to brown, medium-grained to coarse, massive	14.0
4. Shale: maroon	13.0
3. Sandstone: gray, medium-grained, massive	3.0
2. Covered: sandy shale	7.0
1. Sandstone: gray; medium-grained, massive, base not exposed (Nos. 1, 2, and 3 comprise the colloquial Washington Irving sandstone.)	20.0

60. SEC. 22, T. 19 N., R. 10 E. MEASURED ¼ MILE WEST OF NE CORNER.

Wann formation.	
17. Sandstone: massive, buff, medium-grained, to coarse-grained; top eroded, upper part of the colloquial Washington Irving sandstone	25.0
16. Shale: gray	4.0
15. Sandstone: massive, cream-colored	1.0
14. Shale: weathers red	7.0
13. Sandstone: massive	2.0
12. Shale, sandy	2.0
11. Sandstone: massive	2.0
10. Shale	10.0

	Feet
9. Sandstone: cream to tan-colored; fine-grained, thin-bedded, lower part of the colloquial Washington Irving sandstone	10.0
8. Shale: gray to maroon	28.0
Iola formation.	
Avant limestone member.	
7. Sandstone: buff, fine-grained, thin-bedded	3.0
6. Shale	7.0
5. Sandstone: yellow, fine-grained	4.0
4. Shale	2.0
3. Sandstone: Fusulina-bearing bed in base, gray limestone bed in top 1 foot thick	3.0
2. Shale: gray to yellow	10.0
1. Limestone: gray, fossiliferous; colloquial lower Avant	7.0

61. SEC. 26, T. 19 N., R. 10 E. MEASURED FROM ¼ MILE EAST OF S¼ CORNER WESTWARD TO TOP OF HILL.

Wann formation.	
11. Sandstone: rough, medium-grained, massive, top eroded	2.0
10. Covered	10.0
9. Sandstone bench	2.0
8. Covered	25.0
7. Sandstone bench, thin slabs	2.0
6. Covered	20.0
5. Sandstone bench: slabs 1 foot thick	3.0
4. Covered	8.0
3. Sandstone bench: slabs 0.5 feet thick	2.0
2. Covered	8.0
Iola formation.	
Avant limestone member.	
1. Limestone: the colloquial upper Avant; gray, weathers red; fossiliferous, base not exposed, equivalent to upper part of the Avant of the type locality	5.0

62. SEC. 35, T. 19 N., R. 10 E. MEASURED ¼ MILE EAST AND 1/8 MILE NORTH OF SW CORNER, UP HILL NORTHWARD.

Wann formation.	
19. Sandstone: brown, coarse-grained, top eroded	5.0
18. Covered	5.0
17. Sandstone	1.0
16. Covered: shale	6.0
15. Sandstone	1.0
14. Covered: shale	7.0
Iola formation.	
Avant limestone member.	
13. Limestone: white to red; fossiliferous, equivalent to upper part of the Avant of the type locality	5.0
12. Shale: gray	3.0
11. Sandstone: limy, brown	1.5
10. Covered: sandstone and shale	6.5
9. Sandstone	1.0
8. Shale, sandy	4.0
7. Sandstone	1.0
6. Shale, sandy	4.0
5. Sandstone	1.0
4. Shale, sandy	6.0
3. Sandstone	1.0
2. Shale, sandy	7.0
1. Sandstone: limy, probably equivalent to basal part of Avant of type locality	1.0

	Feet
63. SEC. 36, T. 19 N., R. 10 E. MEASURED FROM TOP OF MASSIVE SANDSTONE AT S¼ CORNER NORTHWARD TO TOP OF HILL.	
Iola formation.	
Muncie Creek shale member.	
14. Shale: top eroded	5.0
Paola limestone member.	
13. Sandstone: brown; medium-grained, massive; lies at the horizon of the Paola limestone	1.5
Chanute formation.	
12. Covered: shale	12.0
11. Sandstone: brown, fine-grained	1.0
10. Covered: shale	5.0
9. Sandstone: brown; massive, medium-grained	3.0
8. Covered: probably shale	21.0
7. Sandstone: brown, fine-grained	1.0
Chanute formation and Dewey formation.	
6. Rubble-covered slope: probably shale, upper part probably contains lower part of Chanute formation	61.0
Dewey formation.	
5. Limestone: gray to brown; fossiliferous, the colloquial lower Dewey limestone	3.0
Nellie Bly formation.	
4. Covered: shale	15.0
3. Sandstone: reddish-brown, fine-grained, about	2.0
2. Covered: shale	25.0
1. Sandstone: massive, base not exposed.	

	Feet
64. SEC. 28, T. 19 N., R. 11 E. MEASURED FROM THE BASE OF THE LOST CITY LIMESTONE IN EAST-WEST ROAD AT N¼ CORNER PAST CLUB HOUSE AND CONTINUING ON SOUTHWESTWARD TO TOP OF HILL ¼ MILE SOUTH OF NW CORNER:	
Nellie Bly formation.	
10. Sandstone: brown, massive, coarse-grained, top eroded	5.0
9. Covered: shale	5.0
8. Sandstone: brown, thin-bedded, fine-grained	5.0
7. Covered: shale	115.0
6. Sandstone bench by club house: brown, fine-grained, about	5.0
5. Covered: shale	44.0
Hogshooter formation.	
Winterset limestone member, basal bed only present.	
4. Limestone: dark, crinoidal, contains phosphatic nodules	1.0
Lost City limestone member.	
3. Shale	0.5
2. Limestone: gray, massive, weathers reddish-brown	22.0
Coffeyville formation.	
1. Shale: not measured.	

	Feet
65. SEC. 31, T. 19 N., R. 11 E. MEASURED ALONG NORTH SIDE OF NW¼.	
Chanute formation.	
26. Shale: weathers gray to red, top not exposed	11.0
25. Sandstone: reddish-brown, fine-grained	1.5
24. Shale: weathers red	0.8
23. Sandstone: buff to reddish-brown, to beds 0.2 to 0.5 feet thick with shale partings	2.0
22. Shale: dark, weathers buff	11.0

	Feet
Dewey formation.	
21. Shale: dark clay shale with limestone nodules in base	5.0
20. Limestone: gray to reddish-brown; grades downward into sandstone and contains sandstone in irregular masses size of eggs and as stringers, grades upward through nodular limestone into limestone nodules in overlying shale, the colloquial upper Dewey	2.0
19. Sandstone: gray to reddish-brown; fine-grained, massive, upper foot calcareous	3.0
18. Shale: gray, weathers buff	0.3
17. Sandstone: weathers buff, fine-grained	0.5
16. Shale: weathers buff	2.5
15. Sandstone: weathers buff, fine-grained	0.4
14. Shale: weathers buff	0.1
13. Sandstone: weathers buff, fine-grained	0.8
12. Shale: dark, weathers gray to buff	14.0
11. Shale: dark, weathers yellow	8.3
10. Limestone: bluish-gray, weathers reddish-buff, fossiliferous	0.8
9. Shale: dark, not well exposed	4.0
8. Limestone: brown, sandy; fossiliferous, packed with fragments of large Myalina-like shells	0.8
7. Shale: dark, upper 0.6 feet calcareous	2.7
6. Sandstone: weathers light brown to yellowish, fine-grained	0.3
5. Shale: dark	4.0
4. Sandstone: brown to buff, fine-grained	0.3
3. Shale: weathers bluish gray	1.0
2. Limestone: brown, fossiliferous	0.3
Nos. 2 to 10 inclusive constitute the colloquial lower Dewey.	
Nellie Bly formation.	
1. Shale: weathers bluish gray, not measured.	

66. SEC. 18, T. 19 N., R. 12 E. SECTION OF THE LOST CITY LIMESTONE MEMBER OF THE HOGSHOOTER FORMATION, MEASURED IN CONNECTION WITH SAMPLING FOR CHEMICAL ANALYSIS. TO REACH THIS QUARRY FOLLOW THE ROAD EAST ALONG THE SOUTH SIDE OF THE ARKANSAS RIVER FROM THE SOUTH END OF THE HIGHWAY BRIDGE AT SAND SPRINGS. QUARRY OF STANDARD PAVING CO.

Hogshooter formation.	
Lost City limestone member.*	
3. Limestone: upper part of the Lost City member; dark, massive; weathers in irregular layers 0.5 to 1.0 feet thick, fossiliferous	10.0
2. Limestone: middle of the Lost City member; massive, light-gray, fossiliferous	15.0
1. Limestone: lower part of the Lost City member; massive, dark to light-gray, fossiliferous	15.0

* Chemical analyses indicate that all of the Lost City member in this vicinity is pure enough for many chemical uses.

67. SECS. 19 AND 20, T. 19 N., R. 12 E. FROM THE BRIDGE A SHORT DISTANCE WEST OF THE S¼ CORNER SEC. 20 WESTWARD ALONG ROAD TO TOP OF SECOND HILL, WHICH IS NEAR THE S¼ CORNER SEC. 19.

Hogshooter formation.

Lost City limestone member.

9. Limestone: base exposed ¼ mile north of the road, not measured.

	Feet
Coffeyville formation, approximately the upper half.	
8. Shale: lower 2 feet exposed in road remainder covered north of road, estimated	10.0
7. Sandstone: weathers reddish-brown, poorly exposed	5.0
6. Shale: not well exposed about	40.0
5. Sandstone: weathers reddish-brown; fine-grained, massive to thin-bedded, about	18.0
4. Shale: weathers gray, slightly silty	8.0
3. Siltstone: thin, irregular bedding; weathers gray, about	5.0
2. Shale: dark, weathers gray to reddish-brown; some silty streaks	63.0
1. From bridge to SW corner section 20, covered, probably shale	60.0

68. SEC. 21, T. 19 N., R. 12 E. MEASURED IN THE ROAD UP THE HILL IN THE NE¼ SE¼.

Coffeyville formation, middle part.	
5. Sandstone: medium-grained, weathers brown; deeply weathered, poorly exposed; base forms a prominent topographic feature around the hill	15.0
4. Shale: gray	25.0
3. Sandstone: gray, medium-grained; poorly exposed, deeply weathered	10.0
2. Shale: poorly exposed	17.0
1. Sandstone and sandy shale, same as Nos. 9 to 14 of the section measured up the east end of the high hill in SE¼ NE¼ sec. 22, T. 19 N., R. 12 E., about	35.0

69. SEC. 22, T. 19 N., R. 12 E. MEASURED UP THE EAST END OF THE BIG HILL IN THE SE¼ OF THE NE¼ OF THE SECTION.

Coffeyville formation.	
14. Sandstone: thin-bedded and silty, to the top of the hill	25.0
13. Sandstone: gray fine-grained; weathers brown	1.0
12. Shale, sandy	1.5
11. Sandstone: gray, fine-grained	0.8
10. Shale: sandy and thin sandstone beds	4.0
9. Sandstone: gray, weathers brown; medium-grained, imprints of plants; a single massive bed	3.0
8. Somewhat slumped but material indicates silty gray shale	90.0
7. Sandstone: gray, medium-grained; weathers brown, beds 0.2 to 1.0 foot thick	13.0
6. Shale: gray, silty to clay	23.0
5. Siltstone, sandy: gray, lenticular bedding, grades upward into silty shale	17.0
4. Shale: gray, open gulley, no sign of hard beds	70.0
3. Shale: gray	3.0
2. Shale: black, fissile, phosphatic nodules	8.0
Checkerboard limestone.	
1. Limestone: base not exposed, not measured.	

70. SEC. 34, T. 19 N., R. 12 E. MEASURED FROM THE LIMESTONE NEAR THE S¼ CORNER WESTWARD TO THE TOP OF THE HILL.

Coffeyville formation, lower part.	
5. Sandstone: gray to brown, medium-grained; thin irregular bedding, top eroded	5.0
4. Shale: dark, silty, contains limonitic streaks	18.0
3. Covered: allowing 10 feet for dip	55.0

	Feet
Checkerboard limestone.	
2. Limestone: dark, fossiliferous, massive; weathers yellowish-brown	3.0
Seminole formation.	
1. Shale: bluish gray, not measured.	

71. SEC. 2, T. 19 N., R. 13 E. MEASURED PRACTICALLY ALONG STRIKE FROM THE POINT WHERE THE MAIN DRAINAGE CROSSES THE OUTCROP OF THE LENAPAH (ELEVENTH STREET) LIMESTONE, ABOUT ¼ MILE NORTH OF S¼ CORNER, SOUTHWESTWARD TO THE BASE OF THE SEMINOLE, SOUTH BANK OF THE ROAD CUT ABOUT ¼ MILE WEST.

Seminole formation.	
12. Sandstone: lower sandy member, not measured.	
Holdenville (Memorial) shale.	
11. Shale: clay shale with silty streaks	10.0
10. Limestone: dark, crinoidal, ferruginous; weathers yellowish brown	0.2
9. Shale: clay shale, dark with a few silty streaks	18.0
8. Sandstone: thin fine-grained to silty beds a few inches thick, interspersed with sandy silty shale	10.0
7. Shale: dark clay shale with a few silty sandy streaks	32.0
Lenapah (Eleventh Street) limestone.	
6. Limestone: brown, hard, fossiliferous	1.5
5. Shale: dark, calcareous, weathers gray	2.5
4. Limestone: gray, nodular, fossiliferous	0.2
3. Shale: clay shale, dark, weathers gray	3.0
2. Limestone: weathers earthy and brown	1.0
Nowata shale.	
1. Shale: probably dark when fresh, weathers gray, base not exposed	5.0

72. SEC. 11, T. 19 N., R. 13 E. FROM THE W¼ CORNER NORTHWARD UP HILL, NEARLY ALONG STRIKE.

Seminole formation, lower part.	
3. Shale: a thin cap at the top of the hill, base of middle shaly member, top eroded	2.0
2. Sandstone: gray, fine-grained, with thin (2 in.) wavy bedding, no shale beds, the lower sandy member	25.0
Holdenville (Memorial) shale.	
1. Shale: not measured.	

73. SEC. 13, T. 19 N., R. 13 E. MEASURED FROM THE NW CORNER SOUTHWESTWARD UP HILL.

Holdenville (Memorial) shale.	
4. Covered: weathered sandstone, broken and slumped, not measured.	
Lenapah (Eleventh Street) limestone.	
3. Limestone: thin-bedded, crinoidal; weathers yellowish-brown	0.5
Nowata shale.	
2. Alternating shale and flagstones, the latter limy and possibly silty	35.0
1. Shale: clay shale, greenish-gray when weathered and wet, base not exposed	6.0

74. SEC. 22, T. 19 N., R. 13 E. MEASURED FROM LENAPAH LIMESTONE OUTCROP ¼ MILE EAST OF SE CORNER WESTWARD TO BASE OF SEMINOLE FORMATION 1/8 MILE WEST. DIP ALLOWED 50 FEET PER MILE.

	Feet
Seminole formation, lower part.	
5. Sandstone: not measured.	
Holdenville (Memorial) shale.	
4. Shale: section corner to base of lower Seminole sandstone	29.0
3. Covered to section corner, probably shale	7.0
2. Sandstone: fine-grained, micaceous; weathers brown; thin-bedded, top not well exposed	3.0
Lenapah (Eleventh Street) limestone.	
1. Limestone: gray to brown, fossiliferous, about	2.0

75. SEC. 22, T. 19 N., R. 13 E. FROM THE HORIZON OF THE LENAPAH LIMESTONE AT THE NE CORNER WESTWARD TO THE BASE OF THE SEMINOLE FORMATION AT THE N¼ CORNER, DIP ALLOWED 50 FEET PER MILE.

Seminole formation, lower part.	
6. Sandstone: thin-bedded, fine-grained; appears to rest unevenly on the underlying shale, not measured.	
Holdenville (Memorial) shale.	
5. Shale: dark to gray	5.0
4. Shale: dark with thin, silty limonitic streaks	5.0
3. Limestone: one or more layers about 1 inch thick, fossiliferous, conglomeratic, small rounded fragments of limy to sideritic silt and abundant crinoid stems, intercalated with sideritic to limonitic silty flags, total about	1.0
2. Covered: probably shale	50.0
Lenapah (Eleventh Street) limestone.	
1. Covered but should be present at about this place.	

76. SEC. 34, T. 19 N., R. 13 E. MEASURED FROM WATER'S EDGE IN THE CREEK ½ MILE SOUTH OF THE NW CORNER SOUTHWARD TO THE TOP OF THE HILL A LITTLE SOUTH OF THE SW CORNER. NORTH DIP ESTIMATED TO BE 30 FEET PER MILE.

Seminole formation, lower part.	
8. Shale: sandy; occupies flank of hill east of road and south of SW corner sec. 34, not measured.	
7. Sandstone: brown to gray, fine-grained, thin-bedded, about	5.0
Holdenville (Memorial) shale.	
6. Covered: probably shale	65.0
5. Sandstone: brown, fine-grained, thin-bedded; probably the same sandstone exposed in road ¼ mile north of SW corner section 34, about	5.0
Lenapah (Eleventh Street) limestone.	
4. Limestone: brown, sandy, fossiliferous; in road immediately south of the bridge	2.0
3. Covered	4.0
2. Shale and thin brown to yellow fossiliferous limestone, found under bridge	2.0
Nowata shale.	
1. Shale and limy possibly silty flagstones, crop out in south bank of stream down to water's edge under bridge	4.0

77. SEC. 35, T. 19 N., R. 13 E. MEASURED FROM THE BASE OF THE FLAGS JUST EAST OF THE CENTER OF THE EAST LINE OF THE SW¼ TO THE TOP OF THE HILL SOUTHWESTWARD.

Seminole formation, lower part.	
11. Covered: probably thin-bedded sandstone to top of hill	10.0
10. Bench: seems to be a massive sandstone, about	3.0

Feet

Holdenville (Memorial) shale.

9. Covered: probably shale 40.0
8. Bench: probably sandy shale or thin-bedded sandstone 5.0
7. Covered: probably shale 35.0
6. Silty limestone or limy siltstone: east side of road cut along east line of section 1.0
5. Covered: probably shale, upper part exposed in road cut 15.0

Lenapah (Eleventh Street) limestone.

4. Limestone: reddish brown; crinoidal, platy, not well exposed.... 1.5

Nowata shale.

3. Covered: probably shale 5.0
2. Shale and limestone flags: not well exposed 20.0
1. Shale: not measured.

78. SEC. 35, T. 19 N., R. 13 E. MEASURED FROM ¼ MILE NORTH OF THE SW CORNER SOUTH TO THAT CORNER.

Holdenville (Memorial) shale.

3. Covered: probably shale.

Lenapah (Eleventh Street) limestone.

2. Sandstone: brown, deeply weathered, probably originally limy 5.0

Nowata shale.

1. Shale: not measured.

79. SEC. 3, T. 19 N., R. 14 E.; SEC. 2, T. 19 N., R. 13 E. FROM BASE OF OOLOGAH LIMESTONE ¼ MILE WEST OF SE CORNER SEC. 3, T. 19 N., R. 14 E. TO LENAPAH LIMESTONE ¼ MILE WEST OF THE SE CORNER SEC. 2, T. 19 N., R. 13 E., ALONG U. S. HIGHWAY NO. 66. DIP ALLOWED 50 FEET PER MILE.

Lenapah (Eleventh Street) limestone.

4. Limestone: not measured.

Nowata shale.

3. Covered: shale 135.0

Oologah formation.

2. Limestone: poorly exposed 45.0

Labette Shale.

1. Shale: not measured.

80. SEC. 11, T. 19 N., R. 14 E. FROM STREAM ABOUT ¼ MILE EAST OF SW CORNER WESTWARD TO CORNER.

Oologah formation.

4. Limestone: not measured.

Labette shale.

3. Shale: sandy 4.0
2. Sandstone: grades into No. 1, no distinct separation 20.0
1. Shale: sandy; weathers light yellow, grades into No. 2, base not exposed 20.0

81. SEC. 20, T. 19 N., R. 14 E. MEASURED IN A ROAD CUT ¼ MILE WEST OF THE NORTHEAST CORNER.

Oologah formation.

3. Limestone: white, massive, fossiliferous, top eroded 3.0
2. Shale: black, appears massive where fresh, laminated where weathered, weathers yellow; limy, fossiliferous 12.0
1. Limestone; brown, cherty; massive to thin-bedded, base not exposed 3.0

82. SEC. 25, T. 19 N., R. 14 E.; SEC. 26, T. 19 N., R. 13 E. FROM TOP OF FT. SCOTT LIMESTONE SE CORNER SEC. 25, T. 19 N., R. 14 E. TO LENAPAH LIMESTONE ¼ MILE WEST OF SE CORNER SEC. 26, T. 19 N., R. 13 E. WEST DIP ALLOWED 50 TO 70 FEET PER MILE.

	Feet
Holdenville (Memorial) shale, lower part.	
7. Sandstone: reddish brown, thin-bedded, fine-grained	10.0
Lenapah (Eleventh Street) limestone.	
6. Limestone	1.5
Nowata shale.	
5. Limestone flags with intercalated limy shale	26.0
4. Covered: shale	178.0
Oologah formation.	
3. Limestone: lower part, about	40.0
Labette shale.	
2. Covered: probably shale, possibly some sandstone, may include the Little Osage shale member of the Fort Scott limestone	240.0
Fort Scott limestone.	
Higginsville limestone member.	
1. Limestone: not measured.	

83. SEC. 27, T. 19 N., R. 14 E. MEASURED 0.1 MILE WEST OF SE CORNER.

	Feet
Oologah formation.	
12. Limestone: bluish gray, thin-bedded, cherty, top eroded	7.0
11. Limestone: bluish gray, weathers brown; fossiliferous, may be silty, thin-bedded	4.5
10. Marl	1.5
9. Limestone: dark gray, fossiliferous	1.0
8. Marl: fossiliferous	1.5
7. Shale: gray, fossiliferous	1.5
6. Shale: dark to gray	1.5
5. Shale: almost black	1.0
4. Limestone: blue to brown, fossiliferous	1.5
Labette shale.	
3. Shale: gray, limy, fossiliferous	1.5
2. Shale: almost black	10.0
1. Shale: silty, weathers tan; contains a few fossiliferous limestone concretions, base not exposed	10.0

84. SEC. 6, T. 19 N., R. 15 E., SEC. 3, T. 19 N., R. 14 E. FROM THE TOP OF THE FORT SCOTT LIMESTONE AT ABOUT 0.5 MILE EAST OF THE SW CORNER SEC. 6, T. 19 N., R. 15 E. WEST ALONG U. S. HIGHWAY NO. 66 TO BASE OF OOLOGAH LIMESTONE ¼ MILE WEST OF SE CORNER SEC. 3, T. 19 N., R. 14 E. WEST DIP ALLOWED 30 TO 50 FEET PER MILE.

	Feet
Oologah formation, lower part.	
5. Limestone: not measured.	
Labette shale.	
4. Covered: probably dark shale	110.0
3. Sandstone: poorly exposed, (possibly some shale) gray, fine-grained; thin-bedded, base about 0.4 miles east of SW corner sec. 2, T. 19 N., R. 14 E., top in draw ½ mile west of same corner, about	40.0
2. Covered: shale, may include the Little Osage shale member of the Fort Scott limestone	100.0

Feet

Fort Scott limestone.

Higginsville limestone member.

1. Limestone: not measured.

85. SEC. 6, T. 19 N., R. 15 E. MEASURED IN THE ROAD CUT ON STATE HIGHWAY NO. 33 JUST WEST OF SPUNKY CREEK, THE FORT SCOTT LIMESTONE WAS MEASURED IN THE BANK OF A NORTHWARD FLOWING CREEK 3/4 MILE WEST AND ¼ MILE NORTH.

Fort Scott limestone.

Higginsville limestone member.

15. Limestone: gray, massive to thin-bedded; fossiliferous, top eroded at this locality but measured 8 feet in the bank of a north flowing creek about 3/4 mile west and ½ mile north of this locality 8.0

Senora formation.

14. Shale: black, fissile, contains phosphatic concretions; upper one foot weathers gray 3.5
13. Limestone: dark, dense, massive, possibly siliceous 2.5
12. Shale: dark, calcareous 1.5
11. Limestone: gray, fossiliferous, thin-bedded to massive 8.0
10. Shale 0.5
9. Coal 0.1
8. Under clay 0.5
7. Sandstone: fine-grained, gnarly bedding; weathers brown to yellow 3.0
6. Shale: dark, silty 8.0
5. Sandstone: shaly and silty 6.0
4. Covered: probably silty shale 6.0
3. Sandstone: brown, fine-grained, silty; harder ledges at top and bottom 8.0
2. Shale: silty 2.0
1. Covered 3.0

86. SEC. 7, T. 19 N., R. 15 E. MEASURED IN A DRAW 1/8 MILE EAST OF THE SW CORNER. ON LUTHER H. WHITE'S PLACE.

Labette shale.

5. Covered: shale, not measured.

Fort Scott limestone.

Little Osage shale member.

4. Shale: black, fissile, phosphatic nodules; measured just north of the section corner 10.0

Higginsville limestone member.

3. Limestone: gray, fossiliferous, massive, about 3.0

Senora formation.

2. Shale: black, fissile, phosphatic nodules; well exposed at the spillway 300 feet down the draw 6.0
1. Limestone: Breezy Hill, top only exposed.

87. SEC. 7, T. 19 N., R. 15 E. LOG OF A WATER WELL, NEAR SW CORNER, SUPPLIED BY LUTHER H. WHITE.

11. Soil 7.0

Fort Scott limestone.

Higginsville limestone member.

10. Limestone 9.0

Senora formation.

9. Black slate (fissile shale with phosphatic nodules) 6.0
8. Limestone: Breezy Hill 6.0
7. Shale: white 2.0

	Feet
6. Coal	0.5
5. Shale: gray	4.5
4. Sand: gray, fine-grained, micaceous; no water	20.0
3. Shale: gray, sandy	20.0
2. Shale: gray	33.0
1. Limestone: gray; salt water	5.0

88. SEC. 7, T. 19 N., R. 15 E. SECTION BEGINS IN CREEK BED ABOUT ¼ MILE SOUTH AND A LITTLE EAST OF NW CORNER AND EXTENDS SOUTHWARD TO TOP OF HILL.

Labette shale, lower part.	
7. Covered to top of hill, probably shale	20.0
6. Shale: dark	10.0
5. Shale: gray	1.5
4. Shale: black, fissile	2.0
3. Shale: black, hard, fissile with phosphatic nodules	2.5
Fort Scott limestone.	
Little Osage shale member.	
2. Shale: black, fissile	3.0
Higginsville limestone member.	
1. Limestone: only top exposed, not measured.	

TOWNSHIP 20 NORTH

89. SEC. 12, T. 20 N., R. 9 E. MEASURED FROM THE ALLUVIUM 1/8 MILE WEST OF THE CENTER WESTWARD TO TOP OF HILL. TO REACH THIS POINT GO NORTH FROM THE CEMETERY ON THE SOUTH SIDE OF U. S. HIGHWAY 67.

Tallant formation.	
10. Sandstone: massive, medium to coarse-grained, gray, weathers brown, top eroded	15.0
9. Covered: shale	10.0
8. Sandstone: massive, coarse-grained, gray, weathers brownish red	30.0
Barnsdall formation.	
Unnamed shale member.	
7. Covered: shale	70.0
Okesa sandstone member.	
6. Bench: probably sandstone	20.0
5. Covered: probably shale and sandstone	25.0
Wann formation.	
4. Bench: thin ferruginous sandstone, weathers in chips and flakes, probably limy	1.0
3. Covered: shale	6.0
2. Sandstone	5.0
1. Covered: talus slope	50.0

90. SEC. 7, T. 20 N., R. 10 E. MEASURED ALONG THE ROAD FROM A POINT SOMEWHAT NORTH OF THE S¼ CORNER TO A POINT SOMEWHAT SOUTH OF THAT CORNER.

Barnsdall formation.	
Okesa sandstone member.	
7. Shale: top eroded	10.0
6. Sandstone	10.0
Wann formation.	
5. Shale: dark, weathers gray to yellow	50.0
4. Sandstone	10.0
3. Shale	10.0

	Feet
2. Sandstone: gray, massive, medium-grained; weathers reddish brown	28.0
1. Shale: maroon, not measured.	

91. SEC. 8, T. 20 N., R. 10 E. MEASURED FROM ALLUVIUM AT HOUSE, CENTER SW¼ UP HILL SOUTHWESTWARD.

Barnsdall formation.	
Okesa sandstone member.	
8. Sandstone: shaly, top eroded	5.0
Wann formation.	
7. Covered: dark clay shale, weathers yellow	50.0
6. Sandstone: gray to buff, medium-grained	2.0
5. Covered: shale	10.0
4. Sandstone: gray to buff; medium-grained, thin-bedded, cross-bedded	20.0
3. Shale: maroon	30.0
2. Sandstone: gray, massive, medium-grained; base may not be exposed	12.0
1. Talus slope	24.0

92. SEC. 22, T. 20 N., R. 10 E. MEASURED UP HILL SOUTHEASTWARD FROM THE NW CORNER.

Wann formation.	
11. Shale top eroded, not measured.	
10. Sandstone: massive, medium to coarse-grained, brown	15.0
9. Shale, maroon	20.0
8. Sandstone, medium-grained, red	10.0
7. Shale, maroon	50.0
6. Sandstone, massive, medium-grained, brown	20.0
5. Covered	6.0
4. Sandstone, massive, medium-grained, brown	40.0
3. Shale with a few sandstone beds less than 1 foot thick	30.0
2. Sandstone, fine-grained	1.0
1. Covered: mostly shale, probably includes part of the Avant limestone member of the Iola formation	74.0

93. SEC. 35, T. 20 N., R. 10 E. MEASURED IN NE¼.

Wann formation.	
6. Covered to top of hill: exposures in vicinity indicate gray shale with a few sandstone beds less than 1 foot thick	20.0
5. Sandstone: light brown to reddish brown, medium-grained	5.0
4. Covered: southwest end of ridge exposed and shows gray shale with a few sandstone beds less than 1 foot thick	45.0
Iola formation.	
Avant limestone member.	
3. Limestone: gray, weathers brownish red; fossiliferous, probably dolomitic, intercalated with limy sandstone; probably equivalent to upper part of Avant of type locality	15.0
2. Covered: southwest end of ridge is exposed and shows gray shale with a few sandstone beds less than 1 foot thick; equivalent to middle part of Avant limestone of type locality	25.0
1. Limestone: gray, weathers brownish red; sandy, probably dolomitic, fossiliferous, intercalated with limy sandstone; equivalent to lower part of Avant of type locality	10.0

94. SEC. 35, T. 20 N., R. 10 E. MEASURED IN NW¼ SW¼ SE¼.

Iola formation.	
Avant limestone member.	
4. Limestone: gray, weathers brownish red; fossiliferous, probably dolomitic, intercalated with sandstone, equivalent to upper part of Avant of type locality	15.0

	Feet
3. Covered: probably shale; equivalent to middle part of Avant of type locality	20.0
2. Limestone: gray, weathers brownish red; fossiliferous, probably dolomitic, intercalated with sandstone; equivalent to lower part of Avant of type locality	15.0
Muncie Creek shale member.	
1. Shale: dark, base not exposed, about	25.0

95. SEC. 36, T. 20 N., R. 10 E. MEASURED IN NW¼ SE¼ SW¼.

Iola formation.	
Avant limestone member.	
3. Sandstone: weathers buff to reddish brown, top eroded; upper part of Avant limestone	15.0
2. Covered: probably shale	20.0
1. Limestone: gray, weathers red; probably dolomitic, sandy, fossiliferous, intercalated with limy sandstone	10.0

96. SEC. 36, T. 20 N., R. 10 E. MEASURED FROM TOP OF THE COLLOQUIAL SHELL CREEK SANDSTONE, CENTER OF THE SW¼ NE¼ TO TOP OF AVANT LIMESTONE IN ROAD NEAR NW CORNER. 20 FT. ALLOWED FOR WESTWARD DIP.

Wann formation.	
7. Shale: top eroded	5.0
Iola formation.	
Avant limestone member.	
6. Limestone: lower part gray and sandy limestone, middle portion gray sandstone, upper portion gray sandy limestone which weathers reddish brown; probably equivalent to upper part of Avant of type locality	10.0
Muncie Creek shale member,	
Paola limestone member, and	
Chanute formation.	
5. Covered: probably includes shale and limestone of the Avant member, the Muncie Creek shale member, and the Paola limestone member of the Iola, the Chanute formation and possibly part of the Dewey formation	95.0
Dewey formation.	
4. Limestone: gray, fossiliferous, about	2.0
3. Covered: probably shale	45.0
2. Limestone: brown, sandy, about	2.0
Nellie Bly formation.	
1. Sandstone: not measured.	

97. SECS. 3 AND 4, T. 20 N., R. 11 E. MEASURED IN SE¼ SE¼ SEC. 4 AND SW¼ SW¼ SEC. 3.

Iola formation.	
Avant limestone member.	
10. Limestone: gray, fossiliferous; weathers brownish red, probably equivalent to upper part of Avant of type locality	3.0
9. Covered: shale	20.0
8. Bench: probably sandstone	5.0
Muncie Creek shale member.	
7. Covered: shale, upper part probably equivalent to lower part of the Avant of the type locality	40.0
Paola limestone member.	
6. Bench: probably limy sandstone equivalent to Paola limestone	2.0
Chanute formation, and	
Dewey formation.	

	Feet
5. Covered: shale, probably includes shale equivalent to part of the Dewey formation	20.0
Dewey formation, lower part.	
4. Limestone: gray, fossiliferous, weathers red	2.0
3. Covered: shale	5.0
2. Limestone: gray, fossiliferous, weathers white	2.0
Nellie Bly formation.	
1. Sandstone: the colloquial Shell Creek sandstone at the top of the Nellie Bly, not measured.	

98. SEC. 9, T. 20 N., R. 11 E. MEASURED IN THE NW¼ SE¼ SECTION 9, UP OLD ROAD FROM AVANT LIMESTONE TO BASE OF A MASSIVE SANDSTONE.

Wann formation.	
10. Sandstone: medium-grained, massive, reddish brown, top eroded, makes timbered uplands.	
9. Shale: gray, weathers red	12.0
8. Sandstone: reddish brown, fine-grained	3.0
7. Shale: weathers yellow, contains occasional sandy siltstone beds less than 1 foot thick	80.0
6. Siltstone: platy, weathers yellow	2.0
5. Shale: weathers light yellow	7.0
4. Siltstone: platy, weathers yellow	1.0
3. Shale: weathers light yellow	23.0
Iola formation.	
Avant limestone member.	
2. Limestone: gray, sandy, fossiliferous; weather brownish red, equivalent to upper Avant of type locality	5.0
1. Covered: shale, equivalent to main mass of Avant of type locality, not measured.	

99. SEC. 9, T. 20 N., R. 11 E. MEASURED IN THE SE¼ SECTION 9, FROM THE DEWEY LIMESTONE OUTCROP IN CREEK NORTHWEST TO AVANT LIMESTONE OUTCROP ON POINT OF HILL WEST OF HAY BARN.

Wann formation, basal part.	
7. Shale, not measured.	
Iola formation.	
Avant limestone member.	
6. Limestone: gray, fossiliferous, weathers yellow to brownish red; probably upper Avant of type locality	3.0
5. Covered: shale, probably equivalent to main mass of Avant of type locality	30.0
4. Bench: growing persimmon trees, probably limy sandstone; equivalent to basal part of Avant of type locality	1.0
Muncie Creek shale member,	
Paola limestone member, and	
Chanute formation.	
3. Covered: probably shale with a few thin sandstone beds, probably includes Paola limestone near the middle and the Chanute formation and part of the Dewey formation in the lower part. The upper part of the Dewey was probably removed by pre-Chanute erosion	80.0
Dewey formation.	
2. Limestone: sandy, weathers brown, fossiliferous	2.0
Nellie Bly formation.	
1. Sandstone: top of the colloquial Shell Creek sandstone, not measured.	

100. SEC. 13, T. 20 N., R. 11 E. FROM A POINT ON THE EAST BANK OF THE DRAW NORTHWESTWARD UP HILL ALL IN SE¼ SE¼.

	Feet
Nellie Bly formation, middle part.	
4. Sandstone: caps hill, not well exposed, top eroded, in upper part of Nellie Bly	10.0
3. Covered: probably shale	90.0
2. Sandstone: several beds with sandy shale partings but is massive a short distance southward	15.0
1. Shale: not measured.	

101. SEC. 14, T. 20 N., R. 11 E. WESTWARD FROM STREAM AT THE E¼ CORNER OF THE SECTION TO TOP OF HILL.

Nellie Bly formation.	
11. Covered to the top of the hill, probably thin-bedded sandstone near top of Nellie Bly	11.0
10. Covered: probably sandy shale	17.0
9. Sandstone	1.0
8. Covered: probably sandy shale	5.0
7. Sandstone: uneven bedding, medium-grained, yellowish brown	20.0
6. Shale: partly covered, weathers red	65.0
5. Bench: probably sandstone	2.0
4. Covered: shale, weathers reddish brown	28.0
3. Bench: probably sandstone	2.0
2. Covered: probably shale	8.0
1. Stream bed.	

102. SEC. 16, T. 20 N., R. 11 E. MEASURED FROM NW¼ SW¼ SW SEC. 16 TO CENTER NW¼ NW¼ SEC. 17.

Iola formation.	
Avant limestone member.	
5. Covered: shale, top eroded, about	10.0
4. Limestone: gray, fossiliferous, weathers red; probably equivalent to lower part of Avant limestone of type locality	2.0
Muncie Creek shale member,	
Paola limestone member,	
Chanute formation, and	
Dewey formation.	
3. Covered: probably includes Muncie Creek shale member and Paola limestone member of the Iola formation, the Chanute formation, and part of the Dewey formation	70.0
Dewey formation, lower part.	
2. Limestone: gray to reddish brown, fossiliferous	2.0
Nellie Bly formation.	
1. Sandstone: not measured.	

103. SEC. 16, T. 20 N., R. 11 E. MEASURED IN THE NW¼.

Wann formation.	
9. Shale: not measured.	
Iola formation.	
Avant limestone member.	
8. Limestone: gray, sandy, fossiliferous, weathers red; upper part of Avant of the type locality	8.0
7. Covered: shale	12.0
6. Bench: probably limy sandstone, about middle Avant of type locality	2.0
Avant limestone member,	
Muncie Creek shale member,	
Paola limestone member, and	

	Feet
Chanute formation.	
5. Covered: shale, upper part probably equivalent to lower Avant, lower part probably includes Paola limestone and upper part of Chanute formation	58.0
Chanute formation.	
4. Bench: probably sandstone	2.0
Chanute formation and	
Dewey formation.	
3. Covered: shale, includes part of the Dewey formation, upper part of Dewey probably removed by pre-Chanute erosion	30.0
Dewey formation: lower part.	
2. Limestone: brown, sandy, fossiliferous	2.0
Nellie Bly formation.	
1. Sandstone: massive, not measured.	

104. SEC. 17, T. 20 N., R. 11 E. MEASURED IN THE NW¼ SE¼ SE¼.

Dewey formation, upper part probably removed by pre-Chanute erosion.	
4. Covered: shale, top eroded	5.0
3. Limestone: gray, fossiliferous, weathers white to brownish red	2.0
2. Covered, shale	7.0
1. Limestone: gray to reddish brown, fossiliferous	2.0
Nellie Bly formation.	
Sandstone: not measured.	

105. SEC. 19, T. 20 N., R. 11 E. FROM LIMESTONE IN DRAW WEST OF ROAD NORTHEASTWARD UP HILL, IN NE¼ NE¼ SEC. 19.

Wann formation.	
15. Sandstone: gray, weathers in slabs 1 to 2 feet thick, top eroded, lower part of the colloquial Washington Irving sandstone	20.0
14. Covered: shale	32.0
13. Bench: probably sandstone, about	1.0
12. Covered: shale	30.0
Iola formation.	
Avant limestone member.	
11. Bench: occupies about the horizon of the top of the Avant of the type locality, probably limy sandstone	1.0
10. Covered: shale	8.0
9. Limestone: sandy, gray, weathers reddish brown	2.0
8. Covered: shale	20.0
7. Bench: lower part of the Avant, probably limy sandstone	1.0
Muncie Creek shale member.	
6. Shale: dark, partly covered, upper part probably equivalent to lower part of the Avant of the type locality	45.0
Paola limestone member.	
5. Bench: probably limy sandstone equivalent to Paola limestone	2.0
Chanute formation.	
4. Covered: shale	36.0
Dewey formation.	
3. Bench: limy sandstone; the colloquial upper Dewey	2.0
2. Covered: shale	38.0
1. Limestone: gray, fossiliferous; the colloquial lower Dewey	2.0

	Feet
106. SEC. 20, T. 20 N., R. 11 E. FROM NORTH BANK OF THE CREEK ¼ MILE SOUTH OF THE CENTER, NORTHWARD UP HILL TO TOP OF THE COLLOQUIAL SHELL CREEK SANDSTONE.	
Nellie Bly formation.	
10. Covered to the top of the hill, probably thin-bedded sandstone and shale, near top of Nellie Bly	20.0
9. Sandstone: medium-grained, weathers reddish brown	2.0
8. Covered: probably shale	15.0
7. Sandstone: massive, medium-grained, gray, forms blocks 6 by 20 feet	11.0
6. Covered: shale	4.0
5. Sandstone: massive, more evenly bedded than No. 4, medium-grained, gray	9.0
4. Sandstone: medium-grained, white to red, dense to porous, very gnarly bedding. Solution cavities ranging from small pits to "rock shelters" indicating that the rock was originally limy	8.0
3. Sandstone: medium-grained, gray, roughly bedded	6.0
2. Covered: probably shale	15.0
1. Bed of creek; on shale.	
107. SEC. 1, T. 20 N., R. 11 E. AND SEC. 6, T. 20 N., R. 12 E. FROM THE LIMESTONE IN THE CREEK 1/8 MILE EAST OF THE W¼ CORNER SEC. 6, T. 20, R. 12 E. WESTWARD TO THE TOP OF THE HILL NEAR THE CENTER OF SEC. 1, T. 20 N., R. 11 E. MEASUREMENTS WERE MADE IN SUCH A WAY THAT THE DIP WOULD BE UNIMPORTANT.	
Nellie Bly formation.	
17. Sandstone; caps top of hill, medium-grained, massive, about	10.0
16. Covered: probably shale with a few thin sandstones	55.0
15. Sandstone: caps east end of hill, brown, medium-grained, massive, blocks 5 by 20 feet	5.0
14. Covered: probably shale	10.0
13. Sandstone: exposed on west end of hill, fine-grained, massive	3.0
12. Shale: partly covered, weathers yellow to red	72.0
11. Sandstone: fine-grained, thin-bedded, not well exposed	3.0
10. Covered: probably shale	18.0
9. Sandstone: not well exposed, top of a timber belt	3.0
8. Covered; probably sandy shale and thin sandstones	35.0
7. Sandstone: about	2.0
6. Covered: probably sandy shale	6.0
5. Sandstone: medium-grained, two or three massive beds	5.0
4. Covered: probably sandy shale	23.0
Hogshooter formation.	
Winterset limestone member.	
3. Limestone: dark, fossiliferous, large crinoid stems	4.0
2. Limestone: dark, crinoidal, carries phosphatic nodules	1.0
Coffeyville formation.	
1. Shale: base not exposed	4.0
108. SEC. 13, T. 20 N., R. 12 E. MEASURED FROM THE CHECKERBOARD LIMESTONE IN THE CREEK IMMEDIATELY SOUTH OF THE BIG POND, 1/8 MILE SOUTH OF THE NW CORNER, SOUTHWARD OVER THE HILL TO THE W¼ CORNER.	
Coffeyville formation.	
8. Sandy shale and sandstone: not well exposed, caps hill west of road, top eroded	10.0

	Feet
7. Alternating sandstone and silty to sandy shale: not well exposed	40.0
6. Shale: silty	5.0
5. Sandstone: brown with darker brown mottling; relatively soft, fossiliferous, many casts, medium-grained	5.0
4. Shale: dark, well exposed; somewhat silty at the base, grades upward to very silty shale	54.0
3. Covered: probably dark shale weathering gray and somewhat silty in the upper part	57.0
2. Shale: black, fissile, phosphatic nodules in middle 2 feet	5.0
Checkerboard limestone.	
1. Limestone: top pitted by erosion, dark blue, weathers gray; joint cracks 3 to 5 feet apart nearly at right angles break the stone into large nearly square blocks, base not exposed but the thickness in this area is generally	2.5

109. SECS. 15 and 22, T. 20 N., R. 12 E. COMPILED FROM MEASUREMENTS MADE BY BAROMETER TRAVERSES.

Hogshooter formation.	
Winterset limestone member.	
5. Limestone: about	5.0
Coffeyville formation.	
4. Shale	25.0
3. Sandstone and silty shale: top eroded	15.0
2. Covered: probably silty shale	100.0
1. Sandstone and silty shale: not measured.	

110. T. 20 N., Rs. 12 AND 13 E. FROM BASE OF THE SEMINOLE FORMATION 1/8 MILE SOUTH OF THE NE CORNER SEC. 22, R. 13 E. TO THE CHECKERBOARD LIMESTONE 1,500 FEET WEST OF THE SE CORNER SEC. 13, R. 12 E.

Checkerboard limestone.	
13. Limestone	2.5
Seminole formation.	
12. Shale	25.0
11. Sandstone	5.0
10. Shale	15.0
9. Sandstone	5.0
8. Shale	10.0
7. Sandstone	25.0
6. Shale	15.0
5. Sandstone	20.0
4. Shale	95.0
3. Coal: Dawson bed in strip pit not exposed, generally	1.5
2. Shale: about	5.0
1. Sandstone: basal bed of the Seminole	5.0

111. SEC. 15, T. 20 N., R. 13 E. BETWEEN THE RAILROAD BRIDGE AND THE ROAD NEAR S¼ CORNER OF SECTION.

Seminole formation.	
4. Covered: probably shale, lower part of the middle shaly member	10.0
3. Sandstone: brown, fine-grained, massive, the lower sandy member	3.0
2. Sandstone: brown, fine-grained, thin-bedded, the lower sandy member	3.0
Holdenville (Memorial) shale.	
1. Covered: probably gray shale	10.0

Feet

112. SEC. 23, T. 20 N., R. 13 E. FROM THE NW CORNER OF THE SECTION SOUTHWARD 1/8 MILE.

Seminole formation.

2. Sandstone: lower Seminole, thin-bedded, fine-grained, weathers brown, exposed to top of hill but probably not much eroded, about 10.0

Holdenville (Memorial) shale.

1. Covered: shale, gray, base not exposed 30.0

113. SEC. 23, T. 20 N., R. 13 E. FROM A LIMESTONE EXPOSED IN VICINITY OF E¼ CORNER TO BASE OF SEMINOLE FORMATION 1/8 MILE SOUTH OF NW CORNER.

Seminole formation, lower sandy part.

3. Sandstone: thin-bedded, fine-grained, weathers brown; exposed to the top of the hill but probably not much eroded, total thickness in this vicinity, about 10.0

Holdenville (Memorial) shale.

2. Covered: probably shale, about 40.0

Lenapah (Eleventh Street) limestone.

1. Limestone: massive, fossiliferous, weathers reddish brown, not well exposed, about 2.0

114. SEC. 36, T. 20 N., R. 13 E. MEASURED IN BIG ROAD CUT 200 FEET EAST OF THE SW CORNER.

Seminole formation, lower part.

4. Clay: yellowish brown, contains weathered fragments of sandstone; probably represents a sandy shale with thin sandstone beds 4.0
3. Sandstone and shale in alternating beds: sandstone beds 0.1 to 0.5 feet thick, fine-grained, silty; shale, silty; all weathers yellowish to reddish brown, all micaceous, some sandstone beds contain limonitic clay ball inclusions 9.0
2. Sandstone: massive, lenticular, medium-grained, dense, reddish brown 1.5

Holdenville (Memorial) shale.

1. Shale: dark clay shale, weathers yellow, thin-bedded, base not exposed 8.0

115. T. 20 N., Rs. 13 AND 14 E. FROM N¼ CORNER SEC. 19, T. 20 N., R. 14 E. TO 1/8 MILE SOUTH OF NW CORNER SEC. 23, T. 20 N., R. 13 E. DIFFERENCE IN ELEVATION 33 FEET, WEST DIP ALLOWED 55 FEET PER MILE.

Seminole formation, lower part.

3. Sandstone: base of the Seminole, not measured.

Holdenville (Memorial) shale,
Lenapah (Eleventh Street) limestone, and
Nowata formation.

2. Covered 170.0

Oologah formation.

1. Limestone: not measured.

116. SEC. 18, T. 20 N., R. 14 E. JUST NORTH OF THE BRIDGE OVER MINGO CREEK NEAR THE S¼ CORNER.

Nowata shale, lower part.

3. Covered: probably shale 5.0

Oologah formation, upper part.

2. Limestone: Oologah like No. 1, except that it is thinly and unevenly bedded 10.0
1. Limestone: Oologah, gray, massive; many fossil fragments of crinoids, brachiopods, bryozoans; base not exposed, extends down to low water in Mingo Creek 20.0

TOWNSHIP 21 NORTH

117. SEC. 2, T. 21 N., R. 10 E. MEASURED IN THE NW¼ NW¼.

	Feet
Barnsdall formation.	
Okesa sandstone member.	
3. Sandstone: not measured.	
Wann formation.	
2. Covered: shale	50.0
1. Sandstone: not measured.	

118. SEC. 18, T. 21 N., R. 10 E. MEASURED FROM TOP OF SANDSTONE SOUTH OF NE CORNER SOUTHWARD TO SANDSTONE ON SPUR OF HILL.

	Feet
Tallant formation.	
11. Sandstone: brown, coarse-grained, top eroded	10.0
Barnsdall formation.	
Unnamed shale member.	
10. Covered: gray shale	10.0
9. Dolomite: gray, sandy, fossiliferous; weathers brownish red; Wildhorse dolomite	1.0
8. Covered: gray shale	36.0
7. Limestone: brown	0.5
6. Covered: gray shale	12.0
5. Limestone: gray fossiliferous	0.3
4. Shale	5.0
3. Sandstone: limy, fossiliferous	0.3
2. Covered: shale	40.0
Okesa sandstone member.	
1. Sandstone: not measured.	

119. SEC. 18, T. 21 N., R. 10 E. MEASURED FROM TOP OF SANDSTONE SOUTH OF NE CORNER SOUTHWARD TO SANDSTONE ON SPUR OF HILL.

	Feet
Tallant formation.	
11. Sandstone: brown, coarse-grained, top eroded	10.0
Barnsdall formation.	
Unnamed shale member.	
10. Covered: gray shale	10.0
9. Dolomite: gray, sandy, fossiliferous; weathers brownish red; Wildhorse dolomite	1.0
8. Covered: gray shale	36.0
7. Limestone: brown	0.5
6. Covered: gray shale	12.0
5. Limestone: gray, fossiliferous	0.3
4. Shale	5.0
3. Sandstone: limy, fossiliferous	0.3
2. Covered: shale	40.0
Okesa sandstone member.	
1. Sandstone: not measured.	

120. SECS. 21 AND 28, T. 21 N., R. 10 E. MEASURED UP HILL NORTH OF THE CREEK IN VICINITY OF SE CORNER SEC. 21.

	Feet
Barnsdall formation.	
Okesa sandstone member.	
13. Sandstone	3.0
12. Shale	7.0
11. Sandstone	10.0
Wann formation.	
10. Covered: shale	12.0

	Feet
9. Sandstone	10.0
8. Covered: shale	15.0
7. Sandstone: about	5.0
6. Covered: shale	25.0
5. Sandstone: about	2.0
4. Covered: shale	8.0
3. Sandstone: about	3.0
2. Covered: probably shale	25.0
1. Top of a sandstone in bottom of creek.	

121. SEC. 24, T. 21 N., R. 10 E. MEASURED FROM ¼ MILE WEST OF N¼ CORNER WEST TO NW CORNER.

Barnsdall formation.	
Okesa sandstone member.	
3. Sandstone: not measured.	
Wann formation.	
2. Covered: shale	30.0
1. Sandstone: not measured.	

122. SECS. 27 AND 34, T. 21 N., R. 10 E. MEASURED FROM CROSSING OF CREEK IN SW¼ SW¼ SEC. 34, ALONG ROAD NORTHWARD TO CENTER OF SE¼ SEC. 27.

Barnsdall formation.	
Okesa sandstone member.	
9. Sandstone: top eroded	10.0
Wann formation.	
8. Shale: gray	40.0
7. Sandstone	5.0
6. Shale	5.0
5. Sandstone: massive, medium-grained, weathers reddish brown, a few shale beds 1 to 2 feet thick in upper part	55.0
4. Shale: maroon	10.0
3. Sandstone: massive, medium-grained, reddish brown	25.0
2. Shale: dark, weathers gray to yellow	67.0
1. Sandstone: in creek bed, not measured.	

123. SEC. 28, T. 21 N., R. 10 E. MEASURED IN THE NW¼ NE¼ NE¼ ON HILL SOUTH FROM THE CREEK FOLLOWING AN OLD ROAD.

Wann formation.	
3. Sandstone: massive ledge	8.0
2. Covered: probably shale	40.0
1. Top of sandstone in bottom of creek.	

124. SEC. 12, T. 21 N., R. 11 E. UP WINDING ROAD NORTHWARD FROM SW CORNER TO TOP OF HILL.

Wann formation.	
11. Shale: sandy, and thin sandstone beds, top eroded	10.0
10. Sandstone: medium-grained, weathers brown, 1 inch to 16 inches, about	10.0
9. Shale: silty	1.5
Iola formation.	
Avant limestone member.	
8. Limestone: gray, massive, fossiliferous with calcareous shale partings; probably represents only upper part of Avant of type locality	12.0
7. Covered: shale	20.0
6. Bench: probably limy sandstone, probably represents lower part of Avant of type locality	5.0

	Feet
Muncie Creek shale member.	
5. Covered: shale, probably includes Paola limestone member and upper part of Chanute formation	45.0
Chanute formation.	
Cottage Grove sandstone member.	
4. Bench: well covered, appears to be sandstone	5.0
Unnamed shale member.	
3. Covered: shale, may include Thayer coal member at top and part of Dewey formation in lower part	25.0
Dewey formation.	
2. Limestone: dark, weathers yellow to reddish brown, massive, fossiliferous, about	2.5
1. Shale: dark, not measured.	

125. SEC. 12, T. 21 N., R. 11 E. FROM THE JUNCTION OF TWO SMALL STREAMS BETWEEN ¼ AND ½ MILE SOUTH OF NE CORNER TO LIMESTONE IN SPUR OF HILL TO WEST.

Dewey formation.	
5. Shale: not measured.	
4. Limestone: weathers reddish yellow, fossiliferous	1.0
Nellie Bly formation.	
3. Covered: shale	85.0
2. Limestone: dark, weathers reddish brown, packed with crinoid stems, about	0.5
1. Sandstone and sandy shale: not measured.	

126. SEC. 12, T. 21 N., R. 11 E. ¼ MILE SOUTH OF N¼ CORNER.

Wann formation.	
19. Sandstone: massive, top eroded, not measured.	
18. Shale	5.0
17. Sandstone	1.0
16. Shale	3.0
Iola formation.	
Avant limestone member.	
15. Limestone: gray to white, fossiliferous, wavy bedding; probably represents only the upper part of the Avant of the type locality	6.0
Muncie Creek shale member.	
14. Shale: dark	62.0
Paola limestone member.	
13. At this point is a bench growing persimmon trees but no hard bed crops out; probably a limestone or limy shale representing the Paola limestone	1.0
Chanute formation.	
Carbonaceous shale member.	
12. Shale: gray to dark	23.0
11. Smut streak.	
Cottage Grove sandstone member.	
10. Sandstone: limy	0.4
9. Shale: gray	2.5
8. Sandstone: extremely thin-bedded, micaceous, cream to tan colored	4.0
7. Shale	1.5
Thayer coal member.	
6. Coal	0.1
5. Shale	1.0
4. Coal	0.1
Unnamed shale member.	
3. Covered: dark shale	3.0

	Feet
Dewey formation.	
2. Limestone: weathers reddish yellow; fossiliferous, contains fragments of brachiopods, crinoids, and bryozoans	1.0
1. Shale: probably part of the Dewey formation, not well exposed, not measured.	

127. SEC. 14, T. 21 N., R. 11 E. MEASURED FROM 0.2 MILE EAST OF SE CORNER, WESTWARD TO TOP OF HILL.

Wann formation.	
11. Sandstone: a single massive bed, medium to fine-grained; weathers reddish brown, top eroded, lower part of the colloquial Washington Irving sandstone	4.0
10. Covered: shale	78.0
Iola formation.	
Avant limestone.	
9. Limestone: sandy, reddish brown; probably equivalent to the upper part only of the Avant limestone of the type locality	10.0
Muncie Creek shale member.	
8. Covered: shale	50.0
Paola limestone member.	
7. Sandstone: not well exposed, forms bench, probably represents the Paola limestone	5.0
Chanute formation.	
6. Covered: shale	35.0
5. Sandstone: forms a bench, fine-grained, beds 0.5 feet thick	1.5
4. Shale: about	2.0
Dewey formation.	
3. Limestone: probably Dewey, exposed 300 feet north of SE corner of section; light colored, fossiliferous, coal float found in stream above this bed to northwest	1.5
2. Covered: shale	30.0
1. Limestone: weathers white or yellow, fossiliferous; the colloquial Cow Barn limestone of Joseph L. Borden at its type locality; as it is the lowest limestone above the sandstones of the Nellie Bly formation it is here considered a part of the Dewey formation	3.0

128. SEC. 28, T. 21 N., R. 11 E. MEASURED FROM THE LIMESTONE OUTCROP SOUTH OF THE CROSS ROADS, ¼ MILE SOUTH OF THE ROCK SCHOOL HOUSE AT THE E¼ CORNER, NORTHWESTWARD TO SPUR OF HILL.

Iola formation.	
Avant limestone member.	
4. Limestone: weathers reddish brown, not measured.	
Iola formation,	
Chanute formation, and	
Dewey formation.	
3. Covered: shale	70.0
Dewey formation.	
2. Limestone: gray to pink, massive, colloquial Cow Barn limestone	4.0
Nellie Bly formation.	
1. Sandstone: not measured.	

129. SEC. 28, T. 21 N., R. 11 E. FROM LIMESTONE IN ROAD NE¼ SW¼ NORTHWARD TO SPUR OF HILL.

	Feet
Iola formation.	
Avant limestone member.	
7. Limestone: gray, crystaline, a few crinoid stems; top eroded, probably represents only the upper part of the Avant of the type locality	5.0
Muncie Creek shale member.	
6. Shale: weathers gray, upper part probably equivalent to the lower part of the Avant limestone of the type locality	40.0
Paola limestone member.	
5. Topographic bench with limy phosphatic nodules which are not in place, probably represents the Paola limestone	1.0
Chanute formation, and Dewey formation.	
4. Covered: shale, probably includes Chanute formation and, in the lower part, shale equivalent to part of the Dewey formation; the upper part of the Dewey probably having been removed by pre-Chanute erosion	40.0
Dewey formation.	
3. Sandstone: limy, thin-bedded, fine-grained, only 2 feet of lower part exposed	5.0
2. Shale: not well exposed	4.0
1. Limestone: gray, weathers white, packed with crinoid fragments	2.0

130. SEC. 28, T. 21 N., R. 11 E. MEASURED FROM ¼ MILE NORTH OF SE CORNER TO 1/8 MILE WEST OF E¼ CORNER (FROM BASE OF HILL TO POINT CAPPED BY AVANT LIMESTONE).

Iola formation.	
Avant limestone member.	
9. Limestone: top eroded, probably equivalent to only upper part of Avant limestone of type locality	2.0
Avant limestone member, Muncie Creek shale member, Paola limestone member, Chanute formation, and Dewey formation.	
8. Covered: shale	75.0
Dewey formation.	
7. Limestone: yellowish-gray to white; fossiliferous, crinoid stems, and fusulinids abundant; the colloquial Cow Barn limestone	2.0
Nellie Bly formation.	
6. Shale, dark	1.0
5. Sandstone: fine-grained, weathers yellowish brown	1.0
4. Shale: dark, weathers green to brown	12.0
3. Sandstone: thin-bedded, fine-grained; weathers yellow to brownish red	10.0
2. Shale: dark, weathers yellow	15.0
1. Sandstone: thin-bedded, yellow, base not exposed	0.5

131. SEC. 28, T. 21 N., R. 11 E. MEASURED FROM THE BASE OF AVANT LIMESTONE 0.3 MILE NORTH OF E¼ CORNER TO TOP OF MASSIVE SANDSTONE WHICH CAPS SPUR TO WEST.

Wann formation.	
8. Covered: thin-bedded sandstone, top eroded	10.0
7. Sandstone: weathers reddish brown, a single massive bed	5.0
6. Covered: shale	70.0
5. Bench: probably sandstone, about	5.0

	Feet
4. Covered: shale	50.0
3. Sandstone: reddish brown, massive	2.0
2. Covered: shale	3.0
Iola formation.	
Avant limestone member.	
1. Limestone: gray, weathers red; fossiliferous, probably equivalent to the upper part of the Avant limestone at its type locality	5.0

132. SEC. 29, T. 21 N., R. 11 E. MEASURED FROM ABOUT THE CENTER TO A POINT 1/8 MILE NORTH OF THE W¼ CORNER.

Wann formation.	
9. Sandstone	5.0
8. Shale	5.0
7. Bench: sandstone	15.0
6. Covered: shale	35.0
5. Sandstone: gray to yellow or brown, medium-grained, base not exposed, about	20.0
4. Covered: shale	75.0
3. Bench: sandstone, about	5.0
2. Covered: shale	32.0
Iola formation.	
Avant limestone member.	
1. Limestone: fossiliferous, gray, weathers brownish red	5.0

133. SEC. 33, T. 21 N., R. 11 E. MEASURED SOMEWHAT WEST OF THE CENTER.

Wann formation, basal part.	
9. Sandstone: medium-grained; weathers reddish brown; slabs 0.2 to 0.8 feet thick, top eroded	6.0
8. Shale: gray, about	2.0
Iola formation.	
Avant limestone member.	
7. Limestone: gray, fossiliferous, weathers brownish red	2.0
6. Covered: shale	34.0
5. Bench: probably sandstone; persimmon trees indicate lime content, probably equivalent to lower part of Avant lime stone of type locality	2.0
Muncie Creek shale member.	
4. Covered: shale	13.0
Paola limestone member.	
3. Bench: probably sandstone equivalent to Paola limestone	2.0
Chanute formation, and	
Dewey formation.	
2. Covered: shale; may include shale in Dewey formation, upper part of Dewey probably removed by pre-Chanute erosion	28.0
Dewey formation.	
1. Limestone: not measured.	

134. SEC. 33, T. 21 N., R. 11 E. WESTWARD FROM CREEK BED SE¼ SE¼ OF THE SECTION.

Nellie Bly formation.	
5. Covered to the top of the hill, probably shale and sandstone. This is approximately the top of the Nellie Bly formation	10.0
4. Sandstone: poorly exposed, about	5.0
3. Covered: probably shale and thin sandstone	35.0
2. Sandstone: massive, medium-grained, rough bedding	25.0
1. Covered: down to bed of creek, may be shale	5.0

	Feet
135. SEC. 34, T. 21 N., R. 11 E. FROM NEAR E¼ CORNER WESTWARD TO TOP OF A MASSIVE SANDSTONE, ALONG THIS SANDSTONE LEDGE ½ MILE SOUTHWARD, THEN WESTWARD TO TOP OF HILL.	
Nellie Bly formation, begins practically at top of formation.	
9. Followed bed 8 southward ½ mile and measured up to the top of the hill where the top of the colloquial Shell Creek sandstone forms a long westward dip slope, covered but probably sandstone	30.0
8. Sandstone: massive	11.0
7. Covered: probably sandy shale with sandstone beds less than 1 foot thick	17.0
6. Sandstone	4.0
5. Shale	2.0
4. Sandstone	3.0
3. Shale	2.0
2. Sandstone: medium- to fine-grained, a single massive bed	15.0
1. Covered: probably shale with a few sandstone beds	85.0
136. SEC. 35, T. 21 N., R. 11 E. FROM A POINT JUST EAST OF THE CENTER OF THE SECTION EASTWARD TO THE TOP OF THE HILL.	
Nellie Bly formation, middle.	
13. Sandstone: caps top of hill; massive, medium-grained, reddish brown, not measured.	
12. Covered: probably shale, may contain some thin sandstone beds	26.0
11. Bench: sandstone, about	2.0
10. Covered: probably shale, about	15.0
9. Bench: sandstone, about	5.0
8. Covered: probably shale, about	40.0
7. Bench: sandstone, about	2.0
6. Covered: probably shale, about	40.0
5. Sandstone: not well exposed; fine- to medium-grained, massive	10.0
4. Covered: probably shale and thin sandstones	30.0
3. Sandstone: weathers reddish brown, a single massive bed	6.0
2. Covered: probably shale	11.0
1. Sandstone: massive, medium-grained, base not exposed	5.0
137. SEC. 36, T. 21 N., R. 11 E. ALONG THE PIPE LINE FROM A POINT 1/8 MILE WEST OF THE E¼ CORNER OF SECTION NORTHWESTWARD TO THE TOP OF THE HILL. HOGSHOOTER LIMESTONE IS WELL EXPOSED 200 FEET EAST OF THE PIPELINE.	
Nellie Bly formation, lower part.	
8. Covered: shale, to the top of the hill	4.0
7. Sandstone bench: fine-grained, massive	5.0
6. Covered slope: probably sandy shale	32.0
5. Sandstone	2.0
4. Covered: sandy shale	8.0
3. Sandstone bench	2.0
2. Covered: shale	5.0
Hogshooter formation.	
Winterset limestone member.	
1. Limestone: exposed 200 feet east of the pipe line	3.0
138. SEC. 21, T. 21 N., R. 12 E. MEASURED IN EAST WEST ROAD JUST EAST OF WEST ¼ CORNER.	
Nellie Bly formation, lower part.	
6. Shale: sandy with sandstone streaks, top eroded	15.0

	Feet
5. Sandstone: gray to brown, fine-grained	1.0
4. Shale: dark with a thin sandstone near the middle	11.0
Hogshooter formation.	
Winterset limestone member.	
3. Limestone: dark bluish, sandy, fossiliferous	3.0
Coffeyville formation.	
2. Shale: sandy	2.0
1. Sandstone: gray, micaceous, shaly to silty, not measured.	

139. SECS. 29 AND 30, T. 21 N., R. 12 E. MEASURED ALONG ROAD BETWEEN SECS. 29 AND 30 SOUTH OF THE NE CORNER SEC. 30.

Nellie Bly formation.	
5. Sandstone: forms rim of high hill with relatively steep NW dip slope, not well exposed, but generally is dark brown, medium to fine-grained, massive	3.0
4. Shale, dark	20.0
3. Sandstone: fine-grained, weathers yellowish brown	2.0
2. Shale: dark	8.0
Hogshooter formation.	
Winterset limestone member.	
1. Limestone: gray, fossiliferous	2.0

140. SEC. 35, T. 21 N., R. 12 E. IN ROAD SOUTH SIDE TURLEY MOUNTAIN.

Hogshooter formation.	
Winterset limestone member.	
6. Limestone: small crinoid stems and other fossils, contains phosphatic nodules, about	3.0
Coffeyville formation.	
5. Clay shale: gray, some limonitic nodules, plant remains	17.0
4. Coal	0.6
3. Shale: black, flaky to fissile	1.0
2. Clay shale: gray	24.0
1. Sandstone: thin-bedded, light colored; probably the Layton sand of the subsurface, not measured.	

141. SECS. 35 AND 36, T. 21 N., R. 12 E. FROM THE CHECKERBOARD LIMESTONE JUST WEST OF THE RAILROAD TRACK NORTH LINE OF SECTION 36 WEST TO BLACK TOP OVER TURLEY MOUNTAIN THENCE ALONG ROAD TO TOP OF MOUNTAIN.

Nellie Bly formation.	
19. Shale: much weathered, top eroded	4.0
18. Sandstone and shale: sandstone is thin-bedded and silty, shale is silty	10.0
17. Shale: gray, silty	5.0
16. Sandstone: fine-grained, brown, several massive beds	8.0
15. Sandstone and shale: silty	3.0
14. Shale: silty	2.0
13. Sandstone: two massive beds, fine-grained, weathers brown, upper surface of lower bed pitted	3.5
12. Covered: probably shale	15.0
11. Limestone: weathers bright yellow; nodular and much broken, recemented by calcite, not well exposed, about	1.0
10. Shale: poorly exposed, weathers to grayish yellow clay	22.0

	Feet
Hogshooter formation.	
Winterset limestone member.	
9. Limestone: gray to yellow, packed with crinoid fragments; contains phosphatic nodules in basal part, not well exposed, about	2.5
Coffeyville formation.	
8. Shale: poorly exposed, weathers to brownish red clay	17.0
7. Sandstone: fine-grained to silty, thin-bedded, brown	10.0
6. Sandstone: massive beds up to 3 feet thick, separated by thin-bedded bands, a few of the massive beds contain molds of pelecypods. Even the massive beds are parted into thin layers by weathering; fine-grained, brown	24.0
5. Sandstone: thin-bedded, fine-grained, weathers brown	4.0
4. Covered for the greater part: a few exposures of bed rock and the relatively fresh slumped material indicate dark shale, clay shale mostly, silty in upper 15 feet, thickness by barometer 130 feet, corrected for dip to	90.0
Nos. 4 to 19 inclusive measured along black top road over Turley mountain.	
3. Covered: probably dark shale, about	40.0
2. Sandstone: poorly exposed, about	10.0
1. Covered: probably dark shale, about	40.0
Nos. 1 to 3 inclusive measured along section line westward from the exposure of Checkerboard limestone in the road just west of the railroad to the black top road over Turley Mountain. Covered or very poor exposures along section line. Thicknesses of divisions and their descriptions influenced largely by observations on low spur to the south of road.	
Checkerboard limestone.	

142. SEC. 1, T. 21 N., R. 13 E. FROM 0.4 MILE EAST OF NE CORNER TO 500 FEET WEST OF NW CORNER. WEST DIP ALLOWED 40 FEET PER MILE.

Coffeyville formation, lower part.	
8. Shale: not measured.	
Checkerboard limestone.	
7. Limestone: dark, fossiliferous, massive	1.5
Seminole formation.	
6. Covered: shale	20.0
5. Sandstone: thin-bedded, fine-grained, weathers reddish brown, about	5.0
4. Shale: about	35.0
3. Sandstone: poorly exposed at the NE corner section 1, about	5.0
2. Partly covered: shale, about	30.0
1. Coal: Dawson bed, not exposed indicated by strip pit, generally	2.5

143. SEC. 1, T. 21 N., R. 13 E. FROM 1/10 MILE EAST OF SE CORNER TO THE SW CORNER. DIP ALLOWED 50 FEET PER MILE.

Seminole formation.	
6. Shale: not measured.	
5. Sandstone: weathers yellowish brown, thin-bedded silty, about	10.0
4. Covered: silty shale, about	20.0
3. Sandstone: weathers brownish yellow, thin-bedded, silty, about	5.0
2. Covered: shale	70.0
1. Dawson coal, does not crop out, indicated by strip pits, usually	2.5

Feet

144. SEC. 1, T. 21 N., R. 14 E. ALONG THE SOUTH SIDE. WEST DIP ALLOWED 50 FEET PER MILE.

Seminole formation.
3. Limestone: weathers reddish brown, slightly sandy, crinoidal; probably base of the lower sandy member of the Seminole 1.0

Nowata formation, greater part removed by pre-Seminole erosion.
2. Covered: shale 20.0

Oologah formation.
1. Limestone: Oologah, not measured.

145. SEC. 2, T. 21 N., R. 14 E. FROM ¼ MILE EAST OF SE CORNER TO 1/10 MILE EAST OF SW CORNER. WEST DIP ALLOWED 50 FEET PER MILE.

Seminole formation, lower sandy part.
5. Sandstone: not measured.
4. Silty shale: partly covered, top 0.1 mile east of SW corner...... 15.0
3. Sandstone: partly covered, gray, fine-grained, thin-bedded, weathers reddish brown, top just east of culvert 0.2 miles east of SW corner 20.0
2. Shale: partly covered to poorly exposed, sandy, top at mail box 0.45 mile west of SE corner 10.0
1. Sandstone: soft, deeply weathered to reddish brown, thin-bedded, top at SE corner 12.0

146. SEC. 3, T. 21 N., R. 14 E. FROM 0.1 MILE EAST OF SE CORNER TO 0.1 MILE WEST OF THE SW CORNER.

Seminole formation, lower sandy part.
3. Shale: not measured.
2. Sandstone: crops out poorly, soft, fine-grained, weathers reddish brown, may contain sandy shale, west dip 35 feet per mile 40.0
3. Shale: not measured.

147. SECS. 4 AND 5, T. 21 N., R. 14 E. FROM 0.1 MILE WEST OF SE CORNER SEC. 4 TO 0.4 MILE EAST OF SW CORNER SEC. 5.

Seminole formation, lower sandy part.
4. Shale: not measured.
3. Sandstone: soft, fine to medium-grained, thin-bedded, cross-bedded, top at 0.2 mile east of S¼ corner section 5, and again at 0.1 mile west of S¼ corner section 5, west dip on top 35 feet per mile 20.0
2. Shale: top ¼ mile east of S¼ corner section 4 .... 17.0
1. Sandstone: not measured.

148. SEC. 6, T. 21 N., R. 14 E. FROM 0.4 MILE EAST OF SE CORNER TO 0.1 MILE EAST OF SW CORNER.

Seminole formation.
7. Shale: not measured.
6. Coal: Dawson bed does not crop out along road but position is indicated by nearby strip pits which are now filled, verbal reports from residents in vicinity indicate 2.5
5. Shale: estimated 10.0
4. Sandstone: partly exposed, dips west more than 50 feet per mile, about 10.0
3. Covered: shale, sandy, about 7.0
2. Sandstone: silty, light colored, thin-bedded 10.0
1. Shale 15.0

TOWNSHIP 22 NORTH

149. SECS. 23 AND 24, T. 22 N., R. 10 E. FROM CENTER OF NW¼ SEC. 24 WESTWARD TO MOUNTAIN VIEW SCHOOL HOUSE AT THE TOP OF THE HILL IN THE NE¼ OF SEC. 23.

	Feet
Wann formation.	
13. Shale: not measured.	
12. Sandstone: upper part of the Clem Creek, medium to fine-grained, weathers brownish red	6.0
11. Shale: sandy	2.0
10. Sandstone: medium-grained, weathers buff, cross-bedded	40.0
9. Shale: weathers pink to red	1.5
8. Shale: black, coal and carbonized wood	1.0
7. Shale: silty, bluish color, weathers brown or red	3.5
6. Sandstone: thin-bedded, fine-grained, buff color	1.0
5. Shale: weathers reddish brown	2.0
4. Sandstone: massive cross-bedded, weathers reddish brown	3.0
3. Shale: clay shale, weathers greenish gray to reddish brown, silty streaks in upper part	6.0
2. Sandstone: massive, cross-bedded, medium-grained, weathers reddish brown, base not exposed	18.0

150. SEC. 23, T. 22 N., R. 10 E. MEASURED IN THE VICINITY OF THE CENTER NE¼.

Barnsdall formation.	
Unnamed shale member.	
3. Dolomite: lower part of the Wild Horse dolomite lense, top eroded, not measured.	
2. Shale: dark, calcareous, fossiliferous in part	80.0
Okesa sandstone member.	
1. Sandstone: not measured.	

151. SEC. 20, T. 22 N., R. 11 E. MEASURED IN THE VICINITY OF THE NE CORNER.

Wann formation.	
10. Covered: probably sandy shale and thin sandstone beds	23.0
9. Sandstone: yellowish gray, fine- to medium-grained, laminated, lower three feet cross-bedded	8.0
8. Covered: probably shale	30.0
7. Sandstone: gray, massive, cross-bedded, medium-grained, weathers brown, a single massive stratum	17.0
6. Covered: probably shale	17.0
5. Limestone: sandy, gray, weathers brownish red, cross-bedded	6.0
4. Covered: probably shale	23.0
3. Sandstone: gray, massive, medium-grained, with stringers of sandy limestone	9.0
2. Sandstone: gray, massive, medium-grained	20.0
1. Covered talus slope down to alluvium, estimated	50.0

152. SEC. 27, T. 22 N., R. 11 E. FROM BRIDGE OVER HOMINY CREEK ¼ MILE SOUTH OF CENTER OF SECTION EASTWARD AND NORTHWARD UP HILL ALONG ROADS.

Wann formation.	
13. Base of a massive sandstone, not measured.	
12. Shale: sandy with a considerable amount of thin sandstone beds	50.0
11. Sandstone	1.0
10. Shale	3.0
9. Sandstone: buff, fine-grained	0.5
8. Shale: dark sandy	1.0

	Feet
7. Sandstone: buff, fine-grained	0.5
6. Shale: dark, sandy	39.0
5. Shale: dark with thin sandstone beds	11.0
4. Shale: dark, weathers brown to red	40.0
3. Shale: weathers red, a few thin sandstone beds	6.0
2. Shale: bluish gray	11.0
Iola formation.	
Avant limestone member.	
1. Limestone: gray, fossiliferous, weathers out in wavy beds and plates only a few inches thick; crops out in creek bank by bridge, appears to have two or more shale breaks 1 to 2 feet thick in upper part	20.0

153. SEC. 4, T. 22 N., R. 12 E. MEASURED IN W.P.A. QUARRY IN THE SE¼ NE¼. COAL WAS EXPOSED IN THE LOADING PIT NEAR THE BASE OF THE HILL AND JUST ABOVE THE DEWEY LIMESTONE.

Iola formation.	
Avant limestone member.	
7. Limestone: fossiliferous, bluish gray when fresh but weathers to reddish brown. In fresh exposures appears to be composed of massive beds 2 to 4 feet thick but these weather to thin wavy beds and lenses only a few inches thick, top eroded	20.0
Muncie Creek shale member, and	
Paola limestone member.	
6. Rubble-covered shale slope: Paola limestone member, probably lies at the base	46.0
Chanute formation.	
Cottage Grove sandstone member.	
5. Rubble-covered sandstone escarpment	30.0
4. Shale	7.0
Thayer coal member.	
3. Coal	0.1
Shale member.	
2. Shale	10.0
Dewey limestone.	
1. Limestone: not measured.	

154. SECS. 18 AND 19, T. 22 N., R. 12 E. SECTION MEASURED FROM THE LIMESTONE IN THE ROAD NORTH OF JAVINE SCHOOL, ½ MILE SOUTH OF NE CORNER SEC. 19 NORTHWARD TO 0.1 MILE NORTH OF SAME CORNER.

Iola formation.	
Paola limestone member.	
3. Limestone	1.0
Chanute formation.	
2. Covered	35.0
Dewey formation.	
1. Limestone: base not well exposed ,thin wavy beds of limestone 0.2 feet thick intercalated with calcareous shale containing Caninia torquium	17.0

155. SEC. 18, T. 22 N., R. 12 E. BEGINS ON NORTH SIDE OF ROAD ¼ MILE WEST OF SE CORNER SEC. 18, EXTENDS WEST AND NORTH INTO FIELD NORTH OF ROAD.

Chanute formation.	
Carbonaceous shale member.	
4. Shale: dark	8.0

	Feet
Cottage Grove sandstone member.	
3. Sandstone: light gray, micaceous, beds 0.1 to 0.5 ft. thick, shale partings	20.0
Thayer coal member.	
2. Coal	0.1
Shale member.	
1. Shale: not measured.	

156. SEC. 18, T. 22 N., R. 12 E. MEASURED NEAR CENTER OF E½ OF SE¼ UP HILL WESTWARD ALONG ROAD.

Wann formation.	
8. Sandstone: gray to red, fine to medium-grained, beds 1 to 3 feet thick with shale partings, sandstone beds thinly laminated, top eroded	40.0
7. Shale: light gray, weathers dark	80.0
Iola formation.	
Avant limestone member.	
6. Limestone: very fossiliferous	0.2
5. Shale: calcareous	3.0
4. Limestone: gray, weathers white, fossiliferous, massive; weathers in wavy layers 0.2 feet thick	28.0
Muncie Creek shale member.	
3. Shale: weathers dark, phosphatic nodules present but not in place, poorly exposed	60.7
Paola limestone member.	
2. Limestone: fossiliferous, reddish gray, weathers white, much calcite replacing fossils	1.0
Chanute formation.	
1. Sandstone: not measured.	

157. SEC. 31, T. 22 N., R. 12 E. FROM THE EAST END OF THE OUTLYING HILL IN THE SOUTHWEST PART, NORTHEASTWARD TO HOMINY CREEK NEAR THE E¼ CORNER.

Wann formation.	
17. Sandstone reddish brown; fine-grained, laminated; many casts and molds of brachiopods, pelecypods, and other fossils; top eroded	5.0
16. Covered: shale	12.0
Iola formation.	
Avant limestone member.	
15. Limestone: light gray to bluish white; fossiliferous	6.0
Muncie Creek shale member.	
14. Shale: dark; Leiorhynchus and other associated fossils in upper few feet	67.0
Paola limestone member.	
13. Limestone, sandy: yellow to white; fossiliferous	3.0
Chanute formation.	
12. Shale	4.0
11. Sandstone: gray to dark tan; fine-grained, laminated and cross laminated, "wavy"	3.0
10. Shale: dark	23.0
Dewey formation.	
9. Limestone: weathers yellow; fossiliferous, not well exposed	2.0
8. Covered: probably dark shale	60.0
Nellie Bly formation.	
7. Sandstone: not well exposed, thin wavy beds, fine-grained, bears jack oak trees	20.0
6. Covered: shale	45.0
5. Sandstone: fine-grained, beds a few inches thick; weathers brownish yellow, poorly exposed	3.0

	Feet
4. Shale: poorly exposed, about	5.0
3. Siltstone, limy, about	2.0
2. Covered, about	30.0
1. Covered by water, sandstone: "Hominy Falls", about	8.0

158. T. 22 N., Rs. 12 AND 13 E. FROM THE CHECKERBOARD LIMESTONE AT THE NW CORNER SEC. 14, T. 22 N., R. 13 E. TO THE HOGSHOOTER LIMESTONE AT THE N¼ CORNER OF SEC. 5, T. 22 N., R. 12 E.

Hogshooter formation.	
Winterset limestone member.	
4. Limestone: not measured.	
Coffeyville formation.	
3. Largely covered	20.0
2. Largely shale with several sandstones	225.0
Checkerboard limestone.	
1. Limestone: not measured.	

159. SEC. 11, T. 22 N., R. 13 E. ALONG THE NORTH LINE.

Coffeyville formation.	
3. Sandstone bench: not well exposed, top forms dip slope westward, about	5.0
2. Covered: probably shale	55.0
Checkerboard limestone.	
1. Limestone: not measured, generally	2.5

160. SEC. 12, T. 22 N., R. 13 E. BEGINNING AT STREAM ¼ MILE EAST OF SW CORNER EXTENDING WESTWARD 1/8 MILE TO CHECKERBOARD LIMESTONE.

Checkerboard limestone.	
6. Limestone: not well exposed, not measured.	
Seminole formation.	
5. Siltstone: dark, weathers gray, to reddish brown, thin-bedded	4.0
4. Shale: dark, weathers gray to reddish brown, silty	10.0
3. Coal streak	0.1
2. Shale: dark, weathers gray, thin-bedded, silty	8.0
1. Shale: dark, weathers gray, thin-bedded, base not exposed in bed of stream	4.0

161. SEC. 13, T. 22 N., R. 13 E. BEGINNING AT HORSEPEN CREEK ¼ MILE SOUTH OF THE NW CORNER AND EXTENDING NORTH ABOUT 1/8 MILE TO THE CHECKERBOARD LIMESTONE.

Checkerboard limestone.	
3. Limestone: not measured, generally	2.5
Seminole formation.	
2. Covered: probably shale	26.0
1. Sandstone: gray to reddish brown, fine-grained, massive; base not exposed in bed of stream	12.0

162. SECS. 15 AND 16, T. 22 N., R. 13 E. FROM OUTCROP OF CHECKERBOARD LIMESTONE 1/8 MILE WEST OF SE CORNER SEC. 15 TO S¼ CORNER SEC. 16.

Coffeyville formation.	
5. Covered: scarp slope, probably thin-bedded, gray, silty sandstone and silty shale, sandstone weathers brown, top may be eroded but forms dip slope to westward	40.0
4. Covered: probably shale	20.0
3. Sandstone: poorly exposed, about	5.0
2. Covered: probably shale, about	55.0

	Feet
Checkerboard limestone.	
1. Limestone: dark; weathers gray to yellow, fossiliferous	2.5

163. SEC. 15, T. 22 N., R. 13 E. FROM OUTCROP OF CHECKERBOARD LIMESTONE 1/8 MILE WEST OF SE CORNER SEC. 15 TO E¼ CORNER ALONG STRIKE.

Coffeyville formation.	
3. Sandstone: not well exposed	5.0
2. Covered: probably shale	10.0
Checkerboard limestone.	
1. Limetone: dark, weathers gray to yellow, about	2.5

164. SEC. 3, T. 22 N., R. 14 E. IN THE EAST BANK OF CANEY RIVER ¼ MILE WEST OF NE CORNER OF THE SECTION. SAW COAL AND OVERLYING BLACK FISSILE SHALE AT A WORKING IN CREEK BANK, BUT WAS UNABLE TO GET INTO PIT ON ACCOUNT OF HIGH WATER. WILLARD GADDY, ROUTE 1, OOLOGAH, OKLA. OWNS THE LAND AND RALPH DOTSON, SAME ADDRESS, WORKS THE PIT. THEY SUPPLIED THE INFORMATION.

Seminole formation.	
4. Siltstone: gray, limy, top eroded and covered by alluvium, about	1.0
3. Shale: black, fissile, contains phosphatic nodules	4.5
2. Coal: Dawson, 22 to 24 inches thick	2.0
1. Underclay: more than	0.5

Copious spring are reported to be common in such pits. The source of the water may be the alluvium or the underlying lower Seminole sandstone which is probably only a few feet below the coal.

165. SEC. 4, T. 22 N., R. 14 E. HANDLEVEL MEASUREMENTS, DIP NEGLIGIBLE. BEGINNING AT THE EDGE OF ALLUVIUM JUST WEST OF THE S¼ CORNER AND CONTINUING WESTWARD UP HILL ABOUT ¼ MILE.

Seminole formation.	
13. Shale: near top of formation, not measured.	
12. Sandstone: reddish brown, thin-bedded, silty	2.0
11. Shale: gray, silty	3.5
10. Sandstone: gray to brown, massive, exposed in road to south with top in road to west	5.0
9. Shale: gray, silty, poorly exposed in road to south	4.7
8. Siltstone: limonitic	0.7
7. Shale: weathers gray, silty	4.0
6. Sandstone: gray to reddish brown, fine-grained, massive, base shows very little west dip	3.5
5. Clay shale: weathers gray,	5.5
4. Sandstone: reddish brown, fine-grained, massive, cross-bedded	19.0
3. Sandstone: reddish brown to gray, fine-grained, locally limy, limonitic and fossiliferous and contains carbonized plant remains	3.2
2. Sandstone: gray, micaceous, silty, thin-bedded to platy, base of upper sandy member	2.5
1. Shale: gray, micaceous, silty near the top, upper part of middle shale member, base covered by alluvium	21.0

166. SECS. 17 AND 20, T. 22 N., R. 14 E. FROM THE BASE OF A LIMY SILTSTONE IN THE STRIP PIT AT THE DRAW 200 FEET EAST OF THE SW CORNER SEC. 17 TO BASE OF THE UPPER SEMINOLE SANDSTONE 400 FEET SOUTH OF THE SAME CORNER, PROBABLY ALONG STRIKE.

	Feet
Seminole formation.	
6. Sandstone: fine-grained to silty, base of upper sandy member, not measured.	
5. Shale: upper part of middle shale member, dark, thin-bedded, silty in upper part	17.0
4. Covered: probably like No. 3 (south bank of pit ½ mile east of corner shows at least 40 feet of such shale)	23.0
3. Shale: dark, thin-bedded, a few flattened plant stems	12.0
2. Siltstone: dark, limy, a few shell fragments	1.5
1. Shale: black, fissile, contains a few fossil fragments enclosed in phosphatic nodules, poorly exposed but found on dumps north of pit, not measured, the Dawson coal lies only a few feet lower but is not exposed.	

167. SEC. 18, T. 22 N., R. 14 E., SEC. 12, T. 22 N., R. 13 E., FROM THE BASE OF THE UPPER SEMINOLE SANDSTONE, ABOUT 1/8 MILE SOUTH OF THE NE CORNER OF SEC. 18, T. 22 N., R. 14 E. TO THE CHECKERBOARD LIMESTONE (NOT CONSPICUOUSLY EXPOSED) ABOUT THE HOUSE ON THE HILL ¼ MILE NORTH AND 300 FEET WEST OF THE SE CORNER SEC. 12, T. 22 N., R. 13 E. CORRECTIONS FOR DIP DETERMINED FROM A STRUCTURE MAP PREPARED BY BAROMETRIC RECONNAISANCE.

	Feet
Checkerboard limestone.	
6. Limestone outlier: largely removed by farmer and used for riprap in a pond southwest of the house, not shown on Plate I., not measured.	
Seminole formation.	
5. Covered: probably shale, about	20.0
4. Sandstone: thin-bedded, weathers brownish yellow; poorly exposed, deeply weathered, about	5.0
3. Covered: probably shale	5.0
2. Sandstone: thin-bedded to massive, fine to medium-grained, gray; partly covered, base of the upper sandy member	35.0
1. Shale: top of the middle shale member, not measured.	

APPENDIX B

LOGS OF WATER WELLS IN TULSA COUNTY

T. 17 N., R. 12 E.

RELIANCE OIL COMPANY, NO. 17 BERRYHILL
Sec. 9, NE¼NW¼SE¼

	Thickness	Depth
Yellow clay	18	18
Slate	11	29
Brown shale	13	42
Slate	38	80
Sand; *fresh water*	15	95
Shale	165	260

OHIOKAL OIL COMPANY, NO. 5 PRIDE JEFFERSON
Sec. 12, NE¼NE¼

Soil	5	5
Slate	30	35
Sand; *fresh water*	2	37
Slate	68	105

D. W. FRANCHOT COMPANY NO. 14
Sec. 17, NE¼SW¼SW¼

Clay	24	24
Lime	5	29
Shale	161	190
Sand; *fresh water*	62	252
Shale	503	755

THE OHIO CITIES GAS COMPANY, NO. 14 C. M. BOLING
Sec. 27, SW¼NW¼NW¼

Soil	10	10
White shale	25	35
Lime shells	5	40
Sand; *fresh water*	10	50

T. 17 N., R. 13 E.

MCFANN & BROWN, NO. 2 WILSON
Sec. 16, Cen. N½NW¼NW¼

Soil	20	20
Shell	5	25
Slate; *fresh water*	395	420
Lime	10	430

ENFISCO OIL CORPORATION, NO. 1 BAILEY
Sec. 20, NW¼NE¼SE¼

Clay; yellow soft	10	10
Shale	50	60
Sand; *fresh water*	8	68
Shale	438	510

CUMMINGS OIL COMPANY, NO. 3 BUNGER
Sec. 27, SE¼NW¼NW¼

Surface	10	10
Black mud	20	30
Fresh water	40	70
Blue shale	190	260

T. 17 N., R. 14 E.

T. B. Slick, No. 1 Young
Sec. 1, SE¼NE¼SW¼

	Thickness	Depth
Soil	5	5
Subsoil	15	20
Sand; *fresh water*	20	40
Blue mud	10	50
Fresh water	150	200

T. B. Slick, No. 2 Darnell
Sec. 1, NE¼NE¼SW¼

Soil	2	2
Red mud	23	25
Sand; *fresh water*	8	33
Blue mud	27	60
Sand; *fresh water*	140	200
Brown Shale	50	250

T. 17 N., R. 14 E.

Sec. 2, NW¼

Surface	10	10
Sand; *fresh water*	76	86
Shale	600	686

Fisher Oil Company, No. 1 Brown
Sec. 2, SE¼NW¼NW¼

Surface	10	10
Sand; *fresh water*	76	86

Fisher Oil Company, No. 1 Miller
Sec. 3, NE¼SE¼NE¼

Surface	10	10
Sand; *fresh water*	76	86
Shale	600	686

W. E. Elper, No. 2 Moore
Sec. 6 SW¼NE¼NE¼

Soil	10	10
Quicksand	35	45
Black mud	17	62
Hard lime; *fresh water*	20	82
Black mud	48	130

Thos. J. Green, No. 1 Knipper
Sec. 16, NE¼NW¼SW¼

Sandy soil	40	40
Shale	110	150
Sand; *fresh water*	30	180
Shale	80	260

T. 18 N., R. 12 E.

No. 1 Vance
Sec. 3, NW¼NE¼NE¼

Soil	10	10
Shale	50	60
Sand; *fresh water*	8	68
Shells and shale	466	534

W. C. Cates, No. 1 Price
Sec. 12, Cen. WLSW¼NE¼

Soil	10	10
Sand; *fresh water*	25	35
Blue mud	405	440

CATES BROS., No. 1 IRONA PARKS
Sec. 13, SW¼NE¼SW¼

	Thickness	Depth
Sand; *fresh water*	35	35
Blue mud	295	330

Prosey Short, No. 1 Short
Sec. 14, SW¼SW¼SE¼

Soil	3	3
Red clay	25	28
Blue mud	14	42
Quicksand	11	53
Blue shale; *fresh water* at 74	447	500

T. 18 N., R. 13 E.

C. C. BROWN
Sec. 2, NW¼NW¼NW¼

Surface	5	5
Limestone	2	7
Yellow clay; *water,* 600 gallons per hour	8	15
Blue shale	2	26
Limestone	3	29
Sand	11	40
Shale	22	62
Blue shale	22	62

T. 18 N., R. 14 E.

GREEN-TURMAN OIL COMPANY, No. 1 MATTIE BOWLES
Sec. 23, SE¼NW¼SE¼

Soil	3	3
Limestone	7	10
Sandstone	10	20
Shale	15	35
Sandstone	25	60
Limestone	10	70
Shale	80	150
Sandstone	10	160
Shale	30	190
Sand; *fresh water*	110	300

JOHN C. TREFTS, No. 3 TREFTS
Sec. 35, Cen. EL, NW¼SE¼

Soil	4	4
Red clay	51	55
Sand; *fresh water*	10	65
Blue mud	8	73

MARVINK CLOVER, No. 6 MOORE
Sec. 36, SE¼SW¼NW¼

Clay	40	40
Shale	80	120
Sand; *fresh water*	5	125
Shale	20	145

T. 19 N., R. 10 E.

ELKO SYNDICATE, No. 1 BELL NELSON
Sec. 14, SW¼NE¼NW¼

Soil	5	5
Shale	20	25
Limestone	5	30
Shale	30	60
Sand; *fresh water*	54	114
Shale	65	179
Sand; *fresh water*	40	219

T. 19 N., R. 11 E.

O. M. IRELAN AND HOOVER BROS., No. 1 RUSSELL
Sec. 32, NW¼NE¼SE¼

	Thickness	Depth
Soil	5	5
Clay and gravel	5	10
Blue mud	104	114
Limestone; hole full of *fresh water*	35	149

T. 19 N., R. 12 E.

206 E. 2nd street at present site of the Oklahoma Hotel
Sec. 1, NE¼SW¼

Depth		24

N. CINCINNATI AND CAMERON
Sec. 2, NE¼SE¼

Water		24

5TH STREET BETWEEN MAIN
AND BOSTON, SINCLAIR OIL COMPANY
Sec. 1, NW¼SW¼

Well		245

TULSA WORLD BUILDING
Sec. 1, NW¼SW¼

Sandy silty clay	5	5
Sandy silt	10	15
Sandy silt, tan	25	40
Sand; *water*	5	45
Silty, clayey sand	1.5	46.5
Rusty, sandy shale	1.5	48
Blue gray shale	3.4	51.4

FIRST NATIONAL BANK BUILDING
Fifth and Boston streets
Sec. 1, SW¼

Silty sand; fine, red and brown	24	24
Silty sand, fine, light brown	6	30
Silty sand; tan, fine	20	50
Silty sand, tan, medium to fine, *Water*, at 55, circulation lost	5	55
Silty sand; trace of shale	10	65
Sandy shale; blue	3	68
Shale; blue gray	5	73
Soft sandy shale	2.5	75.5
Soft sandy shale	3	78.5
Sandy shale; dark blue gray	10	88.5
Sandy shale; blue gray	4	92.5
Sandy shale	11	103.5
Shale	7.6	111.1

4 N. DETROIT ST., TULSA ICE COMPANY
Sec. 1 NW¼

Depth of well		250
Capacity, about 4 gallons per minute		

100 N. Denver, Baker Truck Rental
Sec. 2, SE¼NE¼

	Thickness	Depth
Soil, limestone, shale, and sandstone to a depth of		160
Depth to *water*; 60 feet		
Capacity of well; about 1½ gallons per minute		

Admiral Street East of Sheridan,
Southwestern Bell Telephone Co.
Sec. 2, NW¼

Silty sand; brown	5	5
Soft shale; light brown	13	18
Soft shale; blue gray	2	20
Shale; blue gray	2	22
Limestone	2.5	24.5
Shale; blue gray	2	26.5
Shale; blue gray	3.5	30

Johnson Well at 19th and Detroit
Sec. 12, SW¼SE¼

Red bed	48	48
Yellow clay	14	62
Quicksand	10	72
Sand; *water*, 175 gallons per hour	10	82
Limestone	29	111
Sandy limestone	17	128
Sand	55	183
Blue shale	10	193

1217 E. 25th Street
Sec. 13, NE¼

Surface	5	5
Sandstone; 250 gallons of *water* per hour	6	11
Red bed	4	15
Yellow clay	6	21
Sandstone	12	33
Blue shale	2	35
Sand	2	37
Broken sand	8	45
Sand	45	90
Blue shale	31	121
Shale	26	147
Sand	13	160
Blue shale	1	161

Williams Well, 243 E. 29th Street
Sec. 13, SE¼NW¼

Red bed	18	18
Quicksand	4	22
Sandy limestone; *water*, 400 gallons per hour	21	43
Hard limestone	13	56
Sand	9	65
Blue shale	10	75

South Peoria and Rose Gardens, S. S. Cone
Sec. 18, NW¼

	Thickness	Depth
Surface	5	5
Fill	15	20
Quicksand	10	30
Shale; *water*, 600 gallons per hour	10	40
Sand; *water*, 800 gallons per hour	11	51
Light shale	12	63
Sand	11	74
Light shale	6	80

Christansen Well, 2222 W. 47th St.
Sec. 27, SE¼

Yellow clay	26	26
Blue shale	7	33
Dark shale	8	41
Blue shale; *water*, 15 gallons per hour	3	44
Limestone	7	51
Shale	44	95
Sandy shale	5	100
Shale	20	120
Sand	18	138
Blue shale	1	139

T. 19 N., R. 13 E.

Stanolind Building, El. 729.08
Sec. 1, SW¼

Silty shale; gray brown	5	5
Silty shale; tan	10	15
Silty fine clay sand; tan	15	30
Soft sand; brown and yellow	8	38
Soft shale; light brown to blue-gray	2	40
Shale; blue gray	3	43
Sandy shale; blue gray	17	60
Limestone; light gray	0.6	61

Evans Investment Company, Haynes No. 1
Sec. 3, NW¼SE¼NW¼

Surface	3	3
Shale	40	43
Lime	4	47
Shale	27	74
Sand, gravel; *water*	2	76
Shale	188	264

1421 E. 19th Street
Sec. 7, SW¼SW¼

Surface	5	5
Red bed	21	26
Quicksand; *water*, 375 gallons per hour	11	37
Lime	7	44
Sand	13	57
Light shale	28	85
Sand	7	92
Sandy shale	6	98
Light shale	15	113
Sand	22	135
Blue shale	5	140

1544 Yorktown Place
Sec. 7

	Thickness	Depth
Surface	5	5
Red bed	6	11
Yellow clay; *water*, 140 gallons per hour	12	23
Sandstone	16	39
Blue shale	2	41
Light shale	15	56
Sand	14	70
Lime	3	73
Sand	82	155
Blue shale	9	164
Shale	12	176
Shale	10	186
Sand	9	195

1600 S. Peoria
Sec. 12

Depth to *water;* 13 feet
Capacity of well; 200 gallons per minute

S. S. Owens, No. 6 Haus Butler
Sec. 13, SW¼NW¼SW¼

Soil	2	2
Clay	13	15
Sand; *fresh water*	1	16
Blue shale	138	154

2652 E. 26th Place
Sec. 18

Surface	4	4
Lime	4	8
Sandstone	4	12
Lime	22	34
Sand; *water*, 10 gallons per hour	7	41
Light shale	7	48
Blue shale	33	81
Dark shale	3	84
Light shale	7	91
Sand	9	100
Sand and shale	10	110
Sand	2	112
Light shale	30	142

31st Place and Utica
Sec. 19, NE¼NW¼

Surface	2	2
Red bed	7	9
Sandstone; *water*, 500 gallons per hour	41	50
Blue shale	2	52
Sand	11	63
Blue shale	33	96
Shale	7	103
Sandy shale	9	112
Sand	8	120
Blue shale	5	125

2640 E. 37TH STREET
Sec. 20, NE¼SW¼

	Thickness	Depth
Surface	1	1
Red bed; *water*, 500 gallons per hour	6	7
Sandstone	25	32
Blue shale	39	71
Dark shale	8	79
Sand	18	97
Blue shale	3	100

38TH STREET AND BIRMINGHAM
Sec. 20, SW¼

Surface	3	3
Red bed; *water*, 140 gallons per hour	8	11
Sandstone	22	33
Blue shale	37	70
Dark shale	9	79
Sandy shale	8	87
Blue shale	8	95
Sand	1	96

SOUTH YALE AND 4TH STREET
STANOLIND OIL COMPANY
Sec. 28

Sandy	6.1	6.1
Sand	2	8.1
Sand	6	14.1
Sandy shale	4	18.1
Shale	12	30.1
Sand	1	31.1
Shale	59	90.1

41ST AND SOUTH LEWIS, JOHN C. DAY WELL
Sec. 29

Surface	3	3
Sand	18	21
Yellow clay	3	24
Blue shale; *water*, 80 gallons per hour	39	63
Dark shale	16	79
Limestone	2	81
Sandstone	15	96
Shale	8	104

2720 E. 44TH PLACE
Sec. 29, NW¼

Surface	5	5
Yellow clay	20	25
Quicksand	5	30
Yellow clay; *water*, 100 gallons per hour	4	34
Blue shale	4	38
Sandy shale	12	50
Blue shale	15	65
Sandy shale	25	90
Sand	6	96
Light shale	8	104

53 AND BIRMINGHAM, S. C. BARRETT
Sec. 32, SE¼NW¼

Surface	5	5
Red bed	25	30
Quicksand	10	40
Shale	30	70
Sand	12	82
Blue shale	3	85

GLIDDEN OIL CORPORATION, NO. 1 PARKS
Sec. 35, SW¼SW¼NW¼

	Thickness	Depth
Soil	3	3
Clay	7	10
Shell and clay	10	20
Sand; *fresh water*	10	30
Shale	155	185

T. 19 N., R. 14 E.

11TH STREET AND KVOO TOWER, WELL NO. 1
Sec. 10

Surface	3	3
Lime	15	18
Yellow clay	6	24
Lime	11	35
Sandy shale	45	80
Broken sand	16	96
Light shale	4	100

11TH STREET AND KVOO TOWER, WELL NO. 2
Sec. 10

Surface	6	6
Lime; *water*, 160 gallons per hour	8	14
Clay	32	46

TOOF AND SCHULTE, NO. 1 FOSTER
Sec. 23, SW¼SE¼NW¼

Soil	8	8
Lime	52	60
Black shale	124	186
Blue shale	90	276
Lime	40	316
Black shale; *fresh water*	15	331

T. 20 N., R. 12 E.

SINCLAIR PRAIRIE OIL CO.
Sec. 24, SE¼NW¼SE¼

Slate	74	74
Sand; *fresh water*	36	110
Slate	16	126

T. 20 N., R. 13 E.

KELLOUGH COMPANY, NO. 1 KELLOUGH
Sec. 9, NW¼NE¼SW¼

Surface	15	15
Quick sand	40	55
Slate	15	70
Sand; *fresh water*	24	94
Slate	94	188

BANNER LAUNDRY
Sec. 31, SW¼SE¼

......................; *water*	120	120
Water sand		185

T. 20 N., R. 14 E.

E. J. RAINEY
Sec. 32, NW¼NE¼SE¼

Soil	6	6
Fresh water	5	11
Shale	104	115

T. 21 N., R. 12 E.

Halcyon Oil Co., No. 1 Phillips
Sec. 1, NE¼SW¼NW¼

	Thickness	Depth
Surface	6	6
Shale	20	26
Sand; *fresh water*	30	56
Shale	9	65

T. 22 N., R. 10 E.

Shell Pipeline Corporation
Sec. 27, SW¼SW¼

Soil and clay	10	10
Sandy clay	35	45
Water sand	15	60
Blue shale	30	90
Water sand	10	100
Red shale	10	110
Sandy shale	10	120
Blue shale	25	145
Water sand	20	165
Red shale	5	170
Lime shale	5	175
Blue shale	3	178
Clay	2	180

Shell Pipeline Corporation
Sec. 27, SW¼NE¼NE¼

Soil	2	2
Red bed	10	12
Brown sand	31	43
Gray mud	8	51
Sand	34	85
Gray shale	9	94
Water sand	30	124
Gray shale	18	142
Red bed	6	148
Water sand	30	178
Blue mud	6	184

Shell Pipeline Corporation
Sec. 27, SE¼NE¼

Soil	1	1
Brown sand	22	23
Red bed	4	27
Brown sand	33	60
Blue mud	5	65
Red bed	15	80
Water sand	8	88
Blue mud	22	110
Brown sand	5	115
Gray sand	9	124

T. 22 N., R. 12 E.

Flesher Petroleum Co., Well No. 2
Sec. 18, SW¼NE¼SW¼

Loam	8	8
Lime	30	38
Shale	62	100
Sand; *fresh water*	20	120
Shale	230	350

T. 22 N., R. 13 E.

BURKEN PETROLEUM CO., No. 1 JORDAN
Sec. 24, Cen.

	Thickness	Depth
Soil	2	2
Clay	2	4
Sandstone	4	8
....	37	45
Sand; *fresh water*	27	72
Shale	37	109

APPENDIX C

PRELIMINARY WATER WELL DATA

IN

TULSA COUNTY

WELL TABLES

RECORD OF WELLS AND SPRINGS IN TULSA COUNTY, OKLAHOMA

Well No.	Location	Sec.	Type Well [a]	Diameter Well	Depth of Well	Depth to water	Date Measured [b]	Method of lift [c]	Quality [d]	Performance during drought	Probable Aquifer
						T. 16 N., R. 12 E.					
1	NW¼NW¼NW¼	2	Dug	....	12	5	....	....	Soft	No change	L. Seminole
2	NW¼NW¼	2	Dr.	6″	40	20	6/20/48	WJ	....	....	L. Seminole
3	SW¼NW¼	10	Dug	....	15	12	....	....	Hard	Good	L. Seminole
4	SW¼SE¼SW¼	11	Dug	....	37	25	....	....	Hard	No change	Holdenville
5	NW¼SW¼SW¼	12	Dug	....	36	28	....	....	Soft	No change	Holdenville
6	SW¼NW¼SE¼	12	OW	....	....	5	....	....	....	....	Holdenville
						T. 16 N., R. 13 E.					
7	NW¼NW¼	3	Dug	....	24	....	....	....	M. hard	No change	Nowata
8	NE¼SE¼	4	Dug	....	18	16	....	....	Salty	Goes dry	Nowata
9	SE¼SE¼SW¼	10	Dr.	....	26	22	....	....	M. hard	Good	Nowata
10	SE¼SE¼SE¼	12	Dr.	....	93	40	....	....	M. soft	No change	Wewoka?
11	SE¼SE¼NE¼	13	Dug	....	50	2	....	....	M. hard	No change	Wewoka
12	SE¼SE¼NE¼	13	Dr.	....	50	25	....	....	M. hard	No change	Wewoka
13	NW¼SW¼	14	Dug	96″	27.4	15.9	6/25/48	CP	....	No change	Alluvium
14	NW¼NW¼SW¼	15	Dug	....	20	18	....	....	Hard	No change	Nowata
15	NW¼NW¼	18	Dug	....	30	25	....	....	Soft	No change	Nowata
16	NE¼NW¼NE¼	19	Dr.	....	25	18	....	....	Hard	Lowers	Nowata
						T. 16 N., R. 14 E.					
17	SE¼SW¼NW¼	5	OW	....	....	78	....	....	Hard	....	Wewoka
18	CEN NE¼SW¼	6	OW	....	....	25	....	....	....	....	Alluvium
19	SW¼	7	Dr.	6″	33	6	7/20/48	WJ	....	....	Alluvium
						T. 17 N., R. 12 E.					
20	NW¼SW¼	14	Dr.	6″	59	29.7	6/24/48	B	(A)	....	U. Seminole
21	SW¼SW¼SE¼	15	Dug	....	42	12	....	....	Hard	Goes dry	M. Seminole
22	NE¼NE¼NW¼	26	Dug	....	40	20	....	....	Hard	Gets low	Seminole
23	NW¼NW¼SW¼	35	Dug	....	35	8	....	....	Hard	Goes dry	L. Seminole
24	SE¼SE¼SE¼	36	Dr.	....	80	22	....	....	Hard	Gets low	Holdenville

[a] Explanation of abbreviations: Dug = Dug; Dr. = Drilled; OW = Oil well; Dv. = Driven; Sp. = Spring.
[b] Wells for which no date appears were recorded in 1936 and 1937 by the State Mineral Survey.
[c] Explanation of abbreviations: B = Bucket; WJ = Water jet; CP = Cylinder pump; Cen = Centrifugal pump; VP = Vacuum pump.
[d] In this column (A) indicates analysis is given in Table XV.

WELL TABLES—(Continued)
RECORD OF WELLS AND SPRINGS IN TULSA COUNTY, OKLAHOMA

Well No.	Location	Sec.	Type Well [a]	Diameter Well	Depth of Well	Depth to water	Date Measured [b]	Method of lift [c]	Quality [d]	Performance during drought	Probable Aquifer
					T. 17 N., R. 13 E.						
25	SE¼SE¼SE¼	2	Dr.	....	....	20	....	....	Soft	No change	Alluvium
26	SE¼SW¼NE¼	13	Dr.	....	22	8	....	....	Hard	No change	Alluvium
27	SE¼SE¼NE¼	14	Dr.	....	28	9	....	....	Hard	No change	Alluvium
28	SE¼SE¼NE¼	15	Dug	....	20	4	....	....	Hard	No change	Nowata
29	NE¼NW¼NW¼	16	Dr.	....	36	31	....	....	Hard	No change	Nowata
30	NW¼NE¼SE¼	20	Dr.	....	....	60	....	....	Hard	No change	Nowata
31	NW¼NE¼NE¼	21	Dr.	....	24	21	....	....	Hard	No change	Nowata
32	SE¼SE¼SW¼	22	Dug	....	23	15	....	....	Hard	No change	Nowata
33	NW¼NW¼NE¼	23	Dr.	....	20	9	....	....	Hard	No change	Alluvium
34	SE¼SW¼SW¼	24	Dr.	....	22	8	....	....	Hard	No change	Alluvium
35	NW¼NW¼NE¼	25	Dr.	....	18	15	....	....	Hard	No change	Alluvium
36	SW¼SW¼SW¼	25	Dr.	2″	18.3	9.8	6/24/48	CP	(A)	....	Alluvium
37	NE¼NE¼NW¼	26	Dr.	....	18	10	....	....	Hard	No change	Nowata
38	SE¼SE¼SE¼	27	Dr.	....	80	70	....	....	M. hard	Goes dry	....
39	NE¼NW¼SW¼	28	Dug	....	35	28	....	....	Hard	No change	Nowata
40	SW¼NW¼NW¼	29	Dug	....	40	6	....	....	Hard	Goes dry	Nowata?
41	NE¼NW¼NE¼	29	Dr.	....	60	20	....	....	Hard	No change	Nowata?
42	SE¼NW¼SW¼	30	Dr.	....	60	25	....	....	Soft	Goes dry	Holdenville
43	SW¼SW¼SW¼	31	Dug	....	22	10	....	....	Hard	No change	Holdenville
44	NW¼NW¼NW¼	31	Dr.	....	30	20	....	....	Hard	No change	Holdenville
45	SE¼SW¼SE¼	32	Dug	....	40	25	....	....	Salty	No change	Nowata
46	NE¼NE¼NW¼	33	Dug	....	20	14	....	....	Hard	No change	Nowata
47	NW¼SW¼SW¼	34	Dug	....	21	12	....	....	Soft	Good	Nowata
48	SW¼SW¼SW¼	35	Dr.	....	35	....	....	....	Hard	Goes dry	Nowata
					T. 17 N., R. 14 E.						
49	NE¼NE¼SW¼	1	OW	....	....	20	....	....	....	....	Terrace deposit
50	SW¼NW¼NW¼	2	OW	....	....	10	....	....	....	....	Terrace deposit
51	NW¼NE¼SE¼	3	OW	....	....	10	....	....	....	....	Alluvium
52	SW¼SW¼NE¼	5	OW	....	....	62	....	....	....	....	Nowata
53	SW¼SW¼SW¼	6	Dr.	....	67	20	....	....	Hard	Good	Nowata?
54	NW¼NW¼NW¼	10	Dv.	....	32	20	....	....	Soft	Plenty	Alluvium
55	NE¼NE¼NE¼	13	Dr.	....	265	60	....	....	Soft	No change	Senora
56	NW¼NE¼NW¼	16	Dv.	....	32	15	....	....	Hard	No change	Alluvium

WELL TABLES—(Continued)
RECORD OF WELLS AND SPRINGS IN TULSA COUNTY, OKLAHOMA

Well No.	Location	Sec.	Type Well [a]	Diameter Well	Depth of Well	Depth to water	Date Measured [b]	Method of lift [c]	Quality [d]	Performance during drought	Probable Aquifer
					T. 17 N., R. 14 E.—(Continued)						
57	SE¼NE¼NE¼	17	Dv.	....	25	23	....	....	Hard	No change	Alluvium
58	SE¼SE¼SW¼	19	Dv.	....	20	10	....	....	Hard	No change	Alluvium
59	Cen SW¼SE¼	22	Dug	....	35	20	....	....	Soft	No change	Alluvium
60	NE¼SE¼NE¼	24	Dr.	....	24	12	....	....	Hard	No change	Alluvium
61	SW¼	27	Dr.	....	24	20	....	....	Hard	Good	Alluvium
62	NE¼SE¼	27	Dug	48″	28	8.4	7/20/48	CP	M. hard	....	Alluvium
63	NW¼NE¼	27	Dug	....	25	22	....	....	M. hard	Little change	Alluvium
64	SE¼SE¼SE¼	30	Dv.	....	25	12	....	....	Hard	No change	Alluvium
65	NW¼NW¼NW¼	30	Dv.	....	21	11	....	....	Hard	No change	Alluvium
66	SE¼NE¼SE¼	31	Dr.	....	20	16	....	....	Hard	No change	Alluvium
67	NW¼SW¼NW¼	32	Dv.	....	20	....	....	....	Hard	No change	Alluvium
68	SW¼SW¼NW¼	33	Dv.	....	25	10	....	....	Hard sulphur	No change	Alluvium
69	SW¼SW¼NW¼	34	Dv.	....	45	30	....	....	Hard	Good	Wewoka
					T. 18 N., R. 12 E.						
70	SW¼SW¼SW¼	1	Dr.	....	68	....	....	....	Hard	No change	U. Seminole
71	SE¼SE¼SE¼	2	Dug	....	38	12	....	....	Hard	Never goes dry	Seminole
72	SE¼SE¼NE¼	3	Dr.	....	190	40	....	....	Hard	Never goes dry	U. Seminole
73	SE¼SE¼NE¼	10	Dr.	....	175	....	....	....	Hard	No change	L. Seminole
74	NW¼NW¼NE¼	11	Dr.	....	70	40	....	....	Hard	No change	U. Seminole
75	NW¼NW¼NW¼	12	Dr.	....	43	30	....	....	Hard	No change	U. Seminole
76	NW¼NW¼NW¼	13	Dr.	....	65	45	....	....	Soft	No change	Holdenville?
77	SE¼SE¼SE¼	15	Dr.	....	5	....	....	....	M. hard	....	U. Seminole
78	NW¼SW¼SW¼	15	Dug	....	20	13	....	....	Soft	Fair	U. Seminole
79	SW¼SE¼SE¼	22	Dug	....	24	20	....	....	Soft	Variable	Alluvium?
80	NW¼NW¼SW¼	23	Dug	....	28	20	....	....	M. hard	No change	U. Seminole
81	NE¼NE¼	25	Dv.	....	26	19	....	....	M. soft	No change	Alluvium
82	SE¼NE¼	25	Dv.	....	24	17	....	....	M. soft	Lowers	Alluvium
83	SW¼SW¼	25	Dr.	....	100	....	....	....	....	....	Seminole
84	SE¼NE¼SW¼	36	Dug	....	30	22	....	....	M. hard	Good	Seminole
85	NE¼NE¼NE¼	28	Dug	....	22	16	....	....	M. hard	No change	Seminole?
86	NE¼NE¼	34	Dr.	....	30	20	....	....	Hard	No change	M. Seminole
87	SE¼NE¼	35	Dug	....	62	15	....	....	M. hard	No change	Seminole

WELL TABLES—(Continued)

RECORD OF WELLS AND SPRINGS IN TULSA COUNTY, OKLAHOMA

Well No.	Location	Sec.	Type Well [a]	Diameter Well	Depth of Well	Depth to water	Date Measured [b]	Method of lift [c]	Quality [d]	Performance during drought	Probable Aquifer
					T. 18 N., R. 12 E.—(Continued)						
88	NW¼NE¼	35	Dr.	......	82	9	......	......	Slight gyp	Goes dry	Seminole
89	NW¼NW¼	35	Dr.	......	32	15	......	......	Hard	No change	Seminole
90	SE¼SE¼	36	Dug	......	22	10	......	......	M. soft	½ normal	Seminole
91	NW¼NW¼	36	Dug	......	12	....	......	......	Salty	Little change	Seminole
					T. 18 N., R. 13 E.						
92	SW¼SW¼SW¼.	3	Dr.	......	80	No wtr.	......	......	No water	......	Nowata?
93	NW¼SW¼SW¼	3	Dr.	......	285	No wtr.	......	......	No water	......	Nowata
94	SW¼SW¼SW¼	3	Dr.	......	58	40	......	......	Hard	Goes dry	Nowata
95	NE¼NE¼NW¼	8	Sp.	......	6	3	......	......	Soft	Goes dry	Holdenville
96	NE¼NE¼NW¼	8	Dr.	......	65	45	......	......	Salty	Goes dry	Nowata
97	SE¼SE¼NE¼	8	......	......	16	9	......	......	Hard	No change	Nowata
98	SE¼SE¼SW¼	11	Dr.	......	60	40	......	......	Hard	Goes dry	Nowata
99	NW¼NW¼SW¼	13	Dr. & Dug	......	40	25	......	......	Hard	No change	Nowata
100	SE¼SE¼SW¼	16	Dug	......	30	25	......	......	M. hard	Good	Terrace deposit
101	NE¼SE¼SE¼	17	Dug	......	26	25	......	......	Hard	Goes dry	Terrace deposit
102	NE¼NE¼SW¼	18	Dv.	......	20	18	......	......	Hard	Good	Alluvium
103	NE¼NW¼NW¼	19	Dv.	1¾"	18	16	7/14/48	CP	(A)	......	Alluvium
104	NW¼SW¼SW¼	20	Dv.	......	20	18	......	......	Hard	No change	Alluvium
105	SE¼NE¼SE¼	20	Sp.	......	Spring	....	......	......	Soft	No change	Alluvium
106	NE¼NE¼NW¼	20	Dv.	......	28	20	......	......	Hard	No change	Alluvium
107	SW¼NW¼SW¼	21	Sp.	......	Spring	....	......	......	Soft	No change	Terrace deposit
108	NE¼NW¼	23	Dug	......	16	....	......	......	Hard	Poor	Nowata
109	SE¼NW¼SW¼	23	Dr.	......	27	23	......	......	Soft	No change	Terrace deposit
110	NW¼SW¼SW¼	23	Dug	......	24	20	......	......	Soft	No change	Terrace deposit
111	SE¼SE¼SE¼	25	Dr.	......	65	40	......	......	Soft	Good	Nowata
112	SE¼SE¼SW¼	25	Dr.	......	50	14	......	......	Soft	Good	Terrace deposit
113	SW¼SW¼SW¼	25	Dug	......	56	38	......	......	Soft	No change	Terrace deposit
114	NW¼SW¼NW¼	25	Dr.	......	80	70	......	......	Soft	No change	Nowata
115	NW¼NW¼NW¼	25	Dr.	......	155	115	......	......	Soft	No change	Nowata
116	SE¼SW¼	25	Dug	......	50	43	......	......	Soft	No change	Terrace deposit
117	NE¼SE¼NE¼	26	Dr.	......	75	68	......	......	Soft	Gets low	Nowata
118	SW¼SE¼SW¼	26	Sp.	......	Spring	....	......	......	Soft	No change	Terrace deposit
119	NE¼NE¼SE¼	26	Dr. & Dug	......	75	65	......	......	Soft	No change	Terrace deposit

WELL TABLES—(Continued)

RECORD OF WELLS AND SPRINGS IN TULSA COUNTY, OKLAHOMA

Well No.	Location	Sec.	Type Well [a]	Diameter Well	Depth of Well	Depth to water	Date Measured [b]	Method of lift [c]	Quality [d]	Performance during drought	Probable Aquifer
					T. 18 N., R. 13 E.—(Continued)						
120	NE¼NE¼SE¼	26	Dr. & Dug	....	75	65	....	....	Soft	No change	Terrace deposit
121	NW¼NW¼SW¼	26	Dr.	....	125	110	....	....	Soft	No change	Nowata
122	NE¼SE¼NE¼	27	Dr.	....	35	30	....	....	Soft	No change	Terrace deposit
123	SE¼SE¼NE¼	27	Dv.	....	30	25	....	....	Soft	No change	Terrace deposit
124	NE¼NE¼NE¼	27	Dr.	....	35	30	....	....	Soft	No change	Terrace deposit
125	SW¼SE¼SE¼	27	Dug	....	50	40	....	....	Soft	No change	Terrace deposit
126	SE¼SE¼SW¼	27	Dr.	....	137	120	....	....	Soft	No change	Nowata?
127	NW¼SW¼SW¼	28	Sp.	....	Spring	....	....	....	Soft	No change	Terrace deposit
128	NW¼NE¼NW¼	28	Sp.	....	Spring	....	....	....	Soft	No change	Terrace deposit
129	NW¼NW¼NW¼	28	Sp.	....	Spring	....	....	....	Soft	No change	....
130	NE¼NE¼NE¼	28	Dr.	60″	60.2	45.6	6/25/45	....	Soft	....	Terrace deposit
131	SE¼SE¼SE¼	29	Dv.	....	....	....	....	....	Soft	No change	Alluvium
132	NE¼NE¼SE¼	30	Dv.	....	21	14	....	....	Hard	No change	Alluvium
133	SE¼NE¼SW¼	31	Dr.	....	90	80	....	....	Hard	Gets low	Lenapah
134	NE¼NE¼NW¼	33	Dr.	....	96	81	....	....	Soft	No change	Nowata
135	NE¼NW¼NE¼	33	Dr.	....	126	110	....	....	Soft	No change	Nowata
136	NE¼NE¼NE¼	33	Dr.	....	130	115	....	....	Soft	No change	Nowata
137	SW¼SE¼SW¼	36	Dr.	....	120	....	....	....	Soft	No change	Terrace deposit
					T. 18 N., R. 14 E.						
138	NW¼NE¼NW¼	1	Dr.	....	35	25	....	....	Hard	Goes dry	....
139	SE¼SE¼SE¼	3	Dug	....	61	30	....	....	Soft	No change	Oologah
140	SW¼SW¼SE¼	4	Dug	....	40	20	....	....	Hard	Goes dry	Nowata?
141	SE¼SE¼NE¼	5	Dug	....	33	16	....	....	Hard	Gets low	Nowata
142	NE¼SE¼NE¼	6	Dug	....	35	25	....	....	Soft	Gets low	Nowata
143	SE¼SE¼SE¼	7	Dug	....	46	22	....	....	Hard	Goes dry	Nowata
144	NE¼NE¼NE¼	8	Dr.	....	40	22	....	....	Hard	Gets low	Nowata
145	SW¼SW¼SW¼	9	Dr.	....	82	50	....	....	Hard	Gets low	Nowata?
146	SE¼SE¼SE¼	10	Dug	....	42	18	....	....	Hard	No change	Labette
147	SE¼SE¼SW¼	10	Dr.	....	38	16	....	....	Hard	Gets low	Nowata
148	NE¼NE¼NW¼	12	Dr.	....	34	24	....	....	Hard	No change	Labette?
149	NW¼NW¼NW¼	13	Dug	....	50	20	....	....	Hard	Gets low	Labette?
150	SE¼SE¼SE¼	14	Dr.	....	85	55	....	....	Hard	No change	Senora
151	SE¼SE¼SW¼	16	Dr.	....	60	....	....	....	M. hard	No change	Nowata

WELL TABLES—(Continued)

RECORD OF WELLS AND SPRINGS IN TULSA COUNTY, OKLAHOMA

Well No.	Location	Sec.	Type Well [a]	Diameter Well	Depth of Well	Depth to water	Date Measured [b]	Method of lift [c]	Quality [d]	Performance during drought	Probable Aquifer
					T. 18 N., R. 14 E.—(Continued)						
152	NW¼NW¼SW¼	21	Dr.	6″	22.5	16.5	6/25/48	CP	M. hard	No change	Nowata
153	NW¼NW¼SW¼	22	Dr.	...	25	5	...	...	M. hard	Poor	Nowata
154	SW¼SW¼NW¼	23	Dr.	...	80	20	...	...	Hard	Goes dry	Senora
155	SE¼NW¼SE¼	23	OW	...	...	290	...	...	...	...	Senora
156	SW¼SW¼NE¼	24	OW	...	...	300	...	...	...	...	Senora
157	NW¼NW¼NW¼	24	Dug	...	45	15	...	...	Hard	Gets low	Senora
158	NW¼NW¼NW¼	25	Dr.	...	30	15	...	...	Hard	No change	Senora
159	SE¼SE¼NE¼	25	Dr.	...	50	15	...	...	Hard	...	Senora
160	SE¼NE¼NE¼	26	OW	...	...	225	...	...	...	...	Senora
161	SW¼SW¼SW¼	26	Dr.	...	30	15	...	...	Hard	Adequate	Senora
162	NE¼NE¼NE¼	27	Dr.	...	35	30	...	...	Hard	No change	Nowata?
163	SW¼NW¼NW¼	27	Dr.	...	20	16	...	...	Hard	Poor	Nowata
164	NW¼SW¼SW¼	27	Dr.	...	18	12	...	...	Soft	Goes dry	Terrace deposit
165	SE¼SE¼SE¼	29	Sp.	...	Spring	...	...	...	Soft	No change	Terrace deposit
166	NW¼NW¼	29	Sp.	...	Spring	...	...	...	Soft	No change	Terrace deposit
167	NE¼NE¼NE¼	30	Dr.	...	24	12	...	...	Soft	No change	Nowata
168	SE¼SW¼SE¼	31	Dr.	...	30	10	...	...	Soft	No change	Terrace deposit
169	NE¼NE¼SW¼	35	OW	...	...	2	...	...	...	...	Terrace deposit
170	Cen NW¼SE¼	35	OW	...	...	55	...	...	...	...	Terrace deposit
171	SE¼SW¼NW¼	36	OW	...	...	120	...	...	...	...	Senora
					T. 19 N., R. 9 E.						
172	NE¼	11	Dr.	6″	110	90	7/ 8/48	WJ	M. soft	No change	Okesa
					T. 19 N., R. 10 E.						
173	SE¼SE¼SW¼	4	Dr.	...	22	9	...	...	Hard	...	Wann
174	NE¼NE¼NE¼	6	Dr.	...	52	12	...	...	Hard	...	...
175	NW¼SE¼NE¼	6	Dr.	...	60	14	...	...	Hard	...	...
176	NW¼SE¼SE¼	12	Dug	...	30	22	...	...	Hard	...	Nellie Bly
177	NE¼SE¼SE¼	16	...	...	Spring	...	...	...	...	...	Iola
178	NE¼	14	Dr.	6″	96	61.7	6/27/48	...	(A)	...	M. Nellie Bly
179	NW¼SE¼SW¼	22	Dug	...	20	0	...	...	Limy	No change	Iola
180	SW¼NE¼SW¼	22	Sp.	...	Spring	...	...	...	Soft	Lowers slightly	Iola
181	NW¼NW¼NW¼	25	Dr.	...	72	22	...	...	M. hard	Poor	Nellie Bly?
182	SE¼SE¼SE¼	26	Dr.	...	25	14	...	...	M. soft	Fair	...

WELL TABLES—(Continued)
RECORD OF WELLS AND SPRINGS IN TULSA COUNTY, OKLAHOMA

Well No.	Location	Sec.	Type Well a	Diameter Well	Depth of Well	Depth to water	Date Measured b	Method of lift c	Quality d	Performance during drought	Probable Aquifer
					T. 19 N., R. 10 E.—(Continued)						
183	SW¼NE¼NW¼	28	Dug	....	22	17	....	....	Soft	Almost dry	....
184	SE¼NE¼SE¼	31	Dr.	....	233	160	....	....	Soft	No change	Nellie Bly
185	SE¼NW¼NW¼	33	Dr.	....	56	34	....	....	Soft	No change	Nellie Bly
186	SW¼NW¼SW¼	35	Dr.	....	150	12	....	....	....	Good	....
187	SE¼SE¼SW¼	36	Dr.	....	35	15	....	....	M. hard	Goes dry	....
188	SW¼SW¼SW¼	36	Dr.	....	19	3	....	....	M. hard	Good	....
					T. 19 N., R. 11 E.						
189	SE¼NE¼SE¼	1	Dug	....	33	28	....	....	Soft	No change	Terrace deposit
190	SW¼NW¼NW¼	6	....	....	68	12	....	....	Hard	No change	Nellie Bly
191	SE¼SE¼SE¼	6	Dr.	....	32	10	....	....	Hard	....	Alluvium
192	NW¼NW¼NE¼	7	Dr.	....	50	22	....	....	Hard	....	Alluvium
193	NW¼	11	Dv.	....	29	24	7/ 7/48	....	M. hard	No change	Terrace deposit
194	SW¼	14	Sp.	....	Spring	....	6/27/48	WJ	Hard	....	Hogshooter
195	SW¼SW¼NE¼	17	Dv.	....	22	16	....	....	Hard	No change	....
196	SW¼SE¼SW¼	25	Sp.	....	Spring	....	....	....	Soft	No change	Hogshooter
197	SW¼SW¼NW¼	27	Dug	....	27	32	....	....	Soft	Lowers	Hogshooter
198	SE¼SE¼SE¼	28	Dr.	....	130	90	....	....	Gyp	Goes dry	Coffeyville
199	NE¼NW¼SW¼	31	Dr.	....	53	20	....	....	Hard	Adequate	Nellie Bly
200	NW¼NE¼SE¼	32	Dr.	....	....	124	....	....	Hard	....	Coffeyville
201	SW¼SW¼SE¼	34	Dr.	....	119	40	....	....	Soft	No change	Coffeyville
202	E½NE¼NE¼	35	Sp.	....	10	....	....	....	Soft	No change	Coffeyville
					T. 19 N., R. 12 E.						
203	SE¼SW¼	3	Dv.	....	20	13	7/24/48	WJ	(A)	Lowers	Alluvium
204	NE¼NE¼NW¼	5	Dr.	....	32	12	....	....	Soft	No change	Terrace deposit
205	NW¼SW¼SW¼	6	Dv.	....	15	12	....	....	Soft	....	Terrace deposit
206	NE¼	10	Dug	12″	....	21.8	6/24/48	CP	....	....	Alluvium
207	....	12	Dr.	6″	244	55	7/22/48	WJ	....	....	L. Seminole
208	SE¼SE¼	24	Dv.	....	28	15	6/23/48	WJ	....	....	Alluvium
209	NE¼NE¼	25	Dr.	1¾″	34	16	7/13/48	VP	(A)	....	Alluvium
210	SE¼SE¼SW¼	31	Dr.	....	139	130	....	....	Hard	Poor	Coffeyville
211	NW¼SW¼SW¼	32	Dr.	....	120	90	....	....	M. hard	No change	Coffeyville

WELL TABLES—(Continued)

RECORD OF WELLS AND SPRINGS IN TULSA COUNTY, OKLAHOMA

Well No.	Location	Sec.	Type Well a	Diameter Well	Depth of Well	Depth to water	Date Measured b	Method of lift c	Quality d	Performance during drought	Probable Aquifer
					T. 19 N., R. 13 E.						
212	SW¼SW¼NW¼	1	Dug	....	36	18	....	....	Hard	Lowers	Nowata
213	SW¼NW¼SW¼	2	Dug	....	28	12	....	....	Hard	Lowers	Holdenville
214	NW¼SE¼NW¼	3	OW	....	....	74	....	....	....	....	Holdenville
215	SE¼	7	Dr.	....	130	44	7/44/48	CP	(A)	....	L. Seminole
216	SW¼NW¼SW¼	13	OW	....	....	16	....	....	....	....	Nowata
217	SE¼SE¼SW¼	14	Dr.	....	25	14	....	....	Hard	Lowers	Nowata
218	SW¼SW¼SE¼	15	Dr.	....	22	12	....	....	Hard	Lowers	Holdenville
219	SE¼NE¼	15	Dug	72″	18.4	11.8	6/27/48	....	....	....	Holdenville
220	SE¼SE¼	23	Dr.	....	25	18	....	....	Hard	No change	Nowata
221	NW¼SW¼SW¼	30	Dug	....	58	32	....	....	Hard	Lowers	Alluvium
222	NW¼NW¼	31	Dr.	....	75	25	....	....	Hard	Lowers	Alluvium
223	NW¼NE¼NW¼	32	Dr.	....	80	50	....	....	Soft	....	Holdenville
224	NE¼SW¼NW¼	35	OW	....	....	20	....	....	....	....	....
					T. 19 N., R. 14 E.						
225	NE¼NE¼NE¼	1	Dr.	....	80	6	....	....	Hard	No change	Labette
226	NE¼NE¼	2	Dug	....	30	18	....	....	Hard	No change	Labette
227	SW¼SE¼SE¼	2	Dr.	....	48	18	....	....	Hard	No change	Labette
228	SW¼SW¼SW¼	6	Dug	....	62	25	....	....	Hard	No change	Nowata?
229	NW¼SW¼SW¼	8	Dug	....	46	16	....	....	Hard	Lowers	Oologah
230	SW¼SE¼SW¼	9	Dug	....	60	20	....	....	Hard	Little change	Oologah
231	SW¼NW¼SW¼	10	Dug	....	30	12	....	....	Hard	Little change	Oologah?
232	SW¼SW¼SE¼	12	Dug	....	25	18	....	....	Hard	Little change	Labette
233	NE¼NE¼NE¼	14	Dr.	....	60	15	....	....	Hard	Little change	Labette
234	SW¼SE¼SE¼	17	Dug	....	20	12	....	....	Hard	Goes dry	Oologah
235	NW¼NW¼SE¼	17	Dug	....	18	9	....	....	Soft	Lowers	Oologah
236	NE¼NE¼NW¼	19	Dug	....	50	20	....	....	M. hard	....	Nowata
237	SW¼NW¼NW¼	20	Dr.	....	25	12	....	....	Hard	No change	Nowata?
238	SE¼NW¼NW¼	24	Dr.	....	85	78	....	....	Hard	Lowers	....
239	SE¼SE¼SW¼	25	Dr.	....	25	18	....	....	Hard	Good	Labette
240	SW¼NE¼NW¼	25	OW	....	....	80	....	....	Hard	....	....
241	SE¼SE¼NW¼	29	Dr.	....	30	20	....	....	Hard	Goes dry	Oologah
242	SE¼SE¼NW¼	30	Dr.	....	40	18	....	....	Hard	Lowers	Nowata
243	SW¼SE¼SW¼	31	Dug	....	32	12	....	....	Hard	Goes dry	Nowata

WELL TABLES—(Continued)
RECORD OF WELLS AND SPRINGS IN TULSA COUNTY, OKLAHOMA

Well No.	Location	Sec.	Type Well [a]	Diameter Well	Depth of Well	Depth to water	Date Measured [b]	Method of lift [c]	Quality [d]	Performance during drought	Probable Aquifer
					T. 19 N., R. 14 E.—(Continued)						
244	NW¼NW¼NW¼	32	Dr.	....	35	22	....	....	Hard	Lowers	Nowata
245	SE¼NE¼NE¼	33	Dr.	....	35	20	....	....	Hard	Lowers	Oologah
246	SE¼NE¼	33	Dr.	6″	64.7	24.09	6/25/48	CP	(A)	Lowers	Oologah
247	NW¼NE¼SE¼	34	Dug	....	25	5	....	....	Soft	Good	Oologah
248	SW¼SW¼SE¼	34	Dug	....	22	8	....	....	Hard	Good	Oologah
249	SE¼NE¼NE¼	36	Dug	....	18	6	....	....	Hard	Good	Oologah
					T. 20 N., R. 10 E.						
250	NE¼SE¼	2	Dr.	....	120	70	....	....	Soft	Unchanged	Wann
251	SW¼NW¼	4	Dr.	....	30	23	....	....	Hard	Fails	Wann
252	NE¼SE¼	6	Dr.	....	19	15	....	....	Soft	....	Wann
253	NW¼SE¼	9	Dv.	1¾″	20	10	7/ 8/48	CP	(A)	....	Alluvium
254	SE¼NE¼	15	Dr.	6″	136	18	7/ 8/48	B	(A)	....	Wann
255	NW¼NE¼	21	Dr.	....	18	8	....	....	....	Fails	....
256	SW¼SW¼	25	Spring	....	....	....	....	....	....	....	....
257	SW¼SW¼	26	Spring	....	....	....	....	....	....	....	....
258	NE¼SW¼	35	Spring	....	....	....	....	....	....	....	....
					T. 20 N., R. 11 E.						
259	NW¼SW¼	5	Dr.	....	22	14	....	....	Soft	....	....
260	NE¼NE¼	9	Dr.	6″	74	10	....	....	(A)	....	Nellie Bly
261	NE¼NE¼	16	Dr.	....	90	30	....	....	Soft	....	....
262	NW¼NW¼	13	Dug	....	48	12	....	....	Hard	....	....
263	SE¼SW¼	21	Spring	....	4	1	....	....	Soft	....	....
264	NE¼SW¼	23	Dr.	....	288	268	....	....	Soft	....	....
265	SE¼SE¼	24	Spring	....	5	1	....	....	Soft	....	....
266	NE¼NE¼	28	Spring	....	2	0	....	....	Soft	....	....
267	SE¼SE¼	36	Dug	....	20	17	....	....	Soft	Fails	....
					T. 20 N., R. 12 E.						
268	SW¼NW¼NW¼	1	Dug	....	21	11	7/ 9/48	....	Soft	Goes dry	Coffeyville
269	SE¼SE¼	8	Dr.	6″	46	22.5	7/ 9/48	WJ	(A)	....	Coffeyville
270	SE¼SW¼SE¼	12	Dug	....	35	29	....	....	Hard	No change	Seminole
271	NE¼SW¼SW¼	17	Dr.	....	80	30	....	....	Hard	Lowers	Hogshooter?
272	NE¼NW¼	17	....	....	24	12	....	....	Soft	Good	Nellie Bly

WELL TABLES—(Continued)

RECORD OF WELLS AND SPRINGS IN TULSA COUNTY, OKLAHOMA

Well No.	Location	Sec.	Type Well [a]	Diameter Well	Depth of Well	Depth to water	Date Measured [b]	Method of lift [c]	Quality [d]	Performance during drought	Probable Aquifer
273	SE¼NW¼SE¼	24	OW	....	....	74	....	....	....	....	Sand
274	SW¼SW¼	25	Dug	....	20	18	....	....	Hard	Goes dry	Seminole?
					T. 20 N., R. 13 E.						
275	NE¼NW¼NE¼	4	Dr.	....	28	16	....	....	Hard	No change	Seminole
276	NW¼SE¼	7	Dr.	....	22	10	....	....	Soft	No change	Seminole
277	SW¼NE¼	7	Dr.	....	65	30	....	....	M. soft	Goes dry	Seminole?
278	NE¼SE¼	7	Dr.	....	20	10	....	....	Hard	Goes dry	Seminole
279	NW¼NE¼SW¼	9	Dug	....	....	24	....	....	....	....	Alluvium
280	SE¼SE¼NW¼	10	Dug	....	26	19	....	....	Soft	No change	Alluvium
281	NW¼NE¼NW¼	11	Dug	....	18	15	....	....	Hard	No change	Alluvium
282	NE¼SW¼	11	Dug	....	21	16	....	....	Hard	Lowers	Alluvium
283	SW¼SW¼	11	Dr.	....	40	30	....	....	Hard	Lowers	Nowata?
284	NW¼NE¼	11	Dug	....	18	17	....	....	Hard	Goes dry	Alluvium
285	NW¼NW¼	11	Dug	....	16	15	....	....	Soft	Goes dry	Alluvium
286	NE¼NE¼	12	Dug	36″	28	20	7/10/48	Cen	(A)	....	Nowata
287	SE¼SW¼	17	Dr.	....	60	30	....	....	M. hard	Goes dry	Seminole
288	SW¼SE¼	17	Dr.	....	40	7	....	....	Hard	No change	Seminole
289	NW¼NW¼	17	Dug	....	22	16	....	....	....	No change	Seminole
290	NW¼NW¼	17	Dug	....	20.5	10	....	....	M. hard	Goes dry	Seminole
291	SW¼NW¼	17	Dug	....	19	18	....	....	Hard	Goes dry	Alluvium
292	NW¼NE¼	17	Dr.	....	63	21	....	....	Soft	....	Seminole
293	NW¼NW¼	18	Dug	....	19	12	....	....	Soft	No change	Seminole
294	NE¼NE¼	18	Dr.	....	61	15	....	....	M. soft	No change	Seminole
295	SE¼NE¼	20	Dr.	....	40	25	....	....	Hard	Goes dry	Seminole
296	NE¼NE¼	20	Dr.	....	65	21	....	....	Hard	No change	Seminole
297	SW¼SE¼	20	Dug	....	35	8	....	....	Very hard	....	Seminole
298	SE¼NW¼	27	Dug	48″	63	48.7	7/10/48	B	(A)	Poor	L. Seminole
299	NE¼NW¼	27	Sp.	....	5	1	....	....	Soft	Good	Seminole
					T. 20 N., R. 14 E.						
300	NW¼NW¼	1	Dug	....	20	9	....	....	M. hard	....	Oologah
301	NW¼NW¼	2	Dug	....	20	15	....	....	hard	....	Oologah
302	SE¼SE¼	9	Sp.	....	Spring	....	....	....	Soft	No change	Labette?

WELL TABLES—(Continued)

RECORD OF WELLS AND SPRINGS IN TULSA COUNTY, OKLAHOMA

Well No.	Location	Sec.	Type Well [a]	Diameter Well	Depth of Well	Depth to water	Date Measured [b]	Method of lift [c]	Quality [d]	Performance during drought	Probable Aquifer
					T. 20 N., R. 14 E.—(Continued)						
303	SE¼SE¼NW¼	23	OW	....	....	316	....	....	....	....	....
304	NW¼NE¼	28	Dug	48″	16.4	4.8	7/10/48	B	Hard	....	Oologah
					T. 21 N., R. 10 E.						
305	NE¼	5	Dr.	10″	186	136	7/12/48	CP	....	....	U. Wann
					T. 21 N., R. 11 E.						
306	NE¼NE¼	1	Dr.	....	64	44	....	....	Soft	Normal	Nellie Bly
307	NW¼NW¼	3	Dug	....	35	33	....	....	Soft	Lowers	Wann
308	NW¼SE¼	9	Dug	....	75	10	....	....	M. soft	Varies	Wann
309	NE¼SE¼	12	Dug	....	12	7	....	....	Hard	Fails	Nellie Bly
310	NE¼NE¼	14	Dug	....	22	18	....	....	Salty	Lowers	Nellie Bly
311	SW¼NE¼	17	Dr.	....	55	35	....	....	Soft	Same	Wann
312	SW¼SW¼	22	Sp.	....	....	....	....	....	Soft	Dry	Dewey?
313	NE¼SW¼	23	Dug	....	10	8	....	....	Hard	Varies	Nellie Bly
314	SE¼NE¼	24	Dr.	....	96	86	....	....	Hard	Fair	Nellie Bly
315	NE¼SW¼	26	Dug	....	35	30	....	....	Soft	Same	Nellie Bly
316	SE¼NE¼	27	Dug	....	20	12	....	....	Hard	Normal	Nellie Bly
317	SE¼NE¼	28	Dr.	6″	74	21.3	7/13/48	CP	(A)	....	Nellie Bly
					T. 21 N., R. 12 E.						
318	SE¼NW¼NE¼	1	Dug	....	28	20	....	....	Hard	Good	Alluvium
319	SW¼SE¼	9	Dr.	6″	61	60	7/13/48	....	M. hard	....	Coffeyville
320	NE¼NE¼NE¼	26	Dr.	....	18	8	....	....	Gyp	No change	Alluvium
					T. 21 N., R. 13 E.						
321	NW¼NW¼NW¼	1	Dr.	....	42	13	....	....	Hard	No change	Seminole
322	NE¼NE¼NE¼	2	Dug	....	32	26	....	....	M. hard	No change	Seminole?
323	SE¼SE¼	3	Dr.	....	65	....	....	....	Sulphur	No change	Seminole
324	NE¼NE¼SE¼	5	Dr.	....	30	10	....	....	Hard	Varies	Coffeyville
325	NE¼SW¼SW¼	7	Dug	....	30	10	....	....	Hard	Goes dry	Alluvium?
326	NW¼NW¼NE¼	10	Dr.	....	119	84	....	....	Hard	No change	Seminole
327	SE¼SW¼SW¼	10	Dr.	....	100	6	....	....	Soft	....	Seminole
328	NE¼NW¼NW¼	12	Dug	....	13	4	....	....	Soft	No change	Seminole
329	NW¼NW¼NW¼	13	Dr.	....	50	10	....	....	Soft	Never goes dry	Seminole
330	NE¼NE¼SE¼	16	Dr.	6″	83	27	7/13/48	B	(A)	....	Seminole

WELL TABLES—(Continued)
RECORD OF WELLS AND SPRINGS IN TULSA COUNTY, OKLAHOMA

Well No.	Location	Sec.	Type Well [a]	Diameter Well	Depth of Well	Depth to water	Date Measured [b]	Method of lift [c]	Quality [d]	Performance during drought	Probable Aquifer
					T. 21 N., R. 13 E.—(Continued)						
331	SE¼SE¼SE¼	23	Dr.	....	40	....	....	....	Soft	Goes dry	Seminole
332	NE¼NW¼NW¼	25	Dug	....	32	20	....	....	Hard	Lowers	Nowata
333	NE¼SE¼SW¼	26	Dug	....	12	9	....	....	M. hard	Varies	Oologah
334	SE¼SE¼SE¼	27	Dug	....	30	8	....	....	M. hard	Varies	Seminole
335	NE¼NE¼SE¼	28	Dr.	....	129	40	....	....	Hard	No change	Seminole
336	NW¼NW¼NE¼	31	Dr.	....	20	8	....	....	Hard	Gets low	Seminole?
337	SE¼SE¼SE¼	33	Dug	....	26	20	....	....	Hard	Goes dry	Seminole
					T. 21 N., R. 14 E.						
338	SE¼NE¼SE¼	4	Dug	....	20	8	....	....	Hard	Never goes dry	Seminole
339	NW¼SW¼NW¼	5	Dr.	....	60	17	....	....	Hard	Never goes dry	Seminole
340	NE¼NW¼NW¼	6	Dug	....	35	15	....	....	Hard	Dry	Seminole
341	SE¼NE¼SE¼	7	Dr.	....	47	15	....	....	Hard	No change	Seminole
342	NW¼NW¼SW¼	8	Dr.	....	75	40	....	....	Hard	No change	Seminole
343	SE¼SE¼SE¼	9	Dug	....	15	10	....	....	Hard	No change	Seminole
344	NE¼NE¼SE¼	16	Dr.	....	60	15	....	....	Soft	No change	Seminole
345	NW¼SW¼SW¼	17	Dr.	....	25	15	....	....	Soft	No change	Seminole
346	SE¼SE¼SE¼	18	Dug	....	25	19	....	....	Med.	No change	Seminole
347	SE¼NE¼SE¼	19	Dr.	....	90	70	....	....	M. hard	No change	Oologah?
348	NW¼NE¼NW¼	19	Dr.	....	40	10	....	....	Hard	Good	Nowata
349	NE¼NE¼NE¼	21	Dr.	....	40	30	....	....	Soft	No change	Nowata?
350	SW¼SW¼	22	Dr.	6″	41	16	7/13/48	CP	(A)	....	Oologah
351	SE¼SE¼SE¼	31	Dug	....	42	18	....	....	Hard	Lowers	Nowata
352	NE¼NE¼NW¼	33	Dug	....	18	12	....	....	....	Good	Oologah
					T. 22 N., R. 10 E.						
353	NW¼NE¼	27	Dr.	10″	184	148	7/12/48	WJ	(A)	No change	U. Wann
					T. 22 N., R. 11 E.						
354	NW¼NE¼	10	Dr.	....	40	28	....	....	Hard	Lowers	Wann
355	NE¼SE¼	12	Dug	....	25	20	....	....	Hard	....	Nellie Bly
356	SE¼NE¼	13	Dug	....	42	30	....	....	Hard	....	Nellie Bly
357	SE¼NE¼	14	Dug	....	23	15	....	....	Soft	Lowers	Wann
358	NW¼NW¼	20	Dug	....	22	10	....	....	Hard	....	Wann?
359	SE¼SW¼	21	Dug	....	....	30	....	....	Soft	....	Wann?

WELL TABLES—(Continued)

Well No.	Location	Sec.	Type Well [a]	Diameter Well	Depth of Well	Depth to water	Date Measured [b]	Method of lift [c]	Quality [d]	Performance during drought	Probable Aquifer
					T. 22 N., R. 11 E.—(Continued)						
360	NW¼SE¼	22	Dr.	8″	56.5	33.8	7/12/48	B	(A)	Lowers	L. Wann
361	SW¼SE¼	24	Dug	....	25	10	....	....	Hard	Fails	Alluvium
362	NW¼SW¼	25	Dug	....	35	25	....	....	Hard	Normal	?
363	NW¼NW¼	26	Dug	....	45	35	....	....	Hard	....	?
364	NE¼SW¼	27	Dr.	6″	43	28.85	7/12/48	CP	(A)	Normal	Alluvium
365	SE¼SE¼	27	Dr.	....	45	....	....	....	Hard	Normal	Nellie Bly
366	NE¼NW¼	28	Dug	....	30	25	....	....	Soft	....	Alluvium?
367	NW¼NE¼	29	Dug	....	27	20	....	....	Soft	....	Alluvium?
368	NE¼NE¼	33	Dug	....	16	....	....	....	Hard	Same	Alluvium?
369	NE¼NE¼	34	Dr.	....	36	6	....	....	Hard	Lowers	Wann
370	NE¼NW¼	36	Dug	....	40	25	....	....	Hard	....	Nellie Bly
					T. 22 N., R. 12 E.						
371	SW¼SW¼SW¼	1	Dr.	....	28	20	....	....	Hard	Good	Alluvium?
372	SE¼NE¼NE¼	2	....	10″	27.9	8.2	7/14/48	CP	Hard	....	Alluvium
373	SE¼NE¼NE¼	2	Dug	....	24	4	....	....	Hard	Good	Alluvium
374	NE¼SE¼	5	Dr.	6″	50	15	7/21/48	WJ	(A)	....	Wann
375	NE¼NE¼NE¼	12	Dug	....	32	15	....	....	Hard	Lowers	Nellie Bly?
376	NE¼SW¼SW¼	13	....	....	27	23	....	....	Hard	No change	Alluvium
377	SW¼NW¼SW¼	18	....	....	....	100	....	....	....	....	Nellie Bly
378	NE¼NE¼NE¼	23	Dr.	....	48	15	....	....	Hard	No change	Alluvium
379	SE¼SE¼NE¼	36	Dug	....	32	28	....	....	Hard	Lowers	Coffeyville
					T. 22 N., R. 13 E.						
380	NW¼SW¼SE¼	1	Dr.	....	18	8	....	....	Hard	Good	Seminole
381	NE¼SE¼NE¼	2	....	....	27	17	....	....	Hard	No change	Coffeyville
382	SE¼SE¼SE¼	11	Dug	....	9	6	....	....	Hard	No change	Checkerboard?
383	NW¼NW¼NE¼	13	Dr.	....	85	35	....	....	Med.	No change	Seminole
384	NE¼NE¼NE¼	13	Dr.	....	30	15	....	....	Hard	No change	Seminole
385	NE¼SE¼NE¼	13	Dr.	6″	81	61	7/21/48	WJ	(A)	No change	U. Seminole
386	SW¼SW¼SE¼	14	Dr.	....	38	16	....	....	Hard	No change	Seminole
387	SE¼NE¼SE¼	15	Dug	....	18	16	....	....	Hard	No change	Coffeyville?
388	SE¼SE¼NE¼	21	Dr.	....	60	8	....	....	Hard,Salty	No change	Coffeyville
389	SW¼SW¼SE¼	22	Dug	....	14	11	....	....	Hard,Salty	Good	Coffeyville
390	SW¼SW¼SW¼	23	....	....	25	20	....	....	Hard	Little variation	Seminole

WELL TABLES—(Continued)

Well No.	Location	Sec.	Type Well[a]	Diameter Well	Depth of Well	Depth to water	Date Measured[b]	Method of lift[c]	Quality[d]	Performance during drought	Probable Aquifer
					T. 22 N., R. 13 E.—(Continued)						
391	SE¼SW¼SE¼	24	Dug	....	67	47	....	....	Med.	No change	Seminole
392	SW¼SE¼	25	Dug	....	27	20	....	....	Soft	No change	Seminole
393	SW¼NW¼	26	Dr.	....	40	10	....	....	Hard	No change	Coffeyville?
394	SW¼SE¼	34	Dug	....	11	6	....	....	Hard	No change	Coffeyville
					T. 22 N., R. 14 E.						
395	SW¼SE¼SW¼	4	Dr.	....	64	50	....	....	Hard	Goes dry	Seminole
396	SE¼SW¼SW¼	5	Dr.	....	75	15	....	....	Hard	No change	Seminole
397	SE¼NE¼SE¼	6	Dug	....	24	18	....	....	Hard	No change	Seminole
398	SW¼SE¼SW¼	7	Dug	....	20	17	....	....	Hard	Goes dry	Seminole
399	NE¼NE¼NE¼	8	Dr.	....	36	18	....	....	Hard	Lowers	Seminole
400	SW¼SW¼	9	Dug	48"	30	15	7/21/48	CP	(A)	....	M. Seminole
401	NW¼SE¼NE¼	10	Dr.	....	35	20	....	....	Soft	....	Seminole
402	SW¼SE¼	16	Dr.	....	60	....	....	....	Gyp	Adequate	Seminole?
403	NE¼NE¼NW¼	18	Dr.	....	40	20	....	....	Soft	No change	Seminole
404	NE¼SW¼SE¼	19	Dr.	....	228	158	....	....	Soft	Lowers	Labette?
405	SE¼SE¼SW¼	28	Dr.	....	73	25	....	....	Soft	....	Seminole
406	SE¼SE¼SE¼	29	Dr.	....	60	6	....	....	Soft	Little change	Seminole
407	SE¼SW¼NW¼	36	OW	....	....	15	....	....	....	....	Oologah

[a] Explanation of abbreviations: Dug = Dug; Dr. = Drilled; OW = Oil well; Dv. = Driven; Sp. = Spring.
[b] Wells for which no date appears were recorded in 1936 and 1937 by the State Mineral Survey.
[c] Explanation of abbreviations: B = Bucket; WJ = Water jet; CP = Cylinder pump; Cen = Centrifugal pump; VP = Vacuum pump.
[d] In this column (A) indicates analysis is given in Table XV.