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GEOLOGY AND MINERAL RESOURCES OF CREEK COUNTY, OKLAHOMA

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with a section on

OIL AND GAS IN CREEK COUNTY, OKLAHOMA

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Norman

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GEOLOGY AND MINERAL RESOURCES OF CREEK COUNTY, OKLAHOMA

BY MALCOLM C. OAKES

ABSTRACT

Creek County is an area of about 972 square miles in the northeastern part of central Oklahoma, the major part between Cimarron River and Deep Fork. Its northeast corner is barely one mile south of the limits of the city of Tulsa. Principal towns are Drumright, Bristow, and Sapulpa. Sapulpa is the county seat.

Creek County is situated on the north flank of the western end of the Arkoma basin. The exposed consolidated rocks are transitional in character between the cyclic deposits of the shelf area, of northeastern Oklahoma and Kansas, and the much thicker deposits of the basin. They are high in the Pennsylvanian section, above the productive coal beds. For the greater part, they are weakly resistant silty sandstones and sandy, silty shales. Sandstone accounts for about one-third of the thickness of the exposed rocks in the north part of the county and about one-half in the south part.

The shales that crop out in the east part of the county, older than the Wann formation, are generally gray and the associated sandstones weather brown or reddish brown. Shales that crop out in the rest of the county, of Wann age and younger, generally weather various shades of red and the associated sandstones weather brownish red or red. Four thin sandy limestones are mapped in the west part of the county and two in the east part.

The nomenclature and classification of pre-Virgil rocks is the same as that used by the writer in his earlier work in Washington, Osage, and Tulsa Counties, as reported in Oklahoma Geological Survey Bulletins 62 and 69, 1940 and 1952. Several of the units continue into Kansas and their Kansas names are used. The classification corresponds, in a general way, with that used in Kansas. There is, however, considerable gradual lateral change in the character of the rocks from northern Washington County to southern Creek County: for instance, the Dewey formation of Washington County consists of limestone and a minor amount of intercalated calcareous shale, but is generally more clastic southward, and in Creek County consists of sandstone in the lower part and sandy shale in the upper part. It contains only thin lenses of small diameter of sandy limestone sparsely distributed in the shale.

Limits of the Virgil group in Oklahoma are comparable to its limits in Kansas. Names of Virgil units are derived from usage in northern Oklahoma and in Kansas, and, with modifications, from usage in the area between the North Canadian River and the north flank of the Arbuckle Mountains.

Four unconformities are indicated in the Pennsylvanian rocks of Creek County: at the base of the Seminole formation, separating the Des Moines series from the Missouri series; at the base of the Chanute formation, separating the Skiatook group from the Ochelata group; at the base of the Barnsdall formation, within the Ochelata group; and at the base of the Vamoosa formation, separating the Missouri series from the Virgil series.

In general, the rocks that crop out in Creek County dip westward at low angles, 30 to 100 feet per mile, most commonly about 60 feet per mile. The low westward dip is modified in areas of local folds and faults, and in some localities the dip is eastward: for instance, on the east flank of the Cushing anticline, in northwestern Creek County, a few miles northeast, east, and southeast of Drumright.

Economic resources of the exposed rocks are modest. They consist of impure limestones of sparse occurrence; chert gravel, in the south central part of the county; inferior sand; abundant shale suitable for brick, tile, and pottery; and considerable accumulations of ground water. In contrast, some of the subsurface rocks of Creek County are prolific sources of petroleum. Production of oil and gas is the principal occupation of the people, followed in order by farming and manufacturing.

INTRODUCTION

Scope and purpose. The primary purpose of this investigation was to study in detail the character, distribution, and thickness of rocks exposed in Creek County in order to apply to these rocks the classification already established for stratigraphically equivalent rocks in northern Oklahoma and in southern Kansas; to describe known deposits of mineral materials of economic value and to seek other such deposits; and to make more precise correlation of the rocks that crop out in Creek County with rocks exposed in other areas in Oklahoma, and elsewhere, and with corresponding units found in drilling for oil and gas in areas farther west.

Location. Creek County is in the northeast part of central Oklahoma, the major part between Cimarron River and Deep Fork. Its northeast corner is barely one mile south of the city limits of Tulsa, in Tulsa County, Oklahoma. It is irregular in shape; but its entire area of 972 square miles is included in Tps. 14 to 19 N., Rs. 7 to 12 E., Indian Meridian.

Accessibility. U. S. Highway 66 crosses the county from southwest to northeast and passes through Depew, Bristow, Kellyville, and Sapulpa. Turner Turnpike parallels U. S. Highway 66 and has access gates at Bristow and Sapulpa. U. S. Highway 77 enters the northeast part of the county with U. S. Highway 66, leaves 66 at Sapulpa, and passes southward along the east side of the county through Kiefer and Mounds. State Highway 27 extends southeastward from Drumright, through Shamrock to Bristow, and thence due south. State Highway 99 enters Creek County at Drumright and passes northward along the west side. State Highway 51 crosses the north part of the county through Mannford. State Highway 33 extends east from Drumright to a junction with U. S. Highway 66, a few miles west of Sapulpa.

The St. Louis and San Francisco Railroad serves Creek County with a main line essentially parallel to U. S. Highway 66 through Milfay, Depew, Bristow, Heyburn, Kellyville, and Sapulpa; a branch line from Depew northwest through Drumright to a junction with the Missouri, Kansas, and Texas Railroad at Cushing, in Payne County; another line southward from Sapulpa along the east side of the county through Kiefer and Mounds; and still another branch line that passes through Mannford in the north part of the county. The Sapulpa Union Railway connects Sapulpa with Tulsa, in Tulsa County. It is essentially a freight line, and serves local business firms in Sapulpa.

FIGURE 1. Index map of Oklahoma showing location of Creek County.

Previous investigations. Drake (1897) spent 6 months making a geological reconnaissance of the coal fields of the Indian Territory, of which Creek County was a part; but it is doubtful that he visited this area, because Creek County has no coal seams of economic value.

Carl D. Smith (1914) reported on the results of an investigation begun in December, 1912, to determine the relations of the accumulations of oil and natural gas and the geologic structure of the Glennpool area, of western Tulsa County and eastern Creek County, Oklahoma. Frank Buttram (1914) made a surface and subsurface study of the Cushing oil and gas field, which included an area around Drumright in northeastern Creek County. A. E. Fath (1917, 1925) made an investigation of the Bristow quadrangle, all of which is in Creek County, with reference to petroleum and natural gas. C. W. Shannon and staff (1917), of the Oklahoma Geological Survey, published a brief discussion of the geology of Creek County, devoted mostly to areas about Drumright, in the northwestern part, and Kiefer, in the eastern part, in a report on petroleum and natural gas in Oklahoma by counties. Carl Beal (1917) made an investigation of the geologic structure in the Cushing oil and gas field and its relation to oil, gas, and water, with a view to more complete recovery of the oil and gas. John W. Merritt and O. G. McDonald (1930) wrote the section on Creek County which appears in Oil and Gas in Oklahoma, Bulletin 40 of the Oklahoma Geological Survey.

In the first two decades of the twentieth century many geologists made investigations in Creek County with a view to finding oil and natural gas; but the results of comparatively little of that work were ever made available to the public, except incidentally in discussions of problems common to that and other areas. Among these geologists were Edward Bloesch (1919) who wrote on unconformities in Oklahoma and their importance in petroleum geology, and Lindon Foley (1926) who wrote on the origin of faults in Creek and Osage Counties, Oklahoma. Other references to field observations in Creek 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 and the Oklahoma Geological Survey.

During the field seasons of 1947 to 1950, inclusive, the author did reconnaissance mapping, some of it in Creek County, incident to compilation of the Geologic Map of Oklahoma (Miser, 1954).

Present investigation. The present investigation was begun in September, 1953, and continued, with long interruptions occasioned by other work, into October, 1956. Further field work was done in the spring of 1957, after the preparation of this report was well along.

The Oklahoma Geological Survey uses aerial photographs, commonly called airplane photographs, as a field base map for most of its geologic mapping. The photographs used for the work in Creek County constituted a full stereoscopic coverage of contact prints from negatives made in 1941 for the Agricultural Adjustment Administration of the Department of Agriculture. Their scale was 1:20,000, or about 3 inches per mile. They had little tip and tilt, and differences in elevation in Creek County are so small that distortion from that cause is negligible. The result is a higher degree of accuracy than is attainable by any method involving sketching.

All indications of mappable stratigraphic features that appeared on the stereoscopic image were marked on the photographs in the office and investigated later in the field, the same photographs serving as a base for the field mapping. All geologic mapping as well as other data, such as drainage and roads, were transferred to township plats of the same scale as that of the photographs by tracing, and the plats were used in the compilation of the geologic map (Plate I).

Stratigraphic sections were measured by hand level wherever possible, and corrections for dip were made if that were deemed necessary. Ordinarily, the elevation of at least one point in each section so measured was determined by barometry, to facilitate its incorporation in the compiled sections of Plate II. However, mappable contacts are generally so far apart that it was necessary to compute the thickness of intervening rocks from their dips, difference in elevation of their contacts with underlying and overlying rocks, and horizontal distances between these contacts. The distances could be measured with sufficient accuracy from the photographs. A Paulin altimeter was used in determining elevations. The crude barometric data were corrected by frequent returns to a selected point, and by reference to the record of a microbarograph set up each day in the area worked that day, taking into account the departure or drift between readings of the microbarograph and readings of the Paulin altimeter at the microbarograph station. Finally, differences in elevation were corrected for the temperature of the air.

The dip of the strata is so low in Creek County that the vertical distance between contacts was considered equal to the thickness of the rocks between them. This assumption results in a much smaller error than the error unavoidably introduced by other factors, such as undeterminable local changes in dip and thickness of strata. This justifiable assumption leads to a great convenience; the vertical distance can be computed quite as accurately and more conveniently in the direction of any component of dip as in the direction of the true or maximum dip; thus one is free to work along established roads, so that the barometry can be done rapidly, and serious errors caused by unsuspected changes in barometric pressure can be avoided.

Each of the eleven sections of Plate II was compiled from computed thicknesses and measured sections in a strip 3 miles wide across the county from east to west. No section was compiled for the strip 3 miles wide across the south side of the county, because a large part of it is covered by surficial deposits, and most exposures are poor in the rest.

Acknowledgments. The citizens of Creek County were outstandingly courteous and cooperative during the field investigation which led to the preparation of this report. They cheerfully supplied much information and made not a single objection to entering upon and crossing their lands.

Francis D. Taaffe, then a student at the University of Oklahoma, was an able field assistant during the summer of 1954. Paul Frederick Laurens de Groot, then a student at the University of Oklahoma, an exchange student from Holland, was a delightful field companion and faithful assistant from August 23 to September 7, 1955.

The work was begun under the direction of Dr. William E. Ham, then Acting Director, and continued under the direction of Dr. Carl C. Branson, the present Director. Thanks are due to both for encouragement during the field work and for helpful advice and constructive criticism during the preparation of this report. Thanks are also due to Dr. Louise Jordan for subsurface information about the rocks that crop out in Creek County, and for improvement of the manuscript.

Roy D. Davis, Draftsman, and his two assistants, Mrs. Marion E. Clark and Miss Eleanor Cline, have gone much beyond their duties in the preparation of the geologic map, compiled sections, and other illustrative material.

GEOGRAPHY

Topographic features. Parts of Creek County appear on each of the following topographic sheets of the United States Geological Survey: Yale, Drumright, Stroud, Hominy, Nuyaka, Bristow, Sapulpa North, and Kiefer. Together, they cover the county. The contour interval of these sheets ranges from 10 to 50 feet.

The maximum relief is about 450 feet, between the exit of Deep Fork, in the southeast part of the county, elevation about 650 feet above sea level, and the tops of the highest hills, northeast of Shamrock, elevation about 1,100 feet. Deep Fork enters the southwest part of the County at about 740 feet above sea level and thus drops about 100 feet in crossing the south part. Cimarron River enters the northwest part of the county at about 750 feet above sea level and drops about 100 feet, to about 650 feet above sea level, at its confluence with the Arkansas River, near Keystone, in Tulsa County; the Arkansas continues the drop to about 610 feet at a point in Tulsa County about 5 miles north of the northeast corner of Creek County. Thus the Cimarron-Arkansas drops about 140 feet across and along the north side of Creek County. High points between the Arkansas and Deep Fork, in eastern Creek County, are about 900 feet above sea level, and some of the highest are within a few miles of each river. The surface of Creek County is a much dissected tableland, or plain, which slopes about 250 feet from the west side to the east side.

The present topography is the result of erosion on beds of unequal resistance. Rocks at the surface are mostly silty shale and nonresistant sandstone, the latter either poorly sorted clay, silt, and sand or thin sandstone beds closely interspersed with silty, sandy shale bands. However, at intervals of several tens of feet are more resistant beds, generally sandstones 5 to 10 feet thick, and a few sandy limestones one to 15 feet thick. Some of the more resistant beds extend entirely across the County, others for only a mile or even less.

All strata were deposited essentially horizontal; subsequently they were uplifted and tilted, so that now they dip, or slope, in a direction slightly north of west at rates generally 30 to 100 feet per mile, but most commonly 60 feet per mile. However, in local areas the dip is much less, and, in some, is even toward the east. Erosion has proceeded far enough to produce the alternating ridge and plain type of topography common on rocks of this character and structure. The drainage is dendritic, resembling the branches of a tree, and the streams have, at some places, cut deep restricted valleys flanked by hills whose sides are broken by changes in slope, low terraces, and even short cliffs, all of which are caused by the more resistant strata.

Drainage. The north part of Creek County is drained by Cimarron River, Polecat Creek, and other tributaries of the Arkansas River; all join the Arkansas outside of Creek County. The south part is drained by Deep Fork, and even the waters of Deep Fork ultimately reach the Arkansas, east of Eufaula, by way of North Canadian and Canadian Rivers. The principal tributary of Cimarron River from the north is Dragoon Creek; from the south principal tributaries are Tiger, Buckeye, and Salt Creeks. The principal tributaries of Polecat Creek, from the north, are Figure Eight, Brown's, Little Polecat, and Rock Creeks; from the south they are Dog, Mosquito, Rowland, Neversweat, Mountain, Euchee, Skull, and Childress Creeks. Principal tributaries of Deep Fork, from the north, are Salt and Little Deep Fork Creeks.

Economic development. At the beginning of the 20th century ranching was the principal industry of Creek County; then the farmer arrived. By 1915 much of the bottom land along the streams was in cultivation and the farms were climbing the hillsides. Eventually, practically all tillable upland was in cultivation. Corn, cotton, and hay, in the order of value, were the principal crops. But erosion began its work on the bare, depleted, sandy land. Soon the upland fields were gullied and sheet washed and the bottom lands were buried under the sterile sand from the hillsides. Cotton, corn, and feed crops are still raised, but most of the old fields are used for pasture and stock raising is again a prominent occupation.

After 1915, oil production became the principal occupation of the people and even now it is probably the source of livelihood for most. However, manufacturing is gaining in importance. In addition to small manufactures and services dependent on the oil industry, there are a brick plant, a pottery, and two glass factories at Sapulpa, and a garment factory and a bleach factory at Bristow.

SURFACE STRATIGRAPHY

The pre-Pennsylvanian rocks in the area north of the present Arbuckle and Ouachita Mountains were eroded before the Pennsylvanian rocks were deposited. Near the end of this period of erosion, the area immediately north of the present mountains began to sink and eventually formed the structural and depositional feature formerly called the McAlester basin or the Arkansas-Oklahoma coal basin, but recently called the Arkoma basin (Branson, 1956, p. 83-86), which was invaded by the sea.

The land north of the Arkoma basin, around the west flank of the present Ozark uplift and northward, also sank slowly but remained a relatively stable shelf area throughout Pennsylvanian time. The Arkoma basin continued to sink, and thus a depositional trap was maintained in which the coarser clastics from the land to the south accumulated. In spite of continued sinking, this trap was well filled most of the time; ordinarily, part of the finer clastic materials passed on northward and settled in the shelf area, possibly with similar clastic materials from other sources. Indeed, the water seems to have been more shallow most of the time over the basin area than over the shelf area, and sedimentation was commonly much as it would have been had there been no basin. However, the net result was that thousands of feet of sediments accumulated in the basin while only hundreds of feet accumulated on the shelf.

Slight recurrent tectonic disturbances caused the shallow sea to withdraw briefly from time to time from parts or all of both basin and shelf areas; and resulted in erosion, at times only local, at other times general. Numerous coal beds, widespread over both basin and shelf, indicate that at times vast marshy areas were little above sea level and that little or no other sedimentation was in progress there. At other times the supply of clastic material was not more than enough to keep filled the trap maintained by the subsiding basin, and more or less pure limestone accumulated in the clear waters of the shelf area. These limestones grade southward into silty, sandy shales and even into sandstones of the basin area. Occasionally, calcareous shales, sandstones, and even local impure limestones were deposited across the basin area.

There is no sharp break between the alternating thick shales and sandstones typical of the basin and the thinner, definitely cyclic units typical of the shelf, but the one grades into the other through an intermediate zone in which the rocks are reminiscent of both basin and shelf. Creek County lies in this intermediate, transition zone, on the north flank of the basin, and the exposed rocks are high in the Pennsylvanian section, above the productive coal beds. They were deposited late in the Pennsylvanian period, when the basin was sinking less rapidly in relation to the rate of sedimentation, and the difference in thickness of the shelf and basin facies is not so strikingly great as in the earlier Pennsylvanian rocks. The basin is not evident in the structure of the surface rocks, which dip slightly north of west at low angles.

General character. Aside from the alluvium of present streams, alluvial terrace deposits made by the present or ancient streams, and eolian deposits, the rocks that crop out in Creek County are, for the greater part, silty shale and nonresistant sandstone. The nonresistant sandstone is composed, in some areas, of poorly sorted clay, silt, and quartz sand grains, in other areas, of thin sandstone beds alternating with thin bands of silty shale. At widely spaced intervals are more resistant beds of better sorted, more firmly cemented sandstone, generally 5 to 20 feet thick, which make mappable escarpments. Some of these escarpments extend across the County from north to south, but others extend only a mile, or even less. Generally the outcrop of such a local bed is so narrow that it is represented on the geologic map (Plate I) by a single black line. The dip slopes as well as the scarp slopes are on the nonresistant sandstone and silty shale which are poorly exposed in most areas. The proportion of sandstone is greatest in the south part of the County and least in the north part.

Four mappable limestone units, one to 15 feet thick, crop out along the west side of the County. They are the Lecompton and Turkey Run limestone members of the Pawhuska formation and the Bird Creek and Wakarusa limestones in the Vanoss formation. Sandy limestone beds of the Iola formation extend a short distance into Creek County from the north, but grade into sandstones, some of which are calcareous. The Nellie Bly formation contains a few discontinuous calcareous sandstone beds. The Hogshooter formation, which contains 40 feet of limestone in Tulsa County, extends into Creek County, but the limestone thins rapidly, and is represented by a few calcareous sandstone lenses south of Sapulpa.

The shales that crop out in eastern Creek County, lower than the Wann formation, are generally gray and the associated sandstones weather brown or reddish brown. Shale that crops out in the rest of the County, above the base of the Wann formation, generally weathers various shades of red; the associated sandstones weather brown, reddish brown, or red.

Nomenclature, correlation, and classification. In the course of his work in Washington County Oakes (1940) found that many individual Missourian beds continue with unbroken outcrops across the state line from Kansas. Other Kansas units exhibit such a change of facies that they are unrecognizable in Oklahoma. A sufficient number of the Kansas units are present in northern Oklahoma to permit a broad classification that corresponds, in a general way, with the classification used in Kansas. The named units of the Washington County area could be traced continuously across the Tulsa County area, and, regardless of considerable change in the character of some of the rocks, the same names and classification were used in the interest of simplification (Oakes, 1952). Now the same units have been traced into Creek County, and once again the same names and classification have been used; though there is still further change in the character of some of the rocks, as from limestone to sandstone and from clay shale to silty shale and nonresistant sandstone.

The Holdenville shale (IPhd), the oldest unit that crops out in Creek County, was placed in the upper part of the Marmaton group of the Des Moines series by Oakes (1952, p. 19). The Vamoosa formation and younger rocks in the western part of Creek County are placed in the Virgil series as a result of field work done by Oakes (1949, 1950) incident to compiling the Geologic Map of Oklahoma (Miser, 1954).

Pennsylvanian System

By far the greater part of the Pennsylvanian rocks of northern Oklahoma is included in three main divisions: the Des Moines series, the Missouri series, and the Virgil series. Rocks studied in this investigation include the uppermost part of the Des Moines series, the Missouri series, and the greater part of the Virgil series. They are Middle and Late Pennsylvanian in age.

DES MOINES SERIES

The Des Moines series in northern Oklahoma is divided into three groups. In ascending order they are the Krebs group, the Cabaniss group, and the Marmaton group. Only a small part of the Holdenville shale at the very top of the Marmaton group is exposed in Creek County, about a mile southeast of Mounds.

MISSOURI SERIES

The Missouri series is set off from the underlying Des Moines series by an unconformity and by a 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 an unconformity which is marked by a faunal change and by truncation of beds.

Moore, Newell, Dott, and Borden suggested a division of the Missourian rocks of Oklahoma and southern Kansas into two groups, Skiatook and Ochelata, using the unconformity at the base of the Chanute formation as the boundary between them (Moore and others, 1937). The logic of this division, as applied to the rocks of Washington County, was subsequently fully demonstrated by Oakes (1940a, 1950b). There is evidence of the unconformity separating the two groups in Tulsa and Osage Counties (Oakes, 1952). In one area in Creek County, vicinity of the southeast corner of T. 16 N., R. 9 E., sandstone is continuous from the base of the Dewey to the top of sandstone in the lower part of the Chanute formation, indicating that pre-Chanute erosion may have completely removed the shale which forms the upper part of the Dewey in Creek County.

Skiatook Group

Ohern (1910) was the first to use the term "Skiatook." He applied the name to the beds between the base of his Lenapah limestone and the base of the Dewey limestone, but his Lenapah later proved to be the Checkerboard limestone, and the term "Skiatook" fell into disuse. Moore, Newell, Dott, and Borden (Moore and others, 1937) redefined Skiatook and used it as a group name for the rocks between the unconformity at the base of the Missouri series and the top of the Dewey limestone, or, where the Dewey is absent, at the base of sandstone in the lowermost Chanute shale.

There is abundant evidence that there is an unconformity between the Dewey and the Chanute in parts of Washington County, and less certain evidence in parts of Tulsa and Osage Counties. The principal evidence of such an unconformity in Creek County is absence of the shale in the upper part of the Dewey formation in the vicinity of the southeast corner of T. 16 N., R. 9 E., which suggests post-Dewey, pre-Chanute erosion there.

TABLE 1

SUBDIVISIONS OF THE SKIATOOK GROUP IN CREEK COUNTY, OKLAHOMA

Missouri series
- Skiatook group
  - Dewey formation
  - Nellie Bly formation
  - Hogshooter formation
  - Coffeyville formation
  - Checkerboard limestone
  - Seminole formation
- *Unconformity*

Des Moines series

SEMINOLE FORMATION

Nomenclator. Taff (1901) called it the Seminole conglomerate and Seminole formation.

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 in rugged hilly country northwestward in the Seminole nation, making rough timbered lands (Taff, 1901, p. 4).

History of usage. Taff defined the lower limit of the Seminole formation in the Coalgate quadrangle as the base of the conglomerate that, by implication of text and map, lies next above the Holdenville shale, but he left the upper limit undefined, except to imply that it is about 150 feet above the base of the conglomerate which constitutes the lower part. Morgan (1924) fixed the upper limit definitely at the base of the DeNay limestone, which is about 150 feet above the base of the conglomerate in the northeast part of the Stonewall quadrangle.

As a result of the work of various geologists, the Seminole formation was shown with a fair degree of accuracy on the Geologic Map of Oklahoma (Miser, 1926) as far north as the south side of Tulsa County.

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 (Ohern, 1918 and Bloesch, 1930). Consequently, that part of the Seminole below the Dawson coal was erroneously included in the Nowata formation, and that part above was included in the Coffeyville formation. Robert H. Dott and Ronald J. Cullen, in 1933, while working on a project of the Tulsa Stratigraphic Society, found that the Seminole formation includes the Dawson coal and extends northward as far as the Kansas-Oklahoma line, and that its base marks the boundary between the Des Moines rocks and the overlying Missouri rocks.

Dott first proposed the use of the term "Seminole' in northeastern

Oklahoma informally at a meeting of the American Association of Petroleum geologists in Tulsa in 1936. Such use was proposed formally by Robert H. Dott and John M. Ware in a contribution to an article by Miller and Owens (1937), and in the same year by Moore, Newell, Dott, and Borden (Moore and others, 1937), who fixed the top of the northern Seminole at the base of the Checkerboard limestone, hoping that the Checkerboard would prove to be equivalent to the DeNay, or at least occupy a stratigraphic position so close to that of the DeNay that no violence would be done.

The choice was, indeed, a fortunate one. From the work of Ries (1954, p. 54) in Okfuskee County, Weaver (1954, p. 77, 78) in Hughes County, and Tanner (1956, p. 61) in Seminole county, we are able to say that the outcrops of the two limestones are not continuous, and that probably the two are not continuous underground to the west, but they do occupy substantially the same stratigraphic position. Each is only a few feet below a sandstone which has been traced from exposures near Okemah, Okfuskee County, where its relation to the Checkerboard is clear, to outcrops in western Hughes County, and in eastern Seminole County, where its relation to the DeNay limestone is equally clear.

Distribution. The Seminole formation (IPsl) crops out in a relatively narrow band from 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, Oklahoma. Sandstone and shale representing the upper part of the formation continue into Kansas. The Seminole crops out along the east side of Creek County from south of Mounds northward. The base is not exposed in the County except in the vicinity of Mounds.

Character. At the type locality in Seminole County, the Seminole formation contains 50 feet of chert conglomerate in the lower part, and the lower part is generally sandy and at many places, even in Tulsa County and farther north, it contains at or a few feet above the base, small angular noncalcareous fragments of chalky texture which are presumed to be weathered chert. Above the lower sandy zone, in Creek and Tulsa Counties, is a middle shaly zone which contains the Dawson coal. Local residents report that many years ago the Dawson coal was strip mined near the W¼ cor. sec. 3, T. 16 N., R. 12 E., a short distance east of the Tulsa-Creek County line, and that it is about 2 feet thick. In 1952 there was no indication of a pit in that vicinity. The upper zone of the Seminole in Creek County contains much sandy shale and nonresistant sandstone, but is, on the whole, much less sandy than the lower zone. Coal is exposed on the east side of the road near the gate to the cemetery south of Mounds; it is in the upper sandy zone and is not the Dawson coal.

Stratigraphic relations. In Creek County and northward, the Seminole formation rests unconformably upon the Holdenville (Memorial) shale, Lenapah limestone, and Nowata shale. The Seminole is conformable with younger rocks, and is overlain by the Checkerboard limestone from the Kansas-Oklahoma line southward to sec. 23, T. 11 N., R. 9 E., southwest of Okemah in Okfuskee County; by shale[1] from that locality south

[1] This shale is in the lower part of the Coffeyville formation in the area north of the North Canadian River and in the lower part of the Francis formation in the area south of the North Canadian River, the Coffeyville being equivalent to the lower part of the Francis.

to sec. 20, T. 7 N., R. 8 E., in Hughes County; and by the DeNay limestone from there southward.

Correlations. The Seminole formation of Creek County is continuous with the Seminole of the type locality. Lower beds of the Seminole are progressively overlapped by higher Seminole beds in the area between Tulsa County and the Kansas-Oklahoma line. Only the upper 20 feet or so of the Seminole extends into southern Kansas; it is mapped there as the Hepler sandstone and overlying shale, in the Pleasanton group (Oakes and Jewett, 1943).

CHECKERBOARD LIMESTONE

Nomenclators. The name "Checkerboard" seems to have crept into general usage without formal definition. Hutchison (1911) made reference to it by name. Carl D. Smith (1914) used the name in describing it. Fath and Emery (1917) mentioned it by name.

Type locality. Gould (1925) designated the exposures on Checkerboard Creek, in T. 15 N., R. 11 E., as the type locality of the Checkerboard limestone.

Original description. No description can be quoted as the original description. In 1925 Gould gave the following description:

> The Checkerboard limestone member of the Coffeyville formation lies near the base of the formation. It is 2½ to 3 feet thick, fine-grained and fossiliferous; bluish-white on fresh surfaces but becomes yellowish-white on weathered surfaces. In bare areas the limestone presents a "checkerboard" appearance, due to solution channels along the joints, which occur in two sets, the one crossing the other. From this characteristic feature the limestone was for years known as the "Checkerboard lime," but the geographic locality which is here designated as its type locality is the exposures on Checkerboard Creek in T. 15 N., R. 11 E. (Gould, 1925, p. 72).

History of usage. The earliest published reference to the bed now known as the Checkerboard limestone is by Gould, Ohern, and Hutchison (Gould and others, 1910). They showed its outcrop on a sketch map of a part of eastern Oklahoma extending as far south as the North Canadian River, in Okfuskee County, but erroneously called it the Lenapah limestone.

There is nothing else in the literature to indicate that the term "Checkerboard" has ever been used in any but its present sense. Moore and others (1937) included the sandy basal beds of the Coffeyville in the Seminole formation, restricted the term "Coffeyville" to apply only to the strata between the Checkerboard limestone and the Hogshooter (Dennis) formation, and raised the Checkerboard to formation rank.

Distribution. The outcrop of the Checkerboard limestone (IPcb) extends from sec. 23, T. 11 N., R. 9 E., in Okfuskee County, where it grades into shale, northward to the Kansas-Oklahoma line (Miser, 1954). It also extends many miles into Kansas (Oakes and Jewett, 1943). The Checkerboard crops out along the east side of Creek County, from the vicinity of Mounds northward.

Thickness and character. The Checkerboard limestone in Creek County is a single bed about 2½ feet thick. It is massive, dark blue, fossiliferous, and breaks into blocky to splintery fragments in weathering. It 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.

The Checkerboard limestone is conveniently exposed at the following places in Creek County, all in Range 12 East: SW cor. sec. 18, T. 16 N.; near the school house in Mounds; in the road south of the NE cor. sec. 19, T. 16 N.; at the SW cor. sec. 16 and in the road immediately south of the NE cor. sec. 16, T. 17 N.; along the course of the stream from the E¼ cor. sec. 9, to the NE cor. sec. 4, T. 17 N.; in the road in the SE NW sec. 28, T. 18 N.; around the hill in the NE¼ sec. 21, T. 18 N.; in the road ¼ mile south of the NW cor. sec. 16, T. 18 N.; in the east-west road near the center of sec. 8, T. 18 N., on the west side of the stream.

There are also two excellent exposures of the Checkerboard across the line in Tulsa County, one about ¼ mile east of the NW cor. sec. 3, T. 18 N., R. 12 E. and the other south of the west ¼ cor. sec. 10, T. 18 N., R. 12 E.

Stratigraphic relations. The Checkerboard limestone is underlain conformably by the Seminole formation and overlain conformably by the Coffeyville formation.

Correlation. The Checkerboard limestone of Oklahoma is the same as the Checkerboard limestone of Kansas where it lies in shale of the Pleasanton group, between the Hepler sandstone and the Knobtown sandstone (Jewett, 1954, p. 40, fig. 5). The work of Ries (1954) in Okfuskee County, Weaver (1954) in Hughes County, and Tanner (1956) in Seminole County, has shown that the Checkerboard and DeNay limestones are not continuous in outcrop, but that they lie between conspicuous sandstone units, a few tens of feet apart, that are continuous from the vicinity of the southernmost Checkerboard outcrop in Okfuskee County to the vicinity of the northernmost DeNay outcrops in Hughes and Seminole Counties. The Checkerboard and DeNay limestones, therefore, occupy nearly the same stratigraphic position.

Detailed section. For an outcrop section that includes the Checkerboard limestone see section numbered 53 in the Appendix.

COFFEYVILLE FORMATION

Nomenclators. Schrader and Haworth (1906).

Type locality. Vicinity of Coffeyville, Kansas.

Original description.

> The name Coffeyville formation, after the town of Coffeyville, is here adopted for the portion of the geologic section included between the base of the Drum and the top of the Parsons[1] (Schrader and Haworth, 1906).

History of usage. Coffeyville as a formation name has had a checkered history. Schrader and Haworth (1905) used the name in a table which indicated that it included the Cherryvale shale, Dennis limestone, Galesburg shale, Mounds Valley limestone, and the Ladore-Dudley shale, with a total thickness of 250 feet. A year later the same authors formally defined it in the original description quoted above. Actually, this did not change its upper and lower limits. Ohern (1910) used the name Curl formation

[1] The Parsons limestone included the Altamont limestone at the base and the Lenapah limestone at the top. The name was discarded by Moore (1953, p. 64).

for all strata lying above the Lenapah limestone and below the Hogshooter limestone. Inasmuch as he thought that the Hogshooter was equivalent to the lower part of the Drum limestone of Kansas, he apparently intended to make his Curl formation equivalent to the Coffeyville formation. However, we now know that the Hogshooter limestone is the direct continuation of the Winterset limestone of Kansas, Missouri, and Iowa, which is considerably lower than the Drum.

Gould, Ohern, and Hutchison (Gould and others, 1910) miscorrelated the Lenapah with the Checkerboard and thus erroneously extended the Lenapah as far south as the North Canadian River. Ohern (1918) corrected this mistake but at the same time made another by stating that the Dawson coal replaces the Lenapah south of Nowata. Gould (1925) stated: "due to its position above the Lenapah limestone and below the Hogshooter limestone the Coffeyville is equivalent to the Curl formation of Ohern (a later name)." However, by accepting Ohern's opinion that the Hogshooter was the lower part of the Drum, Gould actually excluded the Cherryvale shale and the Winterset limestone from the upper part of the Coffeyville formation, as defined by Schrader and Haworth (1906), although he did include them in his note on correlation. Miser (1926) placed the top of the Coffeyville formation at the base of the Hogshooter limestone and placed the base of the Coffeyville at the top of the Lenapah limestone from the Kansas-Oklahoma line to Lenapah, but from Lenapah to Tulsa he seems to have placed the base of the Coffeyville at the outcrop of the Dawson coal. Thus, for several years, the Coffeyville in Oklahoma included considerably less at both top and base than did the Coffeyville of Kansas.

By the time Miser (1954) completed the second Geologic Map of Oklahoma, the Seminole formation had been mapped from the Kansas-Oklahoma line to southern Okfuskee County, and Moore, Newell, Dott, and Borden (Moore and others, 1937) had restricted application of the term "Coffeyville" to strata between the Checkerboard limestone, below, and the Hogshooter formation, above. The name Coffeyville is not in current use in Kansas.

Distribution. The Coffeyville formation (lPcf) crops out from the North Canadian River, in Okfuskee County, to the Kansas-Oklahoma line in the vicinity of South Coffeyville, Nowata County. The outcrop crosses the east side of Creek County, but south of the middle of T. 16 N., R. 11 E. the lower part of the formation crops out in western Okmulgee County, owing to a jog in the Okmulgee-Creek County line.

Thickness. The Coffeyville formation increases irregularly in thickness southward across Creek County. It is about 400 feet thick in southern Tulsa County; 375 feet thick in the north part of T. 18 N., northern Creek County; 420 feet in the south part of T. 18 N.; 395 feet in the north part of T. 17 N.; 450 feet in the south part of T. 17 N.; and 500 feet thick in the north part of T. 16 N. Farther south the lower part of the Coffeyville formation crops out to the east, in Okmulgee County, where it was studied by Luff (1956) who stated that the Coffeyville formation is 450 to 500 feet thick, presumably in the south part of T. 16 N., R. 11 E. The Coffeyville formation has not been measured in Tps. 14 and 15 N.

Character. The Coffeyville formation consists mostly of silty shale with a minor amount of clay shale in the lower part, as in Washington and

Tulsa Counties (Oakes, 1940, 1952). However, it also contains lenticular sandstone and sandy shale. Generally, the shales are dark, sparingly fossiliferous, and weather yellow, buff, and various shades of brown and reddish brown. The sandstone is conspicuous out of all proportion to its abundance in relation to the shale, because it caps conspicuously high escarpments and occupies broad dip slopes. Most of the shale, on the contrary, crops out on steep hillsides of relatively small area.

The sandstones of the Coffeyville formation are composed of overlapping and interfingering lenses of sandstone and extremely sandy shale. It is doubtful that the top or base of any of them can be regarded as a stratigraphic surface. The sandstones and the shales are, therefore, here called units. See figure 2.

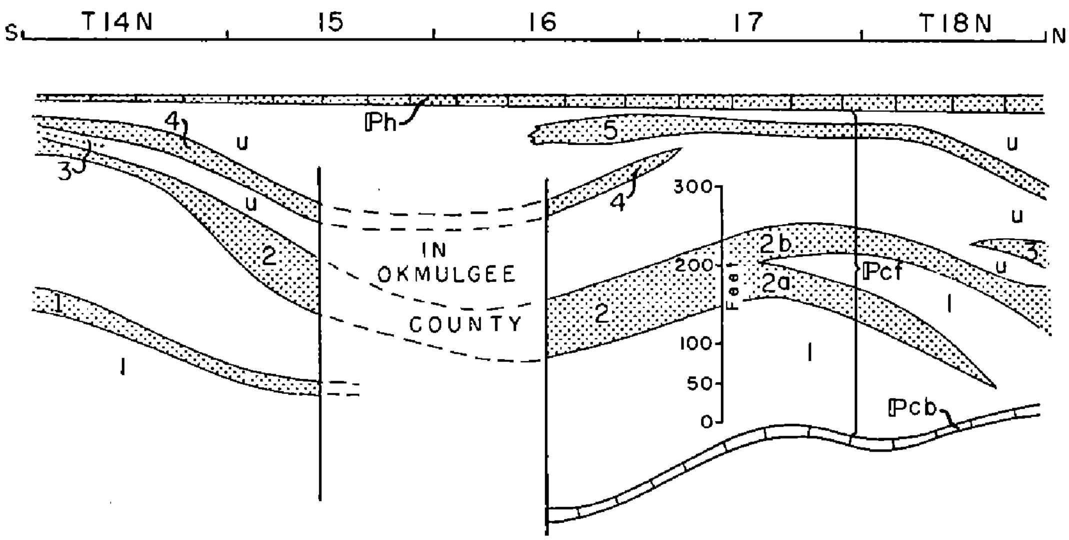

Figure 2. Shows the Coffeyville formation (IPcf), approximately to scale. The Coffeyville consists of the shale units (IPcf-lu) and the sandstone units (IPcf-1,2,3,4,5), and is conformable with the Checkerboard limestone (IPcb), below, and with the Hogshooter formation (IPh), above.

The lowest unit of the Coffeyville formation (IPcf-1) is mostly silty shale, but contains some clay shale and, at the base, a few feet of black fissile shale which contains phosphatic nodules. It is 125 feet thick at the Tulsa-Creek County line in T. 18 N., R. 12 E., but divides into lower and upper tongues about one mile south of that line. The upper tongue is about 100 feet thick in the north part of T. 18 N., but thins to less than 10 feet thick in the north part of T. 17 N. It could not be mapped farther south. The lower tongue is about 25 feet thick where it splits off in the north part of T. 18 N., R. 12 E., but increases in thickness southward to about 200 feet in the north part of T. 16 N. It is probably thicker farther south in Okmulgee County. The upper part of the lower tongue crops out in the east part of T. 14 N., R. 10 E., Creek County, and contains the sandstone unit (IPcf-1), 10 to 20 feet thick and about 200 feet below the top.

The sandstone unit (IPcf-2) is made up of sandstone ledges, commonly 5 to 20 feet thick, interbedded with nonresistant sandstone and even with extremely sandy shale. On the geologic map (Plate I) the base of each resistant sandstone ledge in the unit is represented by a single black line; the entire outcrop of the unit, including the sandy shale, is represented by stippling. The unit is only 15 feet thick in T. 14 N., but about 100 feet thick in T. 16 N. It divides into two tongues (IPcf-2a) and (IPcf-2b) in the north part of T. 17 N., where each is about 45 feet thick. The lower tongue (IPcf-2a) pinches out in sec. 9, T. 18 N., R. 12 E., but the upper tongue (IPcf-2b) extends across T. 18 N. into Tulsa County and seems to grade into shale within a mile.

The upper shale unit of the Coffeyville formation (IPcf-u) extends from the top of sandstone unit (IPcf-2) to the top of the formation, which is the base of the Hogshooter formation, and contains three sandstone units (IPcf-3,4,5), none continuous across the County. It is sandy shale and the upper tongue, above the sandstone unit (IPcf-5), is 80 feet thick at the north line of the County, but thins southward to 35 feet in the vicinity of Sapulpa, a decrease of about 45 feet in a distance of about 5 miles. It is locally calcareous and fossiliferous, and in northernmost Creek County contains a coal seam a few inches thick and generally less than one foot below the Hogshooter limestone.

Two sandstone outcrops are designated (IPcf-3). One is in the north part of the county and the other is in the south part. Each is 10 to 20 feet thick. They are not precisely equivalent.

The sandstone unit (IPcf-4) is about 10 feet thick in Tps. 14 and 15 N., and 30 feet thick in the north part of T. 16 N., but grades into shale in the south part of T. 17 N. Its base is 40 feet above the top of the sandstone unit (IPcf-2) in T. 14 N., but 120 feet above in T. 17 N.

The sandstone unit (IPcf-5) is 10 to 30 feet thick. It crops out from the north line of the County, north line of T. 18 N., to the Okmulgee-Creek County line, the median line of T. 16 N., R. 11 E. It probably pinches out in western Okmulgee County, for it is not found where it should be expected to reenter Creek County, in the north part of T. 15 N., R. 10 E. Its base is from 30 to 55 feet above the top of sandstone unit (IPcf-4) in the north part of T. 16 N. and the south part of T. 17 N. Sandstone at approximately the stratigraphic position of (IPcf-5), in the upper part of the Coffeyville formation, is persistent from the Kansas-Oklahoma line into Creek County. It represents the Dodds Creek sandstone of Kansas and the Layton oil sand of northern Oklahoma.

Stratigraphic relations. The Coffeyville formation is underlain conformably by the Checkerboard limestone and overlain conformably by the Hogshooter formation.

Correlations. The Coffeyville formation is equivalent to the lower part of the Francis formation in the area between the North Canadian River and the Arbuckle Mountains. It is equivalent to strata in Kansas between the Checkerboard limestone, below, and the Dennis (Hogshooter) formation, above.

Detailed sections. For measured outcrop sections of the Coffeyville formation see sections numbered 52, 53, Appendix.

HOGSHOOTER FORMATION

Nomenclator. Ohern (Gould and others, 1910, p. 12).

Type locality. Along Hogshooter Creek, in T. 26 N., R. 14 E., eastern Washington County.

Original description.

> This name is proposed for the limestone which lies immediately above the Curl formation in the Nowata quadrangle. The name is from Hogshooter Creek along whose west bank the limestone is well exposed (Ohern, 1910, p. 28).

History of usage. Ohern (1910) thought that the Hogshooter limestone was equivalent to the lower part of the Drum limestone of Kansas, but his Hogshooter has since been traced into the Winterset limestone member of the Dennis formation of Kansas. Ohern was probably following the opinion of Adams (Adams, Girty, and White, 1903) who, because of a mistake in tracing, mapped the Winterset limestone member of the Hogshooter formation as the Drum limestone from the Kansas-Oklahoma line to the southeast corner of T. 26 N., R. 13 E.

The Dennis formation of southern Kansas contains, in descending order, the Winterset limestone member, the Stark shale member, and the Canville limestone member. The Winterset member is continuous, but the Stark shale and Canville limestone members are lenticular and are not present everywhere along the Dennis outcrop. The outcrop of the Dennis formation has been traced into northern Oklahoma, where the same relations persist. In the vicinity of Sand Springs, western Tulsa County, a limestone about 50 feet thick acquired the colloquial name "Lost City limestone," and Gould (1925) correlated it with the Hogshooter limestone of Ohern. Oakes (1940) found that the Lost City does, indeed, include the Winterset, or Hogshooter limestone of Ohern, in its upper few feet.

The Winterset (Hogshooter of Ohern) is so closely associated with the Stark shale and Canville limestone in northern Oklahoma, and with the Lost City limestone in the Sand Springs area that it seemed desirable to include them all in one formation which would have the convenient advantage of being closely equivalent to the Dennis formation of Kansas. However, the name "Hogshooter" was the oldest name associated with these rocks in Oklahoma and was so firmly entrenched in literature and usage that it was chosen instead of the name "Dennis."

According to present usage the Hogshooter formation contains, in descending order, the Winterset limestone member, the Stark shale member, and the Canville limestone member, in northern Oklahoma, and the Winterset limestone member and the Lost City limestone member, in western Tulsa County. It is not practical to subdivide the Hogshooter formation into members in Creek County.

Distribution. The Hogshooter formation (IPh) crops out from a point about 3 miles north of Okemah, Okfuskee County, northward to the Kansas-Oklahoma line, about one mile west of South Coffeyville, Nowata County. The outcrop crosses eastern Creek County through Sapulpa.

Thickness and character. In the vicinity of Sand Springs, in western Tulsa County, 4 miles north of Creek County, the Hogshooter formation consists of gray crystalline fossiliferous limestone 40 to 50 feet thick and of exceptional purity; yet at the north line of Creek County limestone assignable to the Hogshooter is probably not more than 15 feet thick and is sandy. The greater part of the pure limestone of the Sand Springs area seems to grade southward into sandstone and sandy, silty shale with a maximum thickness of 250 feet in Creek County; but these possible Hogshooter equivalents grade upward into younger rocks and their upper limit is indeterminable. They are, therefore, mapped as the lower part of the Nellie Bly formation, which is next above the Hogshooter formation. The sandy limestone assignable to the lower part of the Hogshooter formation is only one to 3 feet thick at the Turner Turnpike in the north part of Sapulpa. Farther south, sandy calcareous fossiliferous rock one to 5 feet thick, is exposed from place to place in shale between sandstone in the upper part of the Coffeyville formation and the sandstone mapped as the lower part of the Nellie Bly formation. This rock is mapped as the Hogshooter formation, following a precedent set by earlier geologists, mostly petroleum geologists, who supplied maps used in compiling the Geologic Map of Oklahoma (Miser, 1926, 1954).

Exposures of rock mapped as Hogshooter formation in Creek County may be seen at the following places:

T. 18 N., R. 11 E.

In the road along the north side of secs. 2 and 3.
In and north of the road immediately east of the S¼ cor. sec. 2.
In the road at the S¼ cor. sec. 14.
At the top of the cut on Turner Turnpike beneath the overpass in sec. 26, in Sapulpa.
In the railroad cut at the center of sec. 33.

T. 17 N., R. 11 E.

In the SW SE SE sec. 9.
At the top of the hill ¼ mile west of the E¼ cor. sec. 16.
In the top of the spur of the hill ¼ mile west of the SE cor. sec. 16.
Near the center of the SE NE sec. 32.
In the road west of the SE cor. sec. 31.

T. 16 N., R. 11 E.

One-fourth mile west of the E¼ cor. sec. 6.

T. 15 N., R. 10 E.

One-eighth mile south of the NW cor. sec. 27.

T. 14 N., R. 10 E.

In the bed of Frank Henry Creek, about 60 feet east of the bridge on the west line of sec. 4.

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

Correlation. The Hogshooter formation is equivalent to the Dennis formation of Kansas. It grades into shale about 3 miles north of Okemah, Okfuskee County. In the area south of the North Canadian River and north of the Arbuckle Mountains, shale at about the middle of the Francis formation is equivalent to the Hogshooter.

Detailed sections. No detailed sections of the Hogshooter formation were measured in Creek County. See discussion of thickness and character above.

NELLIE BLY FORMATION

Nomenclator. Ohern,[1] 1914.

[1] D. W. Ohern in an unpublished manuscript, Geology of the Nowata and Vinita quadrangles: U. S. Geol. Survey, 1914.

Type locality. On Nellie Bly Creek, in secs. 31, 32, 29 and 28, T. 24 N., R. 13 E., Washington County, Oklahoma.

Original description.

> "Alternating shales and hard gray sandstones, the latter ranging in thickness from a few inches to several feet" from 15 feet on the Kansas line to 200 feet in southeastern Osage County. . . . Rests on the Hogshooter limestone and is overlain by the Dewey limestone (Gould, 1925, p. 74).[2]

[2] Quoted and paraphrased by Gould from Ohern's unpublished manuscript.

History of usage. The name has always been used in its present sense.

Distribution. The Nellie Bly formation (IPnb) crops out from the Kansas-Oklahoma line to the North Canadian River, southwest of Okemah, Okfuskee County. Tuskegee, Newby, Slick, and Kellyville are on the outcrop in eastern Creek County.

Thickness. The Nellie Bly formation is 250 feet thick in the south part of T. 19 N., R. 11 E., western Tulsa County. In Creek County, it is 220 feet thick in the north part of T. 18 N. and 440 feet in the south part; 550 feet in the north part of T. 17 N. and 425 in the south part; 395 feet in the north part of T. 16 N.; 380 feet in the north part of T. 15 N. and 420 in the south part; and 385 feet thick in the north part of T. 14 N.

The rapid increase in thickness of the Nellie Bly from the north line of Creek County to the area southwest of Sapulpa is owing, at least in part, to including shale and sandstone, not present farther north, which may be equivalent in age to the upper part of the Hogshooter formation in Tulsa County.

Character. The Nellie Bly formation consists mostly of sandstones and silty shales. Both are locally fossiliferous, but the fossils are generally poorly preserved. In addition, there is a minor amount of sandy limestone, in beds which range in thickness from a few inches to a few feet and are of local occurrence. The shales form three map units, lower (IPnb-l), middle (IPnb-m), and upper (IPnb-u). The three units are separated by and interfinger and intergrade with the sandstone units (IPnb-2) and (IPnb-4). The lower contains the sandstone unit (IPnb-1), the middle contains the sandstones designated (IPnb-3), and the upper contains the sandstones designated (IPnb-5) and the mapped limestone (IPnb-ls). See figure 3.

The lower shale unit (IPnb-l) is silty. It is not present at the north line of Creek County, but is 10 feet thick less than one mile south and 30 feet thick 3 miles south. It divides into lower and upper tongues 10 feet thick and 50 feet thick, respectively. The upper tongue seems to pinch out along with part of the overlying nonresistant sandstone unit (IPnb-2b) at the middle of T. 17 N. The lower tongue extends to the south side of the County. It increases in thickness from 10 feet in the south part of T. 18 N. to 125 feet in the north part of T. 14 N., where it contains, 20 feet above the base, the sandstone unit (IPnb-1) which is 20 feet thick.

The sandstone unit (IPnb-2) is composed of resistant and nonresistant sandstone and extremely sandy shale. In some localities, the three sorts of rock intergrade and interfinger in a manner which defies description. Resistant sandstone ledges cap escarpments above the less resistant rocks which crop out mostly on steep slopes thickly covered by debris and generally heavily wooded. There are few exposures of these less resistant rocks and little is known about their character in detail. On the geologic map (Plate I) bases of resistant ledges are indicated by black lines and the outcrop of the unit as a whole is indicated by stippling. The unit is from 60 to 125 feet thick across Tps. 14, 15, and 16 N., and much thicker in T. 17 N. It divides into lower, middle, and upper tongues (IPnb-2a), (IPnb-2b), and (IPnb-2c), approximately 10, 115, and 30 feet thick, respectively. The middle and lower tongues are separated by a shale tongue about 20 feet thick, and the middle and upper tongues are separated by a shale tongue about 10 feet thick. The lower and upper tongues pinch out in the south part of T. 18 N. and the middle tongue thins northward to about 10 feet thick immediately south of the Tulsa-Creek County line, where it rests upon sandy limestone of the Hogshooter formation. It seems to grade into the Hogshooter farther north, in Tulsa County.

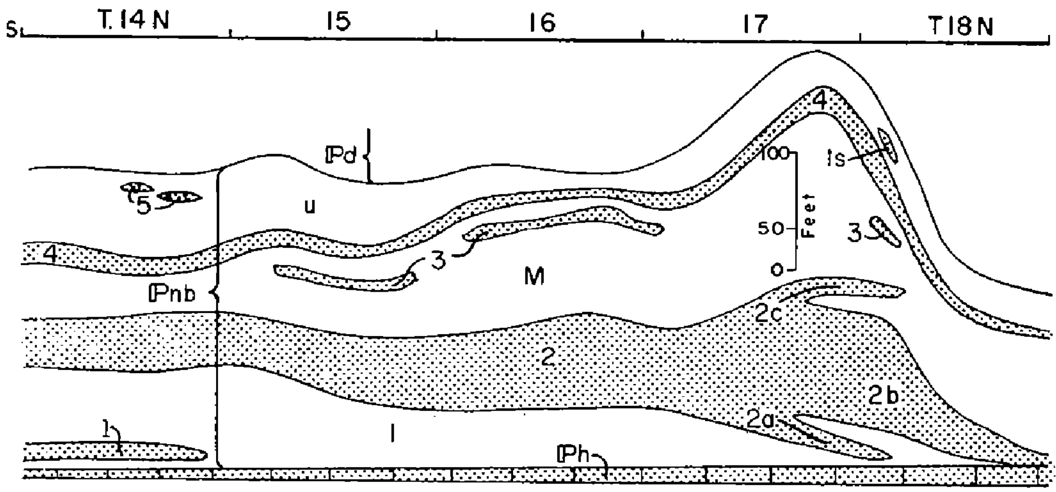

FIGURE 3. Shows the Nellie Bly formation, approximately to scale. The Nellie Bly consists of the shale units (lPnb-lu), the sandstone units (lPnb-1,2,3,4,5), and the sandy limestone (lPnb-ls). It is conformable with the Hogshooter formation (lPh), below, and with the Dewey formation (lPd), above.

The middle shale unit of the Nellie Bly formation (IPnb-m) is mostly silty to sandy shale with a minor amount of fine-grained sandstone. It is 150 feet thick in the north part of T. 18 N., and 115 feet thick in the south part. It contains three sandstone lenses from 15 to 50 feet below the top of the unit. They are not the same, but each is designated (IPnb-3), and is about 10 feet thick.

One-half mile north of the south line of T. 18 N., the unit divides into lower and upper tongues about 30 and 100 feet thick, respectively, separated by the sandstone tongue (IPnb-2c), which has a maximum thickness of about 30 feet. The lower and thinner tongue extends about 3 miles south, to the middle of T. 17 N., where it grades into the sandstone unit (IPnb-2). The upper and much thicker tongue extends to the south side of Creek County. In T. 17 N., it is 210 feet thick in the north part and 15 feet thick in the south part. It is 100 feet thick in T. 15 N., and 40 to 60 feet in T. 14 N.

The unit (IPnb-4) is essentially sandstone. It crops out entirely across Creek County and at many places caps a high escarpment. Like other sandstones of the Nellie Bly, it contains considerable silty, sandy shale and its upper limit, in particular, is hard to pick, which probably accounts for much of the considerable variation in thickness, as here reported. The unit is at least 20 feet thick in T. 14 N.; about 10 feet thick in Tps. 15 and 16 N.; 30 to 40 feet thick in T. 17 N.; and 10 to 45 feet thick in T. 18 N. Silty, sandy limestone lenses one to 10 feet thick are conspicuous in some exposures north of the middle of T. 16 N. One such bed is well exposed where it has been quarried for road metal 60 feet above the road, on the north side of U. S. Highway 66, near the E¼ cor. sec. 28, T. 17 N., R. 10 E. In this quarry, it is weathered in spots, especially along joint cracks, and the weathered material is soft and friable. However, boundaries between weathered and unweathered parts are sharp, and the unweathered parts are hard, strong, and durable as limestone.

This unit (IPnb-4) probably corresponds to strata commonly identified as Dewey limestone in records of wells drilled for oil and gas farther west.

The upper shale unit of the Nellie Bly formation (IPnb-u) is mostly shale, but includes a few sandstone lenses and several sandy limestone beds, the last generally from one inch to 2 feet thick. Outcrops of sandstone and limestone are too local to be shown on the geologic map (Plate I). Exceptions are the two outcrops of calcareous sandstone (IPnb-5) in T. 14 N., and the sandy limestone outcrop (IPnb-ls), 3 to 5 feet thick, in T. 18 N. The unit varies in thickness approximately as follows: 110 feet in T. 14 N.; 100 feet in the south part of T. 15 N.; 80 feet in the north part of T. 15 N.; 40 feet in Tps. 16 and 17 N.; and 50 feet in T. 18 N.

Stratigraphic relations. The Nellie Bly formation is conformable with the Hogshooter formation, below, and with the Dewey formation, above.

Correlations. The Nellie Bly formation is stratigraphically equivalent to that part of the Kansas section between the top of the Dennis formation, below, and the base of the Drum limestone, above. This interval is occupied by the Cherryvale shale in southern Kansas. The Nellie Bly is represented in the area between the North Canadian River and the Arbuckle Mountains by approximately the upper half of the Francis formation.

Detailed sections. For outcrop sections of parts of the Nellie Bly formation see sections numbered 16, 21, 32, 33, 34, 49, 51, Appendix.

DEWEY FORMATION

Nomenclator. Ohern (1910).

Type locality. The old quarry of the Dewey Portland Cement Company, sec. 26, T. 27 N., R. 13 E.

Original description.

> The most striking feature of the Copan beds is a lentil of limestone which is continuous and prominent from a point 2 miles east of Wann, south and west to and beyond the limits of the Nowata quadrangle. The name is from the town of Dewey where the limestone is admirably exposed in the quarry of the cement plant. . . .

> The Dewey lens is a bluish, semi-crystalline limestone, usually somewhat shaly but often massively bedded. On weathering it gives surface fragments which abound in seams of calcite which resist solution more effectually than the non-crystalline mass. Wherever examined the Dewey abounds in fossils, *Campophylum torquium* being especially abundant. (Ohern, 1910, p. 30).

History of usage.

> In studying the oil and gas fields of the Indian Territory, the Drum limestone was traversed by Adams from the outcrop west of Coffeyville to Bartlesville. It occurs on the divide between the Verdigris and Caney, extending southward to Hogshooter Creek, and thence northwestward to Bartlesville (Adams, Girty, and White, 1903).

It is evident from text and map that Adams was following the Hogshooter limestone from the Kansas-Oklahoma line to the southeast corner of T. 26 N., R. 13 E., where he stepped up to the Dewey limestone and followed it to Bartlesville.

Ohern (1910) used the term "Dewey limestone" for a prominent limestone which crops out across the Nowata quadrangle. Sandstone and limestone conglomerate were erroneously shown on the Geologic Map of Oklahoma (Miser, 1926) as Dewey limestone from sec. 13, T. 28 N., R. 14 E., northeastward to the Kansas-Oklahoma line, across an area in which the Dewey was removed by pre-Chanute erosion. Oakes (1940) used the term Dewey limestone in the sense of Ohern. However, Oakes (1952) found that across southeastern Osage County and western Tulsa County stratigraphic equivalents of the Dewey limestone are progressively more sandy and shaly southward, and, in the interest of simple nomenclature, called them the Dewey formation. The term Dewey formation is here applied to sandstone and shale in Creek County which are stratigraphically equivalent to the Dewey limestone.

Distribution. Outcrops of the Dewey formation (IPd) extend from the center of sec. 13, T. 28 N., R. 14 E., Nowata County, southwestward across Washington County, southeastern Osage County, western Tulsa County, central Creek County, and Okfuskee County to the North Canadian River, about midway between Boley and Castle.

Thickness. In Creek County, the Dewey formation is generally from 20 to 50 feet thick.

Character. The Dewey formation was originally called the Dewey limestone and that term adequately indicates its character in Nowata and Washington Counties. However, at most places, it is somewhat shaly and at some places it is sandy. Farther south it is progressively more shaly and sandy. Across much of southeastern Osage County and across western Tulsa County, it consists of relatively thin upper and lower limestone members and a much thicker middle shale member. For that reason Oakes (1952) and Miser (1954) called it the Dewey formation. See figure 4.

One mile north of the Tulsa-Creek County line, the lower limestone member is 14 feet thick and consists of three sandy limestone beds separated by sandy shale. The shale member is 27 feet thick and is sandy in the upper part. The upper limestone member is about 10 feet thick and consists of calcareous sandstone about 3 feet thick, sandy limestone 2 feet thick, and calcareous shale containing limestone nodules about 5 feet thick. The calcareous nodular shale is overlain by sandstone in the lower part of the Chanute formation. Within a mile southward, the upper limestone member of the Dewey grades into shale and the lower limestone member grades into sandstone. This sandstone and its overlying shale constitute the Dewey formation of Creek County. The sandstone is 5 to 20 feet thick, and is locally calcareous and fossiliferous, at least as far south as the south part of T. 16 N. The shale is 5 to 30 feet thick, locally calcareous, sparingly fossiliferous, and contains sparse limestone lenses generally less than one foot thick.

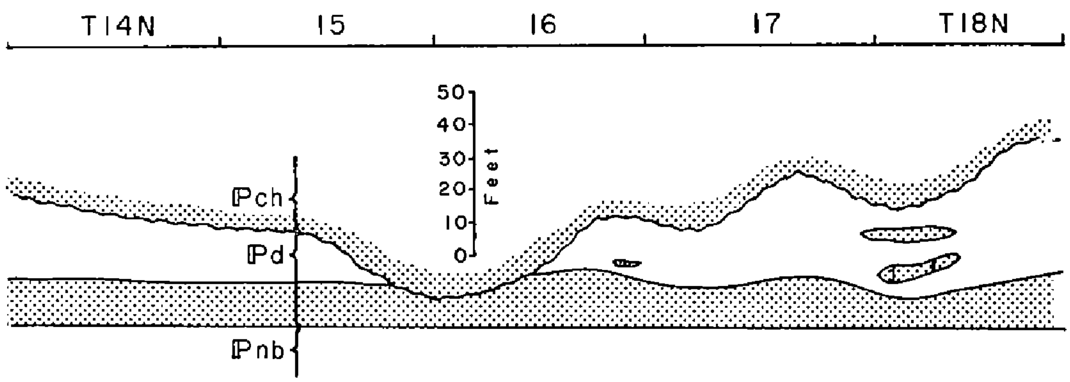

FIGURE 4. Shows the Dewey formation (lPd), approximately to scale. Overlain unconformably by sandstone in the lower part of the Chanute formation (lPch), and underlain conformably by shale in the upper part of the Nellie Bly formation (lPnb). The Dewey is a limestone formation in Washington and Nowata Counties, northern Oklahoma, but grades southward into sandstone and shale in Creek County, where limestone is sparse and sandy. It is mapped as a single unit on Plate I.

Stratigraphic relations. The Dewey formation is conformable with the Nellie Bly formation, below, but, at least in some localities in southern Kansas and northern Oklahoma, it is unconformable with the Chanute formation, above. The unconformity is marked, in some areas, by absence of the Dewey and some older strata and by coarse sandstone and conglomerate at the base of the next younger Chanute formation. There is little evidence of the unconformity in Creek County, excepting the varying thickness of the shale which forms the upper part of the Dewey formation. Indeed, in the vicinity of the southeast corner of T. 16 N., R. 9 E., sandstone is continuous from the base of the Dewey to the top of sandstone in the lower part of the Chanute formation.

Correlations. The Dewey formation is probably equivalent to the Cement City member of the Drum limestone of Kansas, and is probably represented by some part of the Hilltop formation south of the North Canadian River.

Detailed sections. For measured outcrop sections in the Dewey formation see sections numbered 5, 20, 21, 48, 50, 51, Appendix.

Ochelata Group

The name "Ochelata" was first used by Ohern (1910, p. 83) for the middle member of his Ramona formation. It applied to the beds between the Dewey and Avant limestones. In his unpublished manuscript of 1914 Ohern raised "Ochelata" to formation rank and applied the name to beds between the top of the Dewey and the base of his Nelagoney formation. According to Gould (1925, p. 75) the base of the Bigheart sandstone was the base of the Nelagoney; the base of the Bigheart is the base of the Tallant formation of present usage. Miser (1926) drew the upper limit of the Ochelata at the approximate base of the Tallant formation. The upper limit of the Ochelata came to be regarded as coinciding with the base of the Virgil series, in northern Oklahoma, and Moore and others (1937, p. 39-43) raised the term to group rank, defining its lower boundary as the base of the Chanute formation and its upper boundary to coincide with the Missouri-Virgil unconformity. This definition still stands, but Oakes (1952) drew the top of the Ochelata group and the base of the Virgil series at the base of the Vamoosa formation, including the Tallant formation in the Ochelata group. Miser (1954) did the same.

In short, the Ochelata group now extends from the base of the Chanute formation, below, to the base of the Virgil series, above.

TABLE 2

SUBDIVISIONS OF THE OCHELATA GROUP IN CREEK COUNTY, OKLAHOMA

- Virgil series
- *Unconformity*
- Missouri series
  - Ochelata group
    - Tallant formation
    - Barnsdall formation
      - Unnamed shale member
      - Okesa sandstone member
    - *Unconformity*
    - Wann formation
    - Iola formation
    - Chanute formation
  - *Unconformity*
  - Skiatook group

CHANUTE FORMATION

Nomenclator. Haworth and Kirk (1894).
Original description.

Above the Erie (Winterset) limestone there is another system of shales and sandstones which in places reach a thickness of nearly 150 feet, but which along the Neosho River section possibly does not exceed 100 feet. It reaches its maximum thickness in the vicinity of Thayer, where it is estimated to be 150 feet thick. It extends from below Osage Mission to above Chanute, which town may well give it a name, so that it may be called the Chanute shales. Here, as elsewhere, sandstone appears and dis-

> appears with great readiness. Around Thayer the sandstone occurs in heavy beds, some of which produce excellent building material.
>
> Below the sandstone at Thayer a seam of coal is found of sufficient thickness and quality to justify its being worked extensively enough to furnish fuel to Thayer and surrounding country.
>
> Above the Chanute shales lies a heavy system of limestone in which the Iola quarries are situated, the so-called Iola marble (Haworth and Kirk, 1894).
>
> *History of usage.*
>
> Early usage of the term Chanute shale is somewhat confused because of miscorrelations of the limestones below and above. It is clear, however, that it was intended to designate by this name the shale and thin sandstone beds that form the plain extending eastward from Chanute to the prominent escarpment made by the Bronson limestones. The Iola limestone is well exposed in the vicinity of Chanute and it can be traced without difficulty to Iola, about 20 miles to the north. The term Thayer shale is a subsequently introduced name for a synonymous unit. In 1908 Haworth and Bennett restricted application of Chanute shale to include only the upper part of the original Chanute, that is to the beds between the top of the Drum (Dewey) limestone and the base of the Iola limestone. . . . application of Chanute in the restricted sense has come to be accepted generally (Moore, 1935, p. 109).

Newell (1935) restricted application of the synonymous term "Thayer" to the persistent coal bed mined near Thayer, Kansas. The Thayer coal lies at the base of the prominent upper sandstone of the Chanute, which Newell named the Cottage Grove sandstone member.

The rocks assigned to the Chanute formation, in Oklahoma, were included by Ohern (1910) in the lower part of the Ochelata member of his Ramona formation (southern area) and in the lower part of the unnamed interval between the Dewey and Avant limestone lentils of the Copan member of his Wann formation (northern area). According to the classification used on the Geologic Map of Oklahoma (Miser, 1926), these beds lie at the base of the Ochelata formation (Ochelata group), occupying the lower part of the interval between the Dewey and Avant limestones, but on the Geologic Map of Oklahoma (Miser, 1954), they are shown as Chanute formation, lying between the Dewey formation, below, and the Iola limestone (Iola formation), above.

Distribution. The Chanute formation (IPch) crops out across Oklahoma in a direction slightly west of south from the Kansas-Oklahoma line across northwestern Nowata County, Washington County, southeastern Osage County, central Creek County, and Okfuskee County to the North Canadian River. The name is not applied farther south.

Thickness. The Chanute formation in Creek County has a total thickness of 80 feet in T. 14 N.; about 90 feet in T. 15 N.; 110 feet in T. 16 N.; 60 feet in T. 17 N.; 70 feet in the south part of T. 18 N., and 45 feet in the north part.

Character. One to 2 miles north of the Creek County line the Chanute formation consists mostly of silty to sandy shale but contains sandstone beds at or near the base and sandstone beds near the top, closely associated with the overlying sandy Paola limestone member of the Iola formation.

The sandstone beds in the lower part are continuous into and across Creek County and are shown on the geologic map (Plate I) as the sandstone (IPch-1). This sandstone at the base of the Chanute formation is from 10 to 20 feet thick, medium to fine grained, massive to thin bedded, and gray; it weathers brown. See figure 5.

The shale (IPch-2) constitutes the greater part of the Chanute formation in Creek County. It is from 30 to 100 feet thick, generally silty to sandy, and dark gray; it weathers drab to yellow. Sandstone beds in the upper part of this shale just north of the Tulsa-Creek County line extend into and possibly across Creek County, but they do not crop out well and at most places they cannot be mapped or even differentiated from similar, higher sandstone beds that almost certainly represent the Paola limestone member of the Iola formation. The upper boundary of the Chanute is indefinite and gradational.

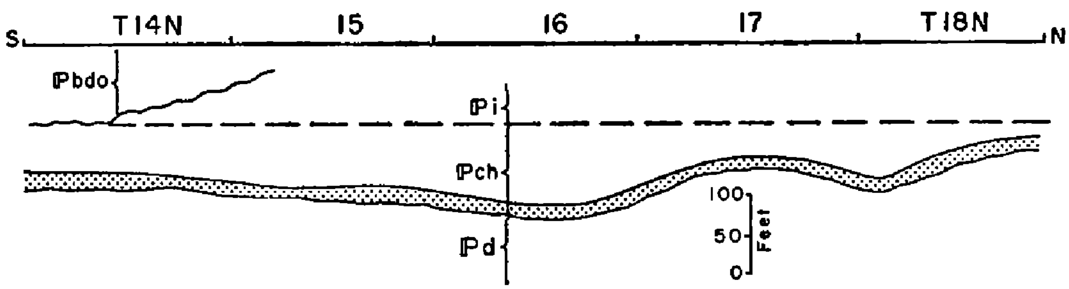

FIGURE 5. Shows the Chanute formation (lPch), approximately to scale. The lower part (lPch-1) is sandstone which seems to rest with a slight unconformity on the Dewey formation (lPd). The upper and greater part (lPch-2) is sandy shale. The Chanute is overlain conformably by the Iola formation (lPi) except in the south part of T. 14 N., where it is probably overlain unconformably by the Okesa sandstone member of the Barnsdall formation. The upper boundary is generally indefinite and gradational.

Stratigraphic relations. The Dewey formation and part or all of the underlying Nellie Bly formation was removed by pre-Chanute erosion in northwestern Nowata County, and the Chanute rests unconformably on the eroded surface. The evidence is not so clear farther south, but the Chanute is probably unconformable on the Dewey, at least from place to place, as far south as western Tulsa County. There is little evidence of the unconformity in Creek County other than the varying thickness of the shale in the upper part of the underlying Dewey formation. In the vicinity of the southeast corner of T. 16 N., R. 9 E., sandstone is continuous from the base of the Dewey to the top of the basal sandstone of the Chanute formation, but even in that locality no exposure was found which contained a clear-cut unconformity. However, it is the rule, rather than the exception, that widespread unconformities in the Pennsylvanian rocks of northeastern

Oklahoma and Kansas are obscure except in certain localities; an unconformity is indicated at the base of the Chanute in the explanation on the geologic map (Plate I) and in the compiled sections (Plate II).

The Chanute formation is overlain conformably by the Iola formation as far south as Little Deep Fork Creek, but the boundary is indefinite and, in part, gradational. South of Little Deep Fork Creek the Iola may very well be present only from place to place, as the result of pre-Barnsdall erosion; it was not identified farther south than the south side of sec. 20, T. 14 N., R. 9 E. Wherever the Iola may be missing in this area the Chanute is thought to be overlain unconformably by the Okesa sandstone member of the Barnsdall formation.

Correlation. The Chanute formation of Oklahoma is continuous with the Chanute shale of Kansas. The name is not applied south of the North Canadian River, but the formation may be represented there by some part of the Hilltop formation.

Detailed sections. For measured outcrop sections of the Chanute formation see sections numbered 5, 20, 51, Appendix.

IOLA FORMATION

Nomenclators. Haworth and Kirk (1894).

Type locality. Vicinity of the town of Iola, Kansas.

Original description.

> Above the Chanute shales lies the heavy system of limestone in which the Iola quarries are situated, the so-called Iola marble. For this reason it may be called the Iola limestone. . . . At Iola it is 30 or 40 feet thick. . . . The character of the rock is remarkable, particularly regarding the unusually thick layers it produces, in this respect surpassing anything else known in the state. On this account rock of any dimensions can be obtained from it, as is practically demonstrated at the Iola quarries (Haworth and Kirk, 1894).

History of usage. Various limestone beds in Kansas have been erroneously correlated with the Iola limestone of the type locality (Moore, 1937), but these misuses of the name are of little interest in Oklahoma. Newell found that the Iola limestone of the type locality is composed of a thicker upper limestone member separated from a lower limestone member 1.5 to 5 feet thick by a few inches of shale containing phosphatic nodules, and that this three fold division is widespread in Kansas. Newell also found that the upper member is equivalent to the Raytown limestone of Missouri and applied that name in Kansas. He named the lower and middle members, respectively, the Paola limestone, from a town in Miami County, Kansas, and Muncie Creek shale, from Muncie Creek in Wyandotte County, Kansas. Newell recognized the Iola formation as far south as the Kansas-Oklahoma line (Newell, 1935, Jewett and Newell, 1935).

Oakes (1940a, 1950b, 1954) has been able to distinguish all three members of the Iola formation as far south as western Tulsa County, Oklahoma. The terms "Iola formation," "Paola limestone member," and "Muncie Creek shale member" are acceptable for use in northern Oklahoma, but the term "Avant limestone member" is used instead of Raytown limestone member, on the basis of priority and equal or greater use. The name "Avant" is well entrenched in Oklahoma usage.

In Creek County, neither the upper nor the lower limit of the formation can be discerned well enough to be mapped, but sandy limestone, calcareous sandstone, and shale which represent the Iola formation can be recognized from the north line almost to the south line.

Distribution. The Iola formation (IPi) extends northward from its type locality, in the vicinity of Iola, Kansas, to south-central Iowa and is present in the Platte Valley in Nebraska (Moore, 1949, p. 102-104). It extends southward into northwestern Nowata County, Oklahoma, and follows a southwesterly course across Washington County, southeastern Osage County, and western Tulsa County.

Sandy limestone, calcareous sandstone, and shale outcrops which represent the Iola have been found from the north line of Creek County to the south line of sec. 20, T. 14 N., R. 9 E. Representatives of the Iola have not been recognized farther south in Oklahoma, and the writer thinks that the Iola was removed there by post-Wann, pre-Barnsdall erosion.

Thickness. Rocks in Creek County here assigned to the Iola formation are from 15 to 50 feet thick, but the total thickness of Iola equivalents is not known.

Character. In its type locality, near Iola, Kansas, the Iola formation contains three members which are, in ascending order, the Paola limestone member, Muncie Creek shale member, and Raytown limestone member. The Iola formation has been traced from its type locality to the Kansas-Oklahoma line by geologists of the State Geological Survey of Kansas, and across northern Oklahoma to the north line of Creek County by the writer.

The Paola limestone member ranges in character from a single layer of brittle dense, dark bluish-gray limestone 1.5 to 2 feet thick, in the vicinity of Iola, Kansas, to marly limestone or calcareous sandstone one to 5 feet thick in Nowata and Washington Counties, Oklahoma. Across southeastern Osage County and western Tulsa County, it ranges in character from a relatively pure limestone to a sandstone and in thickness from one to 5 feet.

The Muncie Creek shale is only a few inches thick in the vicinity of Iola, Kansas, and is generally one to 5 feet thick in other parts of Kansas. A band of phosphatic nodules is a constant characteristic of the outcrop in Kansas and as far south as the north line of Creek County, Oklahoma. The Muncie Creek shale is from one to 30 feet thick in Nowata and Washington Counties, Oklahoma, and one to 30 feet or more in southeastern Osage County and western Tulsa County.

The upper limestone member is called the Raytown in Kansas and the Avant in Oklahoma. In the vicinity of Iola, Kansas, where the Raytown has been extensively quarried, it is light gray and about 28 feet thick. It is thin or absent locally in southern Kansas, and the same is true of the Avant in most of Nowata and Washington Counties, Oklahoma. In contrast, the Avant is 55 feet thick at its type locality in the vicinity of Avant, southeastern Osage County. Only the upper part of this thick phase of the Avant extends across western Tulsa County. There are sandy limestone beds in sec. 4, T. 20 N., R. 10 E. that occupy the same stratigraphic position as the basal beds of the Avant at Avant, and they extend southward across western Tulsa County. The two sets of calcareous beds are called colloquially the upper and lower Avant limestones and are thought to mark the limits of the Avant member, which contains more shale than limestone at the south side of western Tulsa County.

A prominent high escarpment extends almost across Creek County, from the north line to the south side of sec. 20, T. 14 N., R. 9 E. In northern Creek County, it is capped by sandy limestone that represents the Avant limestone member of the Iola formation, but the upper limit of the Avant cannot be determined with sufficient certainty and continuity to be mapped. This limestone grades into the basal part of a thick massive sandstone, the Tiger Creek sandstone of Fath (1925), that caps the escarpment from there southward. The lower part of this sandstone contains, from place to place, rock that is very fine grained to silty, and is cemented by calcium carbonate, where fresh, or is lightweight and porous, where weathered. These rocks contain fossil fusulinids similar to those of the Avant in western Tulsa County, and they almost certainly represent the Avant limestone. The fossil fusulinids are most noticeable as molds and casts in the weathered parts of the silty sandstone, which grades upward into higher parts of the Tiger Creek sandstone of Fath in such a way that the upper limit of Iola equivalents cannot be mapped. See figure 6.

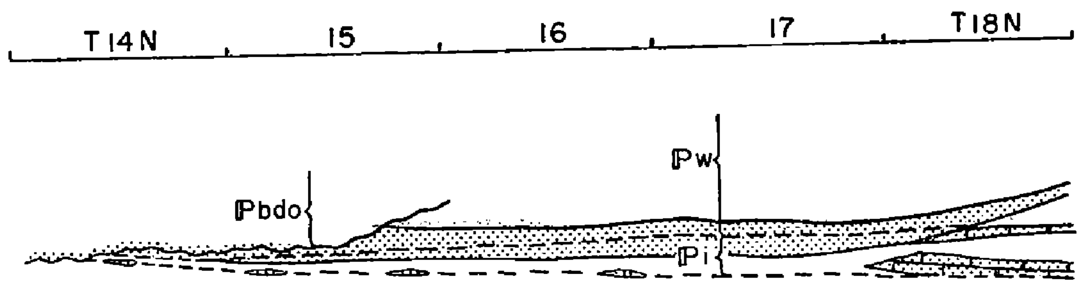

FIGURE 6. Shows the Iola formation (IPi), not to scale. The Iola consists of sandstone, shale, and limestone. It is overlain conformably by the Wann formation north of Little Deep Fork Creek, probably overlain unconformably by the Okesa sandstone member of the Barnsdall formation south of Little Deep Fork, and truncated by the Okesa in extreme southern Creek County. Underlain conformably by the Chanute formation. Both upper and lower boundaries indefinite and graduational in Creek County.

Shale in the steep eastward slope of the escarpment probably represents the Muncie Creek shale member of the Iola formation. Thin sandstone beds are discontinuously exposed at the foot of the eastward slope. Most of these, no doubt, represent similar sandstones which crop out in the upper part of the Chanute formation of western Tulsa County; but from place to place one or more of these thin beds, apparently the highest in the sequence, and rarely more than 5 feet thick altogether, are extremely fine-grained to silty, are calcareous where fresh or lightweight and porous where weathered, and contain fossil fusulinids, here also most noticeable as casts and molds in the weathered parts. The probability is great that they represent the Paola limestone member of the Iola formation, but the outcrop is too discontinuous to be mapped as the lower limit of the Iola.

On the geologic map (Plate I) the Iola formation is therefore represented by a red line printed over a black line which is drawn at the base of the thick sandstone (the Tiger Creek sandstone of Fath) that caps the escarpment.

Stratigraphic relations. The Iola formation in Oklahoma, north of Creek County, is underlain conformably by the Chanute formation, and overlain conformably by the Wann formation. The same is no doubt true of the Iola equivalents in Creek County as far south as Little Deep Fork Creek. If Wann rocks are present farther south, in Tps. 14 and 15 N., R. 9 E., they cannot be distinguished from the Okesa sandstone member of the Barnsdall formation and are mapped with the Okesa, which is thought to overlie the Iola unconformably there. Representatives of the Iola could be recognized only from place to place in this area, and it is altogether possible that the Iola was removed locally by pre-Barnsdall erosion. The writer has not been able to identify any outcrop south of sec. 20, T. 14 N., R. 9 E. as a representative of the Iola formation, and thinks that the Iola was removed there by post-Wann, pre-Barnsdall erosion.

Detailed sections. For measured outcrop sections of Iola representatives see sections numbered 6, 13, 15, 17, 19, 20, 26, 30, 31, 47, Appendix.

WANN FORMATION

Nomenclator. Ohern (1910).

Original description.

> The term Wann formation is proposed for a series of shales, sandstones, and limestones which occupy the interval between the top of the Curl formation and that of the Stanton limestone as that term is used by Haworth and Bennett (Ohern, 1910).

History of usage. The bed most mentioned by Ohern as the top of his Wann formation and the top of the Stanton limestone is that mapped by Oakes (1940a, 1940b) as the Birch Creek limestone, and since Ohern defined the top of his Curl formation as the base of the Hogshooter limestone, his Wann formation included the Hogshooter limestone at the base and the Birch Creek limestone at the top. However, the term "Wann formation" was little used. Ohern ignored it entirely in his unpublished manuscript, Geology of the Nowata and Vinita Quadrangles, 1914, and Gould (1925) did not mention it in his Index to the Stratigraphy of Oklahoma.

Oakes (1940a, 1940b) revived, restricted, and redefined the term "Wann formation" to apply to all strata between the top of the Iola formation, below, and the base of the Torpedo sandstone, above, or the base of the Birch Creek limestone where the Torpedo sandstone was removed by pre-Birch Creek erosion.

Oakes (1951) included the Birch Creek limestone in his Barnsdall formation as the basal member, in northern Oklahoma. The Torpedo sandstone and the shale above the Torpedo and beneath the Birch Creek limestone crop out only in Washington County and in eastern Osage County. This situation led Miser (1954) to place the top of the Wann formation at the base of the Barnsdall formation throughout, and to include the Torpedo sandstone and the shale above it in the Wann formation. This amounts to a minor change in the definition of the Wann formation, but it is significant for northern Oklahoma only.

We here follow Miser (1954) and apply the term "Wann formation" to the rocks that crop out above the Iola formation and below the Barnsdall formation.

Distribution. The outcrop of the Wann formation (IPw) extends from the northeast corner of Washington County, in a direction a little west of south, to south-central Creek County. The writer thinks that there is an unconformity at the top of the Wann and that possibly all of it was removed, at least locally, by pre-Barnsdall erosion in Tps. 14 and 15 N., R. 9 E., southern Creek County. The outcrop is as much as 10 miles wide in some localities between the Kansas-Oklahoma line and Creek County, but in Creek County it does not exceed 2 miles at many places.

Thickness. The Wann formation has a great range in thickness, owing in part to post-Wann, pre-Barnsdall erosion. In Washington County, it is from less than 100 feet to more than 400 feet thick, including the Torpedo sandstone and its overlying shale. It is from 225 to 265 feet thick in southeastern Osage County and western Tulsa County, but is thinner across Creek County. It is from 180 feet thick in the north part of T. 18 N. to 40 feet or less in the south part of T. 16 N. The Wann is probably absent, at least locally, in the area south of Little Deep Fork Creek, in Tps. 14 and 15 N., R. 9 E. Any remnants of the Wann that may crop out in that area are mapped with the overlying Okesa sandstone member of the Barnsdall formation, because they are indistinguishable from it.

Character. The Wann formation varies greatly in character, both vertically and laterally. In northern Washington County it consists mostly of shale, much of it fossiliferous, but it contains also considerable sandstone and a minor amount of marly to sandy limestone in beds a few inches to a few feet thick, and limited in lateral extent. Limestone is more noticeable southward, and in southern Washington County and in adjacent parts of Osage County limestone lenses are thick and prominent. An outstanding example is the exposure of limestone in the road west from Ramona, immediately west from the E¼ cor. sec. 25 T. 24 N., R. 12 E., which is 40 feet thick but splits into thin limestone beds and calcareous shale beds within a mile both to the north and to the south. The Wann formation is less calcareous and is increasingly sandy southward across southeastern Osage County and western Tulsa County.

In Creek County the common boundary between the Wann formation, above, and the Iola formation, below, could not be determined in the field sufficiently well for mapping. See figure 7.

A prominent high escarpment capped by upper Iola and basal Wann rocks extends almost across Creek County from north to south and marks an abrupt and conspicuous change in the character of the rocks that crop out in Creek County. To the east the sandstones are gray and weather brown and the shales are dark to nearly black and weather gray or some shade of yellow. To the west the sandstones are gray to brown and weather brown, reddish brown, or red. The shales are not so dark as to the east; some are variegated and many weather red.

In northern Creek County the Wann consists of sandstone and silty to sandy shale and includes a minor amount of lenticular, sandy limestone which grades rapidly into sandstone southward. On the geologic map (Plate I) the shale is designated (IPw) and the sandstones are designated in ascending order (IPw-1,2,3,4). In a small area in T. 18 N., R. 10 E. sandstone units (IPw-1) to (IPw-3) are mapped together as a single unit, because the shales that separate them in other areas are not well exposed.

The sandstone units consist of sandstone beds and sandy to silty shale. The sandstone is medium to fine grained, massive to thin bedded, gray, and weathers brown. The sandstone units are less shaly southward and are thicker at the expense of the intervening shale. Only two sandstone units and their intervening shale are present in the area between Lake Heyburn and Little Deep Fork Creek. The decrease in the number of units is accompanied by a decrease in total thickness and it is presumed that these are the units (IPw-1) to (IPw-2) and that higher units were removed by post-Wann, pre-Barnsdall erosion. It is possible that there are remnants of the lower part of the Wann in the area south of Little Deep Fork Creek, in Tps. 14 and 15 N., R. 9 E.; if so, they are so much like the overlying Okesa sandstone member of the Barnsdall formation that they cannot be distinguished from it, and are mapped with the Okesa. See figure 7.

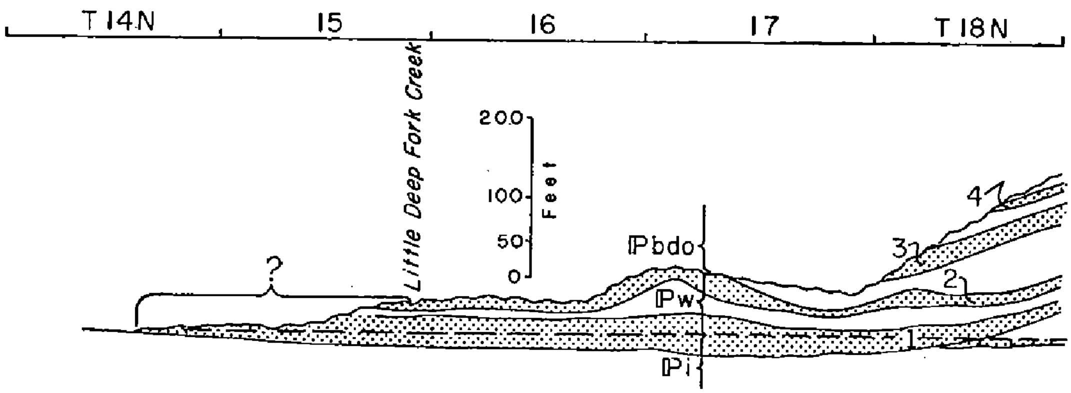

FIGURE 7. Shows the Wann formation, approximately to scale. The Wann consists of shale units (lPw) and sandstone units (lPw-1,2,3,4); unconformable with the Okesa sandstone member of the Barnsdall formation (lPbdo), above; conformable with the Iola formation (lPi), below. Lower boundary is indefinite and gradational. Remnants south of Little Deep Fork Creek, if any, are mapped with the Okesa.

Stratigraphic relations. The Wann formation is conformable with the Iola formation, below, and unconformable with the Okesa sandstone member of the Barnsdall formation, above. It seems that the outcrop of the Wann formation does not extend south of Creek County, and the writer thinks that it was removed by pre-Barnsdall erosion there.

Correlations. 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, probably the South Bend limestone member, above.

Detailed sections. For measured outcrop sections of the Wann formation see sections numbered 17, 19, 26, 28, 30, 31, 44, 45, 46, 47, Appendix.

UNCONFORMITY

The writer (Oakes, 1940a, 194b, 1951, 1952) has long believed that there is an unconformity at the base of the Barnsdall formation; that this unconformity extends at least to the south side of Okfuskee County, and probably into Seminole County; and that it is finally intersected by the unconformity at the base of the Virgil series, probably in Seminole County. However, he knows of no place where such an unconformity would be inferred from local observations alone. The unconformity is inferred from the results of regional studies of the rocks above and below.

The basal member of the Barnsdall formation in northern Oklahoma is the Birch Creek limestone, which is only a few feet thick and is extremely sandy in some places and is argillaceous in others. The Birch Creek is sandy and rests upon the Torpedo sandstone member of the Wann formation at the Kansas-Oklahoma line, where the Torpedo is only 2 feet thick. The Torpedo appears not to extend into southern Kansas. Three miles farther south the Torpedo is 30 feet thick and its overlying shale is 14 feet thick, which places the Birch Creek limestone 45 feet above the base of the Torpedo sandstone. At Twin Mounds, in secs. 34 and 35, T. 28 N., R. 13 E., shale 75 feet thick intervenes between the top of the Torpedo and the base of the Birch Creek, which caps the mounds and is at least 10 feet thick, relatively pure, white, and sparingly fossiliferous.

Across secs. 4 and 9, T. 25 N., R. 12 E., the Birch Creek is rusty brown sandy fossiliferous limestone about 1 foot thick; it is separated by only a few feet of shale from the unfossiliferous Torpedo sandstone, below, and by a like amount of shale from fossiliferous sandstone beds of the Okesa sandstone member of the Barnsdall formation, above. In the road up the escarpment in the southwest part of sec. 15, T. 25 N., R. 12 E., the Birch Creek is sandy and fossiliferous; rests on shale in the Wann formation, older than the Torpedo sandstone member; and is immediately overlain by thin fossiliferous sandstone beds of the Okesa sandstone member of the Barnsdall formation. The Torpedo sandstone and its overlying shale may have been preserved from pre-Birch Creek erosion by being in a shallow syncline; they are not identified elsewhere in Oklahoma or Kansas.

About a mile south of Wolco, at the junction of the Avant and Ramona roads, near the E¼ cor. sec. 25, T. 24 N., R. 11 E., the Birch Creek rests on sandstone which seems to have been an outlier of the Torpedo at the end of the pre-Birch Creek erosion. From this locality southward to the south line of T. 23 N., the Birch Creek is increasingly sandy; rests on shale in the Wann formation older than the Torpedo; and is overlain by the Okesa sandstone member of the Barnsdall formation. Finally, the Birch Creek grades into and is indistinguishable from the basal sandstone of the Okesa.

Farther south, the Okesa rests on shale younger than the Clem Creek sandstone of the Wann formation. South of sec. 19, T. 20 N., R. 10 E., Pawnee County, the Okesa rests on parts of the Wann older than the Clem Creek sandstone member.

In Creek County the Okesa sandstone rests on the Wann formation, but the Wann is thinner southward. It is not difficult to distinguish the Okesa sandstone from sandstones of the underlying Wann formation across

Tps. 19 and 18 N., because the Okesa sandstones are, in general, thinner bedded than sandstones of the Wann and its interbedded shale weathers deeper red than do the shales of the Wann. Across T. 17 N., it is increasingly more difficult to distinguish sandstone of the Wann from sandstone of the Okesa, and across Tps. 15 and 14 N., the sandstones of the two formations are so much alike that any Wann beds that may be present there are mapped with the Okesa. However, representatives of the Iola formation, which underlies the Wann, can be identified from place to place as far south as the south side of sec. 20, T. 14 N., R. 9 E., and have not been found farther south. This is taken to indicate that the Okesa rests on the Iola at least locally for some distance north of that locality, and on the Chanute formation farther south. See figure 7.

According to Ries (1954) the Okesa sandstone member of the Barnsdall formation rests upon the Chanute formation in Okfuskee County, with but little evidence of unconformity other than the southward thinning of the Chanute.

The term "Barnsdall" is not used south of Okfuskee County, but certain patches of red shale immediately below the base of the Virgil in Seminole County may represent the Barnsdall there (Tanner, 1956, p. 86). Farther south Barnsdall and some pre-Barnsdall rocks seem to have been removed by pre-Virgil erosion and along with them went all evidence of the unconformity at the base of the Barnsdall formation.

One should hardly expect evidence of such a widespread unconformity as that at the base of the Barnsdall formation to be limited to Oklahoma. The Birch Creek limestone member of the Barnsdall formation is probably equivalent to the South Bend limestone member of the Stanton formation in southern Kansas, and the South Bend is succeeded, in descending order, by the Rock Lake shale and the Stoner limestone members of the Stanton. According to Moore (1935, p. 134-137) a slight unconformity is indicated at the base of the Rock Lake shale at many places in Kansas, and in Nebraska the Rock Lake shale contains a red zone which signifies emergence.

BARNSDALL FORMATION

Nomenclator. Oakes (1951).

Type locality. The type locality is the area between Barnsdall and Wolco, T. 24 N., R. 11 E., Osage County, Oklahoma. The name is from the town of Barnsdall, formerly Bigheart. This is the same town from which the Bigheart sandstone was named (White and others, 1922). It is felt that this offers no real difficulty, because the type locality of the Bigheart is in the hills west of the town, and the name was long since changed to Barnsdall. The town now called Bigheart is in sec. 3, T. 27 N., R. 10 E., Osage County, and is on the outcrop of neither the Barnsdall formation nor the Bigheart sandstone.

Original description.

> At the state (Kansas-Oklahoma) line the Barnsdall consists of the 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 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 (Oakes, 1951, p. 120).

The upper limit of the Barnsdall formation is the base of sandstone in the overlying Tallant formation, called the Bigheart sandstone (White and others, 1922), in Osage County.

History of usage. The term "Barnsdall formation" is still used in the sense indicated above.

Distribution. The Barnsdall formation extends from the Kansas-Oklahoma line southward through western Washington County, eastern Osage County, western Tulsa County, central Creek County, and western Okfuskee County to the North Canadian River. Patches of red shale below the base of the Virgil series in Seminole County may represent the Barnsdall.

Thickness. The Barnsdall is about 100 feet thick at the Kansas-Oklahoma line, T. 29 N., R. 12 E.; 110 feet in T. 23 N.; 45 feet in T. 22 N.; and 190 feet in T. 19 N., R. 9 E., western Tulsa County. It is irregular in thickness in Creek County, ranging upward from about 140 feet in T. 18 N. to 200 feet in the north part of T. 17 N., and thence downward to about 100 feet in the south part of T. 14 N.

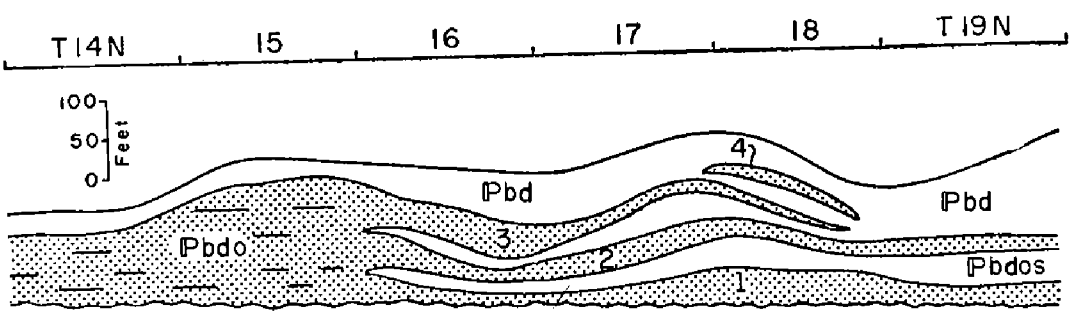

FIGURE 8. Shows the Barnsdall formation, approximately to scale; it consists of the unnamed shale member (lPbd), above, and the Okesa sandstone member (lPbdo), below. The Okesa sandstone member consists of undifferentiated silty shaley sandstone in Tps. 14 and 15 N. Farther north the Okesa contains the sandstone tongues (lPbdo-1,2,3), the sandstone lens (lPbdo-4), and the shale (lPbdos). The Barnsdall is unconformable on older rocks, truncates the Wann and Iola formations, and rests on the Chanute formation in southern Creek County. It is overlain conformably by the Tallant formation.

Character. The Barnsdall formation is heterogeneous in character, but, on the whole, contains progressively more sandstone from north to south, as indicated in the original description, quoted above.

In Creek County as in Tulsa County, the Barnsdall contains a variable number of sandstone units in the lower part, called collectively the Okesa sandstone member. The unnamed shale member, which constitutes the upper part of the Barnsdall, is sandy to silty. It intergrades and interfingers with the Okesa sandstone member. See figure 8.

In T. 19 N., R. 9 E., the Okesa sandstone member contains two sandstone units (IPbdo-1) and (IPbdo-2) and the intervening sandy to silty shale unit (IPbdos) with a combined thickness of 90 feet in the north part and 80 feet in the south part. The sandstones are fine-grained to silty, generally are thin bedded, and are calcareous and fossiliferous locally, the fossils on the outcrop being mostly molds and casts. In this township the unnamed shale member ranges in thickness from 100 feet in the north part to 60 feet in the south part.

In T. 18 N., the Okesa sandstone member includes the sandstone units (IPbdo-1) and (IPbdo-2); the shale unit (IPbdos); and, in addition, above these, the sandstone tongue (IPbdo-3) and the sandstone lens (IPbdo-4). The total thickness is correspondingly greater and ranges from 120 feet in the north part to 170 feet in the south part, including shale elsewhere included in the unnamed shale member, which is thereby reduced in thickness to 30 feet in the north part and 60 feet in the south part.

In Tps. 16 and 17 N., the Okesa includes the sandstones (IPbdo-1), (IPbdo-2), and (IPbdo-3), and the total thickness ranges from 100 feet to 175 feet. The unnamed shale member ranges in thickness from 10 to 60 feet, being thinnest in the south part of T. 16 N.

Compared with outcrops farther north, the sandstones are thicker and coarser, some being medium grained; the shales are more sandy, and the reddish brown to red color of the weathered rock is more noticeable. Southward, it is more and more difficult to map the units of the Okesa member separately, and to distinguish sandstone of the Okesa sandstone member of the Barnsdall formation from sandstone in the underlying Wann formation.

South of Little Deep Fork Creek, in Tps. 14 and 15 N., Rs. 8 and 9 E., southern Creek County, the Okesa sandstone member of the Barnsdall formation is mapped as a single sandstone unit which thins southward, from 160 feet thick to 85 feet thick. It consists dominantly of medium- to fine-grained sandstone, but contains also a considerable amount of extremely sandy shale so intimately intermixed that the whole weathers without much topographic expression of stratification. Red is prominent among the colors of the weathered material. As mapped in this area, the Okesa sandstone rests on the Iola formation as far south as the south side of sec. 20, T. 14 N., R. 9 E., and rests on the Chanute formation farther south where the Iola seems to have been completely removed by pre-Barnsdall erosion. The southward thinning of the Okesa may very well be the result of including in it, at the base, a southward decreasing amount of sandstone that belongs to the Wann and Iola formations. On the other hand, failure to find identifiable representatives of the Iola locally for some distance north of its southernmost known occurrence may indicate that the Iola as well as the Wann was removed completely at some places in that area.

In the north part of T. 15 N., Rs. 8 and 9 E., the unnamed shale member (IPbd), which constitutes the upper part of the Barnsdall formation elsewhere, is only about 10 feet thick and is so sandy that it probably would not have been mapped separately if it had not been thicker and less sandy farther south. It is at least 25 feet thick in the south part of T. 14 N., R. 8 E., and Ries (1954, p. 76, 77) stated that the upper part of the Barnsdall formation is bright red shale 25 to 40 feet thick in T. 13 N., R. 8 E., northern Okfuskee County.

Stratigraphic relations. The Barnsdall formation rests unconformably upon the Wann formation across most of Creek County, truncates the Iola formation in southern Creek County, and, finally, rests unconformably upon the Chanute formation. The Barnsdall in Creek County is conformable with the Tallant formation, above, but is overlain unconformably by lower Virgil rocks across most of Okfuskee County, to the south.

Correlations. The lower few feet of the Barnsdall is probably equivalent to the South Bend limestone of Kansas and Nebraska. The remainder, and greater part, is equivalent to the Weston shale of southern Kansas. Excepting patches of doubtful age, equivalents of the Barnsdall formation were probably removed by pre-Virgil erosion in Seminole County and farther south.

Detailed sections. For measured outcrop sections of Barnsdall rocks see sections numbered 4, 6, 13, 14, 15, 18, 24, 25, 27, 28, 44, 45, Appendix.

TALLANT FORMATION

Nomenclator. Oakes (1951).

Type locality. Vicinity of Tallant, Osage County, Oklahoma.

Original description.

> It consists of sandstone and shale. In Osage County, the only area in which Tallant rocks have been much scrutinized, there are two principal named sandstone members, the Bigheart and the Revard, in ascending order, but the several geologists who have written about them are not in accord as to their limits except, fortunately, that all agree on the base of the Bigheart, the basal member of the Tallant. 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. . . .
>
> Many of the sandstone beds of the Tallant in Osage County are fine-grained and tightly cemented, but locally some are moderately coarse-grained and, in spite of being poorly sorted, are sufficiently porous and permeable to offer possibilities for oil production in areas west of the outcrop, where the Tallant may very well be part of the Tonkawa sand.
>
> . . . The Tallant formation rests conformably on the Barnsdall formation and is overlain unconformably by sandstone in the lower part of the Vamoosa formation of the Virgil series. Across Osage County the basal bed of the Vamoosa is the Cheshewalla sandstone. In the area north of T. 22 N., the basal Virgil and upper Missouri beds are so similar in appearance and there is so little physical evidence of the unconformity between the series that it is only by continuous tracing of a considerable section, above and below, that the contact can be mapped with assurance. It is doubtful that the base of the Virgil series can be recognized from lithologic criteria in subsurface studies in north-central Oklahoma (Oakes, 1951, p. 121).

History of usage. There has been no change in application of the term "Tallant formation."

Distribution. Tallant rocks (IPtl) crop out in a narrow band from the Kansas-Oklahoma line, T. 29 N., R. 12 E., in a direction a little west of south across eastern Osage County, eastern Pawnee County, and central Creek County, through Bristow, to sec. 28, T. 13 N., R. 8 E., northern Okfuskee County. They were removed by pre-Virgil erosion farther south.

Thickness. The Tallant formation in Creek County is irregular in thickness, probably due to pre-Virgil erosion. It is 75 to 100 feet thick in the north part of the County, and 35 to 85 feet in the south part.

Character. The lower part of the Tallant (IPtl-1) is sandstone, medium- to fine-grained thin-bedded to massive gray to brown and weathers brown to reddish brown. It ranges in thickness from 10 to 30 feet in the north and south parts of the county and from 40 to 60 feet in the central part, where it includes sandy shale partings as much as 10 feet thick. The thicker parts are generally permeable along the outcrop, where springs are common, especially in years of heavy rainfall. It no doubt represents the Bigheart sandstone, but may not be precisely equivalent to the Bigheart. See figure 9.

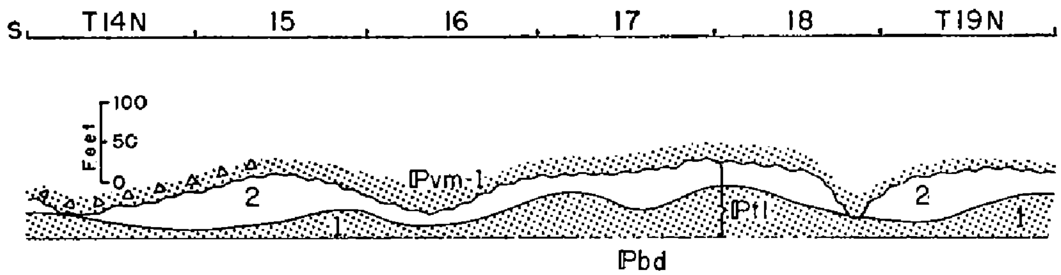

FIGURE 9. Shows the Tallant formation (lPtl), approximately to scale. The Tallant consists of sandstone (lPtl-1) and shale (lPtl-2). It is overlain conformably by sandstone (lPvm-1) in the lower part of the Vamoosa formation. It is underlain conformably by shale (lPbd) in the upper part of the Barnsdall formation.

The upper part of the Tallant (IPtl-2) is generally shale, which ranges irregularly in thickness from 25 feet in the south part to 65 feet in the north part of Creek County. In some of the localities where it is thickest, notably in Tps. 17 and 18 N., Rs. 8 and 9 E., it contains, near the top, sandstone beds generally finer grained than the sandstone in the lower part of the Tallant, and generally 2 to 10 feet thick, beds which are probably remnants from pre-Virgil erosion.

Stratigraphic relations. The Tallant formation is conformable with the Barnsdall formation, below, but unconformable with the Vamoosa formation, in the lower part of the Virgil series, above.

Detailed sections. For measured outcrop sections of the Tallant formation see sections numbered 2, 3, 4, 12, 24, 25, 29, 37, 38, 39, 40, 41, 42, 43, Appendix.

VIRGIL SERIES

According to Moore (1935, p. 143), the name "Virgil' is from the town of Virgil, in eastern Greenwood County, Kansas.

Moore (1931, correlation chart) indicated that the Virgil series extended from an unconformity at the base of the redefined Douglas group to the base of the Americus limestone. Moore (1922) repeated that definition and stated that the unconformity at the base of the Virgil corresponds to the time of major folding in the Arbuckle Mountains and possibly to the time of major deformation in the Ouachita Mountains. Moore (1933) stated that the Virgil series comprises the uppermost part of the Pennsylvanian system and placed its upper boundary at the base of the Foraker (Americus) limestone. Moore (1935, p. 142-144) left the base of the Virgil series at the unconformity at the base of the Douglas group, as before, but placed the top at a widespread but obscure unconformity below the Aspinwall limestone, about 100 feet below the base of the Foraker limestone. He further stated that this unconformity is indicated by several large channel sandstone bodies next beneath the Aspinwall limestone and distributed along at least 300 miles of outcrop, mostly in Kansas and Nebraska, which at places cut 100 feet or more into the uniform succession of beds underlying the Brownville limestone.

Oakes (1948, 1950) mapped the base of the Virgil series from the Kansas-Oklahoma line to the north flank of the Arbuckle Mountains and confirmed the opinions of earlier workers that it is the base of the lowest conglomerate in the Vamoosa formation of Morgan (1924). Ries (1954) restricted the Vamoosa formation by placing its lower boundary at the base of the lowest conglomerate. Moore (1937, p. 38) stated that locally in southern Kansas the sandstone that is inferred to mark the base of the Virgil is quite thin, or may disappear, bringing supposed Virgil shale on upper Missouri shale. The same relationship may well prevail in northern Osage County, Oklahoma. In northern Oklahoma there is little evidence of the unconformity which marks the top of the Virgil series in Kansas, and the upper limit of the Virgil series, and of the Pennsylvanian system, is placed at the top of the Brownville limestone.

In Oklahoma usage the Virgil series in central and northern Oklahoma extends from the base of the Vamoosa formation, below, to the top of the Brownville limestone, above.

TABLE 3

SUBDIVISIONS OF THE VIRGIL SERIES IN CREEK COUNTY, OKLAHOMA

- Permian system
- Pennsylvanian system
  - Virgil series
    - Vanoss formation
    - Pawhuska formation
    - Vamoosa formation
  - *Unconformity*
  - Missouri series

VAMOOSA FORMATION

Nomenclator. Morgan (1924).

Type locality.

A suitable geographic name was not available for this formation. The term finally selected is after the village of Vamoosa which is located in the northern part of the Stonewall quadrangle, about one-half mile west of the outcrop. The formation is typically developed on the main road between Sasakwa and Konawa (Morgan, 1924, p. 125).

Original description.

Where all of the formation is exposed the entire section has an average thickness of 260 feet. At the base is about 30 feet of dark shale that might easily be mapped as a separate formation. No collections were made from this member, but it is very probably fossiliferous. The main mass of the formation is above this shale and has a maximum thickness of about 230 feet. It consists in large part of chert conglomerates, of massive, coarse, red and brown sandstones, and red shales. The clastic material is finer near the top and the red coloration is there also less pronounced.

. . . The Vamoosa formation contains a greater thickness of chert conglomerates than does any other formation of the area. . . . The chert fragments which make up the conglomerates are mostly angular and range in size from a fraction of an inch to as much as three inches in length. The average length, however, is less than an inch (Morgan, 1924, p. 125-126).

History of usage. Morgan himself stated that the dark shale comprising the lower 30 feet of his Vamoosa formation might easily be mapped as a separate formation. With the passage of time it became increasingly clear to geologists familiar with Upper Pennsylvanian stratigraphy in Kansas and Oklahoma that there is an unconformity at or about the stratigraphic position of the lowest conglomerate in Morgan's Vamoosa formation and at the base of certain sandstones in Kansas, and Moore (1931, 1932, and 1935) called the Pennsylvanian rocks above this unconformity the Virgil series.

Oakes (1949, 1950) mapped the base of the Virgil series from the Kansas-Oklahoma line to the north flank of the Arbuckle Mountains and confirmed opinions of earlier workers that it is at the base of the lowest conglomerate in Morgan's Vamoosa formation. Ries (1954, p. 81) formally restricted the Vamoosa formation by placing its lower boundary at the base of the lowest conglomerate.

Ries also placed the top of the Vamoosa in Okfuskee County at the base of a limestone which is the same as that mapped by the writer as the Lecompton limestone from the Kansas-Oklahoma line to southwestern Creek County (Miser, 1954). The Lecompton is not found south of the North Canadian River where it was probably removed by pre-Ada erosion. Morgan (1924, p. 26 and 30-31) stated that the Vamoosa is overlapped by the Ada formation progressively from top to base southward and that the Ada overlaps several formations still older than the Vamoosa and rests on the Viola limestone on the north flank of the Arbuckle Mountains. This indicates an unconformity of considerable extent which Tanner (1956, p. 92-93, 97-98, and 102-103) mapped northward to the North Canadian River. This unconformity has not yet been recognized farther north, but in all probability it truncates the Lecompton limestone beneath surficial deposits associated with the North Canadian River.

In present usage, the base of the Vamoosa formation is at the base of the lowest conglomerate of Morgan's Vamoosa in the Stonewall quadrangle and at the base of similarly situated conglomerate and sandstone northward to the Kansas-Oklahoma line. The top of the Vamoosa, from the Kansas-Oklahoma line to the North Canadian River, is at the base of the Lecompton limestone member of the Pawhuska formation. South of the North Canadian River, the top of the Vamoosa formation is at the base of the Ada formation, which is unconformable with the Vamoosa.

Distribution. The Vamoosa formation (IPvm) crops out in a band, generally from 4 to 9 miles wide, from the north part of T. 4 N., R. 6 E., Pontotoc County, nearly due north across central Seminole County, western Okfuskee County, and western Creek County to eastern Pawnee County; thence slightly east of north across eastern Osage County to the Kansas-Oklahoma line in Rs. 10 and 11 E.

Thickness. According to the best estimates the writer could make, the thickness of the Vamoosa formation ranges from about 300 feet in the south part of Creek County to about 400 feet in the north part, but is only 220 feet thick locally, in the south part of T. 16 N., R. 7 E. Owing to the heterogeneous character and complex stratigraphy of the Vamoosa formation, it is extremely difficult to make a close approximation to the dip at most places along its outcrop and, therefore, to compute its thickness. The estimates given here may be in error 25 percent, plus or minus. Logs of wells drilled for oil and gas west of the outcrop of the Vamoosa indicate that the formation may be as much as 600 feet thick at some places.

Character. The Vamoosa formation in Creek County is lenticular and consists of resistant and nonresistant sandstone and sandy, silty shale. It contains, also, chert conglomerate, at or near the base, in the south part of the county. Sandstone units, composed for the greater part of the most resistant lenses, cap escarpments, some of which extend across the County and others are miles long, but it is by no means certain that either the bases or tops of these units represent truly stratigraphic surfaces. Nevertheless, these units are shown on the geologic map (Plate I) as faithfully and in as much detail as the character of their outcrops permits. The outcrops of the more resistant sandstone units are shown by stippling and the intervening outcrops of units composed of shale and nonresistant sandstone are shown unstippled. See also figure 10.

Generally, the resistant sandstones are medium to fine grained, but some are coarse grained, and a few are conglomeratic; they are thin bedded to massive, and even bedded to cross bedded; a few are almost white, and others are red, but reddish brown and brownish red predominate. The nonresistant sandstones are generally fine grained, silty, and contain much shale, intimately interbedded and intermixed. Most shales are dark red, but some are lavender; all are silty to sandy.

Sandstone is coarsest and most evident in the south part of the County, where several of the resistant units coalesce, shales are thin and inconspicuous, and most of the area supports a dense growth of blackjack trees.

In the north part of the County, the resistant sandstones are finer grained, the units of shale and nonresistant sandstone are most noticeable, and the land is covered by grasses, scrubby blackjack trees, and oak shinnery.

On the geologic map (Plate I) the sandstone units of the Vamoosa formation are designated (IPvm-1,2,3,4) in ascending order, and the intervening units, consisting of shale and nonresistant sandstone, are all designated (IPvm).

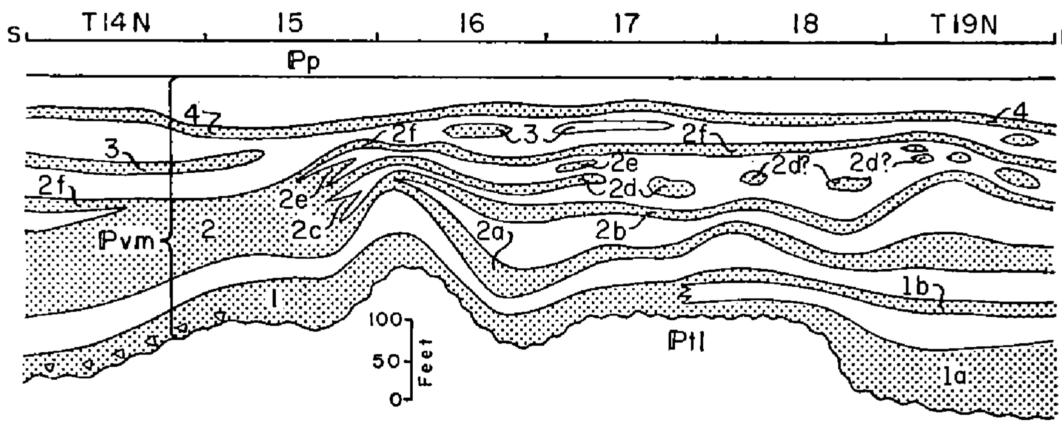

FIGURE 10. Shows the Vamoosa formation (IPvm), approximately to scale. It is composed of resistant sandstone units (IPvm-1,2,3,4) and units of nonresistant sandstone and sandy, silty shale. The Vamoosa is unconformable with the Tallant formation (IPtl), below, and conformable with the Pawhuska formation (IPp), above. On the geologic map (Plate I), the units of nonresistant sandstone and sandy, silty shale are designated (IPvm).

The sandstone unit (IPvm-1) is differentiated from the underlying Tallant formation by the following criteria: it generally caps a prominent escarpment whose east slope is occupied by shale in the upper part of the Tallant formation; it contains chert conglomerate beds at the base in T. 14 N., R. 8 E., and basal beds are coarse to medium grained, at least locally, across the county, the proportion of coarse-grained sandstone being less northward.

This sandstone unit (IPvm-1) is 20 to 40 feet thick in T. 14 N., R. 8 E.; 40 to 50 feet in T. 15 N., R. 8 E.; and 40 to 60 feet in T. 17 N., R. 9 E. Farther north it consists of lower and upper tongues. The lower tongue (IPvm-1a) is resistant sandstone, 10 to 70 feet thick; the upper tongue (IPvm-1b) is also resistant sandstone, 10 to 20 feet thick. The intervening shale and nonresistant sandstone is 10 to 100 feet thick.

The interval from (IPvm-1) to (IPvm-2) is filled by shale and nonresistant sandstone, is from 15 to 50 feet thick, and extends across the County.

The sandstone unit (IPvm-2) is 65 feet thick in the south part of T. 15 N., and equivalent sandstone and shale is 150 feet thick in T. 14 N. It divides northward into sandstone tongues (IPvm-2a,b,c,d,e,f).

The sandstone tongue (IPvm-2a) extends to the north side of the County and is generally from 5 to 25 feet thick. The sandstone tongue (IPv-2b) extends to the north side of the County and is from 5 to 25 feet thick. It is separated from the sandstone tongue (IPvm-2a) by nonresistant sandstone and silty shale 20 to 50 feet thick.

The interval between tongues (IPvm-2b) and (IPvm-2f) is from 75 to 100 feet thick and contains the tongues (IPvm-2c,d,e), but the greater part is occupied by nonresistant sandstone and silty shale. The sandstone tongue (IPvm-2c) is generally less than 10 feet thick and is restricted to the northeast part of T. 15 N., R. 7 E. The sandstone tongue (IPvm-2d) is about 10 feet thick and extends into the south part of T. 17 N., where it is about 20 feet above tongue (IPvm-2b). Several sandstone outliers that cap hills in T. 18 N., R. 8 E are all probably remnants of local sandstone lenses in the interval between (IPvm-2b) and (IPvm-2f) and are designated (IPvm-2d?). A local sandstone outcrop in T. 19 N., Rs. 7 and 8 E. is also designated (IPvm-2d?). A sandy limestone (IPvm-ll), less than 5 feet thick, is present locally in the southwest part of T. 16 N., R. 7E., a few feet below (IPvm-2f). The sandstone tongue (IPvm-2e) is less than 10 feet thick and crops out only in the northeast part of T. 15 N., R. 7 E. An isolated outcrop at about the same stratigraphic position in sec. 19, T. 17 N., R. 8 E. is designated (IPvm-2e?).

The sandstone tongue (IPvm-f) is from 5 to 25 feet thick and extends to the north side of the County.

The interval above (IPvm-2) and below (IPvm-4) is filled mostly with nonresistant sandstone and sandy shale. It is about 100 feet thick in T. 14 N., R. 7 E. and contains a resistant sandstone bed (IPvm-3), 10 feet thick and 60 feet below the top. In the south part of T. 15 N., this interval is about the same in thickness and contains a resistant sandstone bed, also designated (IPvm-3), about 25 feet below the top. Other resistant sandstones at about this same stratigraphic position in Tps. 16 and 17 N., R. 7 E. are also designated (IPvm-3). A sandy limestone (IPvm-lu) is present locally in this interval in the west part of T. 16 N., R. 7 E.

On the structural uplift in Tps. 17 and 18 N., R. 7 E., northeast, east, and southeast of Drumright, northwestern Creek County, are many exposures of lenticular sandstones in the interval between (IPvm-2f), below, and (IPvm-4), above; most are little more resistant than the sandy shale; all are poorly exposed, and the structure is complex. They could not be correlated, one with another, and were therefore not mapped.

The sandstone unit (IPvm-4) extends across the County and is from 5 to 25 feet thick. It was not found in a small area in the northwest part of T. 15 N., R. 7 E., and may be absent there. It is 20 feet thick in the north part of T. 18 N. The interval above (IPvm-4) and below the base of the Pawhuska formation is filled with nonresistant sandstone and sandy shale. It extends across the County and is generally from 5 to 25 feet thick.

Stratigraphic relations. The Vamoosa formation is unconformable with the Tallant formation, below, and conformable with the Pawhuska formation, above. South of the North Canadian River, it is overlain unconformably by the Ada formation. It is not known that the unconformity at the base of the Ada extends north of the North Canadian River, but if it does so it is in rocks younger than the Vamoosa formation, in rocks of the Vanoss formation of this report.

Correlations. The Vamoosa formation is equivalent to rocks in Kansas between the base of the Tonganoxie sandstone, below, and about the middle of the Lecompton limestone, above.

Detailed sections. For measured outcrops sections in the Vamoosa formation see sections numbered 3, 9, 11, 22, 23, 35, 36, 37, 38, 39, 43, 57, Appendix.

PAWHUSKA FORMATION

Nomenclator. Hoover, Herbert C.

Type locality. About 3 miles northwest of Pawhuska, formerly spelled Pawhuski.

Original description.

> The Pawhuska limestone as here defined . . . is made up of a series of limestone beds separated by shale with some associated lenses of sandstone, the whole resting on the Elgin sandstone and in places attaining a maximum thickness of approximately 130 to 180 feet. Except in the highest and lowest beds the appearance of the outcrops and the physical character of the several limestones are very similar, so that it is usually impossible to say at what horizon in the succession any particular outcrop belongs unless its position with respect to the highest and lowest bed in the series can be determined. Usually any limestone occurring in this interval has been called "Pawhuska limestone," but the limestone exposed at the town of Pawhuska is believed to occur in the middle of the succession. The formation is named from its exposure in the Pawhuska quadrangle.
>
> The highest bed of the formation as here delimited was called in the field the "red lime" because in some places it has a conspicuous outcrop of rust-red color (Heald, 1918, p. 66-67).

Heald also stated that the lowest limestone in the Pawhuska formation is the Lecompton limestone of Kansas.

History of usage.

> In 1892 Mr. H. C. Hoover, of the Geological Survey of Arkansas, found at the government lime-kiln three miles northwest of Pawhuski, Oklahoma Territory, Osage Agency, a bed of massive limestone about 100 feet thick, lying horizontally on heavily bedded sandstones. The limestone is fossiliferous but the sandstones are not (Smith, 1894).

The writer has in his possession a letter to C. N. Gould from James Perrin Smith, dated from Stanford University, California, Dec. 13, 1928, in which Smith stated that Herbert Hoover spent nearly a year, as a small boy, at the home of his uncle (by marriage) Major L. J. Miles, Indian Agent of the Osage tribe, in Pawhuska. Hoover paid another visit to Major Miles at Pawhuska in the summer of 1892, just after he had completed his freshman year at Stanford. While on this visit Hoover collected the fossils, later identified by Smith, and wrote a report for his uncle on a cement project in which he named the Pawhuska formation. The report was never published but its content was available to Smith and influenced his writing. The report was at that time, 1928, in the possession of Hoover's brother, J. T. Hoover, at Stanford University.

The thickness of 100 feet mentioned by Smith in the quotation above may have been Hoover's estimate of the thickness of the entire formation or it may have been the thickness of some limestone member, and in that case the original may well have read, a massive bed of limestone about 10 feet thick.

Heald (1918, p. 61, 66-67) clearly indicated that he intended to include in the Pawhuska formation the shale between the lowest limestone member, the Lecompton limestone, and the top of the Elgin sandstone. Miser (1954) placed this shale in the Vamoosa formation. Moore (1949, p. 126) placed the top of the Pawhuska at the top of the Turkey Run limestone and correlated the Turkey Run with the Coal Creek limestone member of the Topeka formation of Kansas. Branson (1956a) restricted application of the term Pawhuska limestone to the base of the Lecompton limestone member, below, and extended it to the top of the Turkey Run limestone member, above. He too correlated the Turkey Run with the Topeka limestone.

Distribution. The Pawhuska formation (IPp) crops out in a band one to 3 miles wide from the Kansas-Oklahoma line, T. 29 N., Rs. 8 and 9 E., across Osage County and eastern Pawnee County. It crops out across the west side of Creek County to the middle of T. 15 N., R. 7 E., and representatives continue along the west side of Creek County and the west side of Okfuskee County to the North Canadian River in T. 11 N., R. 7 E.

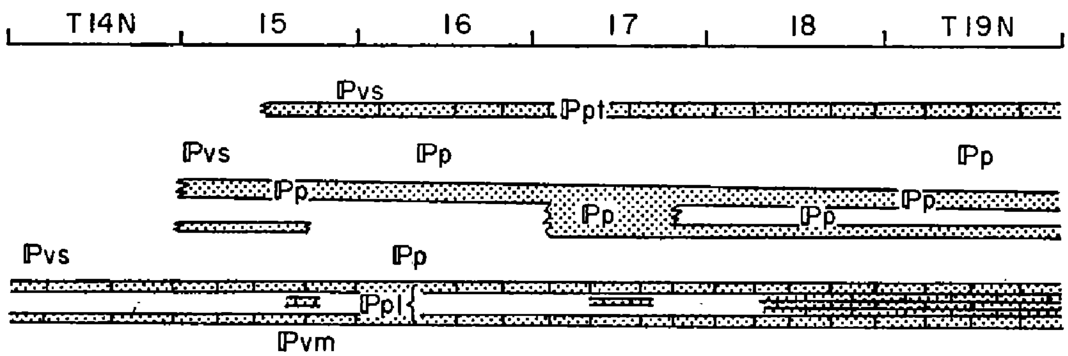

FIGURE 11. Shows the Pawhuska formation (IPp), not to scale. The Pawhuska formation is composed of the Lecompton limestone member (IPpl), at the base, the unnamed shale and sandstone (IPp) and the Turkey Run limestone member (IPt), at the top. Note the interfingering but conformable relation of the Pawhuska with the lower part of the Vanoss formation (IPvs). The Pawhuska is conformable with the Vamoosa formation (IPvm) below.

Character and thickness. The Pawhuska formation in Oklahoma north of Creek County has been studied by four graduate students of the University of Oklahoma, working in consecutively adjoining areas across eastern Pawnee County and across Osage County. The writer has drawn heavily on their theses, which are in the library of the University. They are: Shannon (1954), Carter (1954), Greig (1954, 1957), and Russell (1955).

In Tps. 27, 28, and 29 N., northern Osage County, the Pawhuska formation is about 150 feet thick, and is composed mostly of silty shale but contains considerable sandstone and six named limestone members. The limestones are the lesser but certainly the most conspicuous part of the formation. In ascending order, they are the Lecompton, Plummer, Deer Creek, Little Hominy, Pearsonia, and Turkey Run. Pearsonia is an unpublished named applied by Carter to the "red" limestone of Heald (1918).

The Pawhuska is 180 feet thick in T. 26 N., and 210 feet in T. 24 N. The Pearsonia limestone extends only to sec. 28, T. 26 N., R. 8 E. The

Pawhuska is 100 feet thick in sec. 24, T. 22 N., R. 7 E. The Little Hominy limestone extends no farther south than sec. 32, T. 24 N., R. 8 E.; the Plummer limestone was not found south of the center of sec. 35, T. 23 N., R. 7 E.; and the Deer Creek limestone seems to end in sec. 30, T. 22 N., R. 8 E.

Of the six limestone members of the Pawhuska formation in northern Osage County, only the Lecompton (IPpl), at the base, and the Turkey Run (IPpt), at the top, continue across eastern Pawnee County and into Creek County. The Pawhuska formation continues to thin southward to 56 feet in southern Pawnee County, where it consists mostly of shale and sandstone.

In Creek County the Pawhuska formation is 60 to 75 feet thick from the north line to the south part of T. 16 N., but is only 20 feet thick in one locality near the middle of T. 15 N. See figure 11 and plate II. Farther south the Turkey Run limestone member (IPpt) at the top could not be found and is probably absent, but the Lecompton limestone member (IPpl), at the base, 5 to 10 feet thick, and about 30 feet of shale and sandstone belonging to the formation could be mapped into sec. 6, T. 14 N., R. 7 E. The Lecompton limestone member continues to the south line of Creek County and is the only part of the Pawhuska formation that Ries (1954) could map along the west side of Okfuskee County.

At some places in the north part of T. 19 N., north of the Cimarron River, the Lecompton limestone member consists of gray, fossiliferous, sandy limestone, generally thin-bedded to platy and 10 to 30 feet thick, but locally thinner. In T. 18 N., the Lecompton has much the same character, but is only about 10 feet thick; at some places it is brown, sandy, and only 2 or 3 feet thick. Farther south it is typically two sandy limestone beds, each being one to 2 feet thick, separated by 4 to 6 feet of shale which is commonly gray and locally calcareous and fossiliferous. However, at many places only one bed is exposed, commonly the lower one. In one small area centered at the southeast corner of sec. 31, T. 17 N., R. 7 E., the Lecompton could not be found and possibly is absent. Nearby, along the south line of sec. 6, T. 16 N., R. 7 E., three limestone beds are exposed in a section only 7.5 feet thick, and they probably represent the Lecompton.

Ries (1954) mapped the Lecompton limestone in western Okfuskee County as "Pawhuska" formation and stated that it consists of two thin dolomitic limestone beds separated by gray to greenish-brown shale, the whole being 5 to 10 feet thick.

Stratigraphic relations. The Pawhuska formation is conformable with the Vamoosa formation, below, and conformable with younger rocks, above, as far south as the middle of T. 15 N. It seems that its upper member, the Turkey Run limestone, was not deposited farther south. The Lecompton limestone, the lower member of the Pawhuska, has been mapped southward across Okfuskee County to surficial deposits associated with the North Canadian River, but no representative of the Pawhuska has been recognized farther south, where the Pawhuska probably was completely removed by post-Vamoosa, pre-Ada erosion.

The Ada formation rests upon rocks olders than the Vamoosa formation on the north flank of the Arbuckle Mountains, truncates the Vamoosa, and probably truncates the Lecompton limestone beneath the surficial deposits associated with the North Canadian River. One should expect such an extensive unconformity to be present farther north, but it has not yet been recognized in the area north of the North Canadian River.

Correlations. The Pawhuska formation is equivalent to rocks in Kansas from about the middle of the Lecompton limestone up to the top of the Topeka limestone.

Detailed sections. For measured outcrop sections of the Pawhuska formation see sections numbered 1, 7, 8, 9, 10, 11, 22, 23, 35, 36, Appendix.

VANOSS FORMATION

Nomenclator. Morgan (1924).

Type locality. The name is from the town of Vanoss on the outcrop of the formation in the north-central part of T. 3 N., R. 4 E., Pontotoc County, Oklahoma.

Original description.

> The Vanoss formation consists of alternating sandstones, conglomerates, . . . shales, and a few thin limestones. All the strata are arkosic, some of the sandstones so much so that at first glance a few of them might be mistaken for true granites.
>
> The base of the Vanoss rests on the Ada formation, the contact between the two being the plane dividing the arkosic and nonarkosic materials. Due to the lenticular nature of strata along the contact and to the fact that the Vanoss is progressively overlapping southward no one stratum can be selected to mark the adjacent limits of the formation. The base of the arkosic zone, however, is relatively contemporaneous. . . .
>
> The upper limit of the Vanoss formation is marked by the base of the Hart limestone member of the Stratford formation (Morgan, 1924, p. 33-34).

Morgan took the base of the Hart limestone as the contact between the Permian and Pennsylvanian systems in the Stonewall quadrangle.

As used here. In this report the term "Vanoss" applies to all rocks from the top of the Lecompton limestone member of the Pawhuska formation up to the top of the Pennsylvanian system, which, in northern Oklahoma and southern Kansas, is the top of the Brownville limestone. In all probability, the term, so applied, includes not only Morgan's Vanoss formation, but also his Ada formation and the lower part of his Konawa formation.

Distribution. Rocks to which the term "Vanoss" is here applied crop out in a band 6 to 12 miles wide from the North Canadian River, in northeastern Pottawatomie County and southwestern Okfuskee County, northeastward to the Kansas-Oklahoma line, in north-central Osage County.

Thickness. The lower part of the Vanoss formation crops out in western Creek County, and the maximum thickness of Vanoss beds within the county is about 300 feet, in the northwestern part of T. 19 N., R. 7 E.

Character. The Vanoss formation in Creek County is composed predominantly of gray to red sandy shale, but contains also a minor amount of sandstone, which weathers red to reddish brown, and several thin limestone beds. The Vanoss intergrades laterally with the Pawhuska formation and contains and interfingers with units named in northern Oklahoma and in Kansas, notably the Bird Creek and Wakarusa limestones. See figure 12.

The shale above the Turkey Run limestone member of the Pawhuska formation and below the sandstone unit (IPvs-1) is about 20 feet thick in T. 19 N., but is thinner southward to less than 10 feet in T. 15 N. The sandstone unit (IPvs-1) is 5 to 25 feet thick. The shale between (IPvs-1) and (IPvs-2) is commonly about 50 feet thick. A limestone (IPbc) crops out from place to place in this unit and is commonly gray, fossiliferous, and less than 5 feet thick. It is correlated with the Bird Creek limestone.

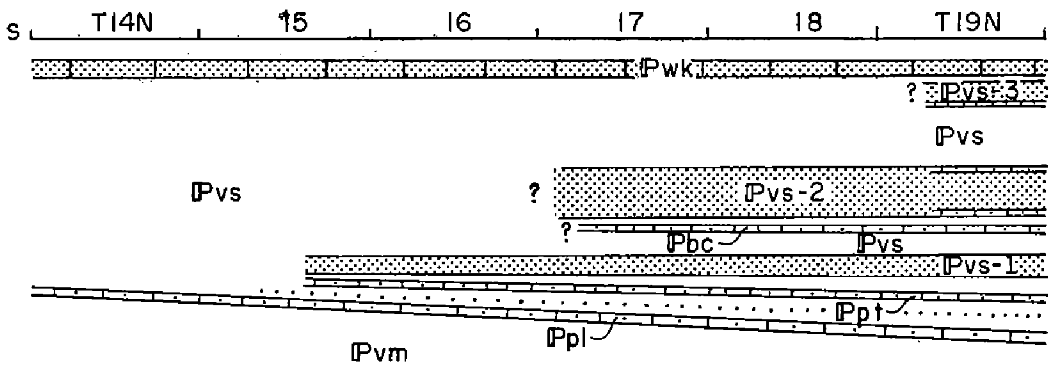

FIGURE 12. Lower part of the Vanoss formation of this report (IPvs). Shows its character and interfingering but conformable relation to the Pawhuska formation (IPpl to IPpt), the Bird Creek limestone (IPbc), and the Wakarusa limestone (IPwk). The symbol (?) indicates that the unit passes out of the county and that its farther extent is unknown. The Wakarusa limestone passes out of the county in T. 19 N., but has been mapped to the south side of T. 14 N.

The sandstone unit (IPvs-2) is 30 to 40 feet thick in T. 19 N., and contains sandy limestone beds locally. The sandy shale unit between (IPvs-2) and (IPvs-3) is 80 to 100 feet thick and contains several thin limestone beds, each of which is probably of only local occurrence. The unit (IPvs-3) contains sandstone and sandy shale, is 25 feet thick, and contains, at the base, a calcareous fusulinid-bearing sandstone bed about 5 feet thick. A gray, sandy, fossiliferous limestone bed (IPwk), a few feet above the unit (IPvs-3), is one to 3 feet thick and is correlated with the Wakarusa limestone.

Detailed sections. For measured outcrop sections of the Vanoss formation see sections numbered 10, 23, 54, 55, 56, Appendix.

QUATERNARY (?) SYSTEM

A deposit of silt, sand, and clay (Qt) mantles the older rocks in limited areas along the north side of Deep Fork and on the north side of Cimarron River. It also covers about 2 square miles on the south side of Cimarron River, in the vicinity of Oilton. At some places, notably along the Cimarron and some of its tributaries, this material is continuous, without a mappable change in character, from the water's edge to the tops of adjacent hills, a difference in elevation of 50 feet or more. However, patches of exposed bedrock in the hillsides indicate that the surficial cover is probably no more than a few feet thick there. This surficial material is probably a mere remnant of much more extensive alluvial deposits made by ancient streams which flowed at higher levels than the present streams, and, no doubt, much of it has been reworked by wind and rain. The land on these deposits is used for growing peanuts, and the sands in the deposits serve as sources of water for domestic use.

QUATERNARY SYSTEM

Flood plain deposits (Qal) along Cimarron River, Deep Fork, and a few other streams are extensive enough to be shown on the geologic map (Plate I). They are composed of clay, silt, and sand. Their maximum thickness is not known, but it is probably between 50 and 100 feet. The streams still overflow from time to time and build the alluvium higher. Some of the best agricultural land of Creek County is on the alluvium, and coarse sand in the lower part yields considerable ground water.

SURFACE STRUCTURE

It was not the purpose of this investigation to make a detailed study of the tectonics of the rocks at and near the surface in Creek County, such as might lead to the discovery of oil and gas in untested areas. Creek County has long since been thoroughly tested by drilling and any new discoveries will probably be in stratigraphic traps and other reservoirs that have little or no indication of their presence in the surface rocks.

In general, rocks that crop out in Creek County dip westward at low angles, from 30 to 100 feet per mile, mostly commonly about 60 feet per mile. This low westward dip is modified in areas of local folds and faults, and surface rocks actually dip eastward at some places; notably in northwestern Creek County, a few miles northeast, east, and southeast of Drumright.

The writer drew most of the contacts shown on the geologic map (Plate I) from aerial photographs; then checked them in the field at convenient or critical places. Contacts were traversed afoot wherever that was deemed advisable. It is more or less by chance that faults of less than 10 feet displacement are found in the course of such mapping. However, a number of such faults were found, as well as some that were larger, and they are shown on the geologic map (Plate I). Fath (1925) mapped the Bristow quadrangle, a part of Creek County, and his map shows some faults which the writer did not find after a rather thorough search, and they are not shown on the geologic map accompanying this report.

Merritt and McDonald (1930, p. 10) described an overthrust fault in the NW¼ sec. 10, T. 18 N., R. 10 E. which trends northeast, cuts the rocks at an angle of about 45 degrees with the vertical, and has a maximum throw of about 60 feet. The writer did not find this fault.

Most of the faults in Creek County trend northwest and are arranged en echelon in belts which trend east of north about parallel to the strike of the strata. Practically all are normal faults and their throw ranges from a few feet to more than 100 feet. They are part of a much larger group of such en echelon faults; in an area which extends from southern Seminole County to the Kansas-Oklahoma line, in northern Washington County and northeastern Osage County, and has its greatest width, about 40 miles, along the line connecting Okemah and Davenport. These faults have been the subject of speculation and comment by many geologists. The consensus of opinion seems to be that each en echelon belt is in some way associated with a deep-seated fault zone, or zone of weakness, and that the surface faults were caused by displacements, probably lateral, along these zones at great depth. These deep-seated faults are probably part of the system of northeastward trending faults so prominent in northeastern Oklahoma, mostly in rocks older than the Cabaniss group of the Des Moines series.

ECONOMIC GEOLOGY

The rocks that crop out in Creek County were deposited in a near-shore environment. Some, indeed, may have been deposited on tidal flats where they were above water part of the time. Moreover, the mud and sand that composed most of them accumulated more rapidly here than farther north, farther away from their source. There were no long periods without deposition to afford the clear water conducive to the accumulation of thick, pure limestones so useful to manufacturing, chemical, and processing industries. Nor were there at any time extensive swamps with abundant vegetation to form, eventually, thick coal beds, valuable because of their freedom from ash and other impurities. Except for a rather uniform westward tilting, these rocks have undergone little disturbance. There has been no intense folding, faulting, and intrusion of igneous rocks such as might have been accompanied by introduction of valuable minerals.

However, these surface rocks are not entirely without economic value. A few sandy limestones of sparse occurrence, in the north part of the county, and conglomerate beds, in the south part, yield materials useful for concrete aggregate and for road surfacing. Sandstone suitable for some sorts of building is rather common. Shale suitable for brick, tile, and even pottery is plentiful in the eastern part of the county. Sand suitable for some kinds of building and in sufficient amount for local use can be obtained from some of the stream channels, and from some of the surficial deposits associated with the streams. Ground water is obtainable in modest amounts and at economic depth almost everywhere in the county, from the numerous permeable sandstone beds, from some of the alluvial deposits along the streams, and from terrace deposits. The Arkansas River, only a few miles north of Creek County, supplies abundant sand for construction and the pure thick Lost City limestone in the vicinity of Sand Springs, also only a few miles north of Creek County, is a convenient source of limestone for all concrete construction and for many chemical uses.

The modest economic resources in the exposed rocks of Creek County are richly augmented by those of the unexposed rocks, the subsurface rocks. They probably contain moderately thick coal beds, too deep for exploitation under present economic conditions. They contain salt brines which could serve an alkali industry. But the greatest mineral resource of Creek County is its petroleum (oil and natural gas) in widespread accumulations.

The oil and gas resources of Creek County are described by Jordan, in another section of this bulletin, and the other mineral resources mentioned above are discussed by the writer in more detail under appropriate headings.

Coal

No coal bed of economic value crops out in Creek County, unless it is the Dawson coal east of Mounds. The Dawson coal should crop out across secs. 9 and 16, T. 16 N., R. 12 E., Creek County, but the writer has not seen a single exposure of that coal. Local residents reported several years ago that the Dawson coal was once mined in a small strip pit near the W¼ corner sec. 3, T. 16 N., R. 12 E., a short distance east of the Tulsa-Creek County line, and that it is about 2 feet thick there. The writer visited that locality in 1952 but found no indication of a strip pit at that time. A coal bed a few inches to possibly 2 feet below the base of the Hogshooter formation is less than 6 inches thick. The southernmost known exposure is at the top of the cut on the Turner Turnpike in the north part of Sapulpa, immediately below the overpass.

The Henryetta and possibly other coal beds should be found underground and should be of mineable thickness and within mineable depth, technically, but they could not be mined profitably under present economic conditions.

Limestone

Good limestone is a valuable resource in any community. It is used for crushed stone and building stone; for making lime; in portland cement, rock wool, and glass; in chemical manufacturing; and in processing industries. No good limestone crops out within the borders of Creek County, but the County is more fortunate than most in having an excellent source of supply within 10 miles of its north line, the Lost City limestone member of the Hogshooter formation.

Checkerboard limestone

The Checkerboard limestone crops out from the vicinity of Mounds northward along the east side of Creek County. It is generally about 2½ feet thick, dark blue, dense, hard, and fossiliferous. Conspicuous joint cracks divide it into nearly rectangular blocks as large as 3 by 5 feet. Its massive character gives it a special value for some purposes, but such a thin bed cannot be expected to yield a great tonnage of stone from any one quarry site. However, it should not be ignored if there is need for a small quantity of heavy stone near its outcrop.

Hogshooter limestone

The Lost City member of the Hogshooter limestone is about 50 feet thick, maximum, and is 40 feet thick over a considerable area in the vicinity of Sand Springs, Tulsa County. It is the nearest source of high grade limestone. The Lost City in that locality is gray massive fossiliferous limestone which makes excellent crushed stone and has been used for building stone. Some of it is composed of a mass of fossils which give polished surfaces a pleasing appearance. It may have possibilities as a decorative stone. Much of the Lost City is sufficiently pure for many chemical uses, being more than 95 percent calcium carbonate.

The Hogshooter limestone is only about 10 feet thick along the north side of Creek County, and is sandy and suitable for little else than crushed stone. It is thinner southward; generally south of Sapulpa, exposures of limestone mapped as Hogshooter are sandy and less than one foot thick. Diligent search along the outcrop might possibly disclose small areas in which calcareous sandstone suitable for road surfacing could be quarried.

Nellie Bly and Dewey formations

In small areas in the north part of the county, siltstone and silty sandstone in the upper part of the Nellie Bly formation and in the lower part of the Dewey formation are so tightly cemented by calcium carbonate that they make crushed stone that meets specifications for road construction, and it has been used in both concrete and asphalt roads. Known localities are as follows: (1) SE NW sec. 35, T. 18 N., R. 10 E.; a quarry in the Dewey formation. (2) Along the east side of the SW¼ sec. 27, and along the south side of the NW¼ sec. 26, T. 18 N., R. 10 E.; a bed in the upper part of the Nellie Bly formation, probably too thin to be useful. (3) In the road in the NW NW sec. 2, T. 17 N., R. 10 E.; a bed in the Dewey formation. (4) SE NE sec. 28, T. 17 N., R. 10 E.; a quarry in the Nellie Bly formation.

Iola formation

Sandy limestone occurs in the Iola formation. It is difficult to draw a sharp line between the Iola and Wann formations in Creek County, and some of the rocks discussed below may be actually in the lower part of the Wann formation.

At a few places in the north part of Creek County, representatives of the Iola formation contain sandy limestone suitable for concrete aggregate and for road surfacing. At other places the rock is actually a siltstone or silty sandstone cemented by calcium carbonate, but even this is useful. Solution of the calcium carbonate cement proceeds inward from exposed surfaces, such as those along joint cracks and bedding planes, and ordinarily there is a sharp line between the weathered material, so soft and friable that it is easily crushed in the hand, and the dense, hard, unweathered core. Usually the entire take from the quarry is put through the crusher and then through the screens, where the weathered, friable part is removed. Persons interested in such rock should visit the following localities: (1) East side of sec. 3, T. 18 N., R. 10 E. (2) NE¼ NE¼ sec. 7, T. 17 N., R. 10 E.

At many places exposed representatives of the Iola consist of siltstone and fine-grained, silty sandstone which is extremely light weight and porous and commonly contains fossils as casts and molds. Probably this rock was well cemented by calcium carbonate which has been removed by solution. Core drilling west of the weathered outcrop might disclose fresh, well cemented rock which would serve instead of limestone for many purposes.

Pawhuska formation

The Pawhuska formation crops out in the western part of Creek County. It contains the Lecompton and Turkey Run limestone members, but only the Lecompton is thick enough to be of economic value, and this only in Tps. 18 and 19 N., Rs. 7 and 8 E.

At some places in that area the Lecompton is 10 feet thick, or even thicker; is blue gray; weathers brown; is fossiliferous, and has thin, wavy bedding. It crushes readily and makes good rock aggregate and road surfacing, but contractors report that wear on crushing and handling machinery is serious.

Building Stone

Practically the only building stone available in Creek County is sandstone. The prevalence of sandstone buildings in the business district of nearly every town attests to the fact that sandstone useful for building is available nearly everywhere. It has not been much used in recent years because the cost of the hand labor involved makes it more expensive than other building materials. During the economic depression two decades ago various relief agencies revived, temporarily, the use of native sandstone. Only a few years ago a thin-bedded sandstone was shipped from Kellyville and used rather widely as veneer on both new and old buildings. There is plenty of sandstone suitable for building, and whenever economic conditions are favorable to stone it will be used.

Sand And Gravel

Sand that can be used for some kinds of construction and in sufficient amount for local use could be secured from some of the streams and their associated surficial deposits, but a really large amount of good sand will probably have to be brought from the Arkansas River, which flows eastward a few miles north of Creek County.

Chert gravel, used mostly for surfacing roads, is obtained from weathered outcrops of the chert conglomerate beds in the lower part of the Vamoosa formation in the south-central part of the county.

Clay And Shale

Brick and tile are made at Sapulpa from shale in the upper part of the Coffeyville formation. A pit in the same shale only a few city blocks away supplies the clay used in the Frankoma Pottery northeast of Sapulpa. No other ceramic plant in the County uses local materials.

No special attention was paid to clay and shale in the course of this investigation, and samples were not taken for laboratory tests. However, both clay and shale were seen at many places, and from cursory examination it seems that material suitable for making brick and tile is plentiful in the east part of the county, but is by no means present everywhere. Sampling and testing adequate to insure a sufficient supply should precede any new undertaking in this industry.

Water Resources

Practically all of the usable water of the world comes from rainfall. Part of the water that falls as rain soaks into the soil and eventually seeps into the rocks; part runs away as streams, which come together into ever larger streams, flow into lakes, and into the ocean. The water of streams and lakes is surface water, and that which is hidden from view in the earth is ground water. Much of the water is alternately surface water and ground water, as it comes to the surface as seeps and springs and again soaks into the ground. Obviously if water is taken from streams and lakes faster than rain replenishes it that source of water will fail, and it should be just as obvious that if water is taken out of the ground, naturally or artificially, faster than the insoak replenishes it that source too will fail. There is no such thing as an inexhaustible source water.

The people of Creek County depend on both surface water and ground water. All but three of the towns depend on ground water. Because there is no perennial stream or lake sufficiently large, and ground water is not available to them in sufficient amount, Sapulpa, Kiefer, and Mounds have constructed artificial lakes to serve as their water supplies. They are in the eastern part of the county where shale outcrops afford lake sites sufficiently impervious to prevent excessive loss by seepage. In addition to loss by seepage, loss by evaporation is also considerable, and a lake should be deep enough (not merely large enough) to allow for the total loss and still have enough water left to supply the demand between rainy seasons.

The demand for water is not so great in the rural areas as in the towns, but it is equally insistent. The rural areas depend on all sources of supply, streams, springs, natural lakes and "water holes," artificial lakes and ponds, and ground water.

An inventory of water wells covering most of Oklahoma was made by the State Mineral Survey, Works Progress Administration Project No. 65-65-538, sponsored and directed by the Oklahoma Geological Survey, 1935-37. The data are not all that might be desired for a scientific study of ground water in Creek County. They were assembled by untrained relief workers by questioning farm owners and tenants who leaned heavily on their memory for such things as depth of wells and depth to water, and on their own estimates and opinions in such matters as productivity of wells and quality of water. However, the definite nature of some of the questions asked and the great mass of material gathered make it possible to form a fairly good estimate of the possibility of developing water supplies at least large enough for a farm family and its animals. These data are at present in the files of the U. S. Geological Survey at Norman. A perusal of them indicates that it should not be difficult to get wells that will yield 75 to 300 gallons of water per day at depths of 25 to 150 feet almost anywhere in the County. Many wells are reported to yield 500 gallons per day. It is noteworthy that wells 150 to 300 feet deep are nearly uniformly the larger producers, as should be expected, because of the greater static pressure at the bottom of the wells, and therefore the greater draw down available. Most wells were unaffected by the extreme drought preceding and accompanying the survey.

Lake Heyburn on Brown's Creek, a tributary of Polecat Creek, in the northeast part of the county, is primarily a flood control lake, designed to protect the valley of Polecat from flash floods. A considerable conservation pool is maintained for recreational purposes and, no doubt, that water would be available to nearby communities in case of extreme emergency.

Ordinarily, in Oklahoma, the largest producing water wells are in the unconsolidated sands and gravels deposited by present streams, and in unconsolidated terrace deposits made by present streams when flowing at higher levels and by ancient streams. Reports of the Mineral Survey mention may wells in such unconsolidated sands and gravels, but none seems to have a greater yield than some of the wells in consolidated sandstone of Pennsylvanian age. Judging from reported depths, none of the wells which serve as municipal supplies is in unconsolidated sand or gravel.

SUMMARY STATEMENTS

1. Creek County is an area of about 972 square miles in the northeastern part of central Oklahoma. It is entirely within the drainage basin of the Arkansas River, but the Arkansas does not touch the county.

2. The surface of Creek County is a much dissected tableland, or plain, which slopes about 250 feet from the west side to the east side. The maximum topographic relief is about 250 feet.

3. Creek County is well supplied with railroads. The highways and other roads are adequate for the needs of the population, but many areas are difficultly accessible for the geologist who is not acquainted with the obscure roads and trails used by the farmers and ranchmen.

4. At the beginning of the present century, Creek County was a land of cattle ranches. Ranching gave way to farming, and most of the tillable land was once in cultivation. But uncontrolled erosion ravaged the land; now only the best is in cultivation and the rest is in pasture. Stock farming is the dominant type of agriculture. Most of the people work in the oil producing industry; there is a small amount of light manufacturing.

5. Creek County is on the north flank of the west end of the Arkoma basin, and the exposed bedrocks are transitional between the basin facies and the shelf facies. They were deposited late in the Pennsylvanian period, when the basin was sinking less rapidly in relation to rate of deposition, and the difference in thickness of the shelf and basin facies is not so strikingly great as in earlier Pennsylvanian rocks. The basin is not evident in the structure of these surface rocks which generally dip somewhat north of west, commonly at a rate of about 60 feet per mile.

6. The greater part of the exposed bedrock of Creek County is silty shale and silty nonresistant sandstone, but resistant sandstones and a few beds of limestone break them up into mappable units. The proportion of sandstone is greatest in the south part of the county and least in the north part. Thirteen named formations are shown on the geologic map (Plate I). A total of 65 bedrock units are designated. Also, two designated units of surficial deposits are shown.

7. A prominently high escarpment, capped for the most part by sandstone representative of the Iola formation, separates the outcrops of gray shale and generally brown to reddish-brown sandstone in the eastern part of the county from the dominantly red to variegated shales and reddish-brown to red sandstones in the west part.

8. Four unconformities are indicated on plates I and II. They are at the base of the Seminole formation, separating the Des Moines series from the Missouri series; at the base of the Chanute formation, separating the Skiatook group from the Ochelata group; at the base of the Barnsdall formation, within the Ochelata group; and at the base of the Vamoosa formation, separating the Missouri series from the Virgil series.

9. Several units of resistant sandstone are mapped in the Vamoosa formation, but it is by no means certain that any is strictly stratigraphic.

10. The surface rocks of Creek County are relatively poor in economic resources, but the subsurface rocks are rich in petroleum.

11. It is easy to get sufficient well water for an isolated farmstead nearly anywhere in Creek County, and all but three of the towns depend on wells. These three, Sapulpa, Kiefer, and Mounds depend on artificial lakes or reservoirs constructed by damming streams on shale outcrops, which are relatively impervious.

OIL AND GAS IN CREEK COUNTY, OKLAHOMA

By

LOUISE JORDAN

INTRODUCTION

Creek County has been an important area of oil and gas production since the first year of Oklahoma's statehood. Approximately 890,000,000 barrels of oil or more than 11 percent of Oklahoma's total production and an unknown but large quantity of gas have come from Pennsylvanian, Mississippian and Ordovician rocks which lie beneath the surface of the County. During many of the early years of petroleum production in Oklahoma, Creek County ranked first among the counties in production of both oil and natural gas. In 1956 and 1957, it was the fifth leading producer, following Garvin, Osage, Carter, and Stephens. During 1957, 6,971 wells produced nearly 9.9 million barrels of oil; and about 50 wells were producing gas at the beginning of the year.

Previous investigations: M. C. Oakes (this bulletin) mentions geologists who made early investigations of the geology of Creek County. Other contributions to the geology and petroleum engineering of oil and gas accumulations in local areas of Creek County include the following: Wardwell and others (1927), Weirich (1929), Riggs and others (1958), on Cushing Field; Martin (1929) on the Depew area; Wilson (1929) on Glennpool; Schwarzenbek and Ross (1922) on Slick Field, and Borden and Brant (1941) on East Tuskegee Field. A bibliography of Oklahoma oil and gas pools was published in 1942 as Bulletin 63 of the Oklahoma Geological Survey. Articles particularly on secondary recovery of oil containing some geological information have been published about a few areas in trade journals since that date. Regional studies covering the area of Creek County include those on Precambrian, Upper Ordovician, and Lower Ordovician rocks by Ireland (1944, 1946, 1955) and Dillé (1956); Simpson group by White (1928), Dapples (1955), and Cronenwett (1956); Pre-Woodford paleogeology by Tarr (1955); and Pennsylvanian rocks by Weirich (1953), Ware (1955), and Kirk (1957).

Present investigation: Early Oklahoma Geological Survey publications, Bulletin 19 (1917) and Bulletin 40 (1928) contain geological information on the prospects for and the accumulation of oil and gas in every county of the state. At the present time, accomplishment of such a project would require the cooperation of hundreds of geologists. As the mapping of areal geology of a county proceeds, it is hoped that an investigation of the geology as related to oil and gas accumulations can be made in order that the results may be included in one bulletin. Study of the subsurface geology of Creek County was commenced in April 1955 and was continued intermittently until completion. In this report regional geology is emphasized, and (1) no oil- or gas-producing area was studied in detail; (2) only approximately 180 electric logs averaging seven wells to a township were available; and (3) samples or lithologic logs of about 70 wells were studied. The structure map contoured on the base of the Woodford (Chattanooga) shale was prepared by using data from available electric logs and from selected drillers logs filed with the Oklahoma Corporation Commission. Probably 25,000 wells have been drilled for oil in the County. For many of the early wells, records were poorly kept or are lacking. Drillers logs are available for some 10,000 wells, but rock samples were not collected or saved from many of them. Today, even though electric logs of the borehole are normally taken, rock cuttings generally are not saved for future use.

Acknowledgments: The author gratefully acknowledges the assistance of many petroleum geologists in Oklahoma who made available information on the geology of Creek County and with whom she discussed problems of stratigraphy and structure. Sincere appreciation is extended to major company and independent geologists: John T. Bado for his work on the structure map; R. A. Brant for his information about Mississippian rocks; and Oscar B. Anderson, Jr., Gerald C. Maddox, Frederick James Smith, Thomas E. Weirich and L. M. Wilshire. The results of investigations undertaken as Master of Science theses in the University of Oklahoma by Bruce Furlow (1956), R. C. Krueger (1957), J. C. Hyde (1957), and M. S. Kirk (1958), with all of whom the author worked, have been incorporated at appropriate places in the report.

HISTORY OF DEVELOPMENT

Active search for petroleum resources in Creek County began in 1906 after the discovery in late 1905 of the Glennpool, the second field of major proportions to be found in Oklahoma. In 1906, about 110 wells were drilled in the field; and the first recorded production was 385,940 barrels for January 1907. A total of nearly 20,000,000 barrels or about 45 percent of the State's annual production came from this field in 1907. Drilling activities to the north, south, and west of Glennpool discovered Bowden in 1906, Sapulpa in 1907, Independent in 1908, and South Sapulpa in 1910. Drilling activities in the southern part of the county preceded the discovery of Glennpool and led to the first successful well in 1907. This well produced gas in the NW corner sec. 2, T. 15 N., R. 9 E. and supplied the town of Bristow for many years. In 1911, a well (sec. 36, T. 17 N., R. 9 E.) in the southern part of the now South Kellyville district, discovered gas at 990 feet with an initial flow of 7 million cubic feet per day. This supply was turned into the twelve-inch pipe line which carried gas to Oklahoma City.

By the end of 1911, Creek County had produced over 92 million barrels of oil. This production is attributed to the Glennpool. In March 1912 the discovery well (SW¼ NW¼ NW¼ sec. 32, T. 18 N., R. 7 E.) of the Cushing Field was completed. The third major field of Oklahoma, Cushing was of such prolific capacity that its production dominated the market of petroleum in the United States for several years. During 1912, oil was produced from the Layton and Wheeler pays which were found at 1,360 feet and 2,140 feet respectively (see electric log of General American's Wheeler No. 16 in NW¼ NE¼ NW¼ sec. 32, T. 18 N., R. 7 E.). In December 1913, oil was discovered in sec. 3, T. 17 N., R. 7 E., in the Bartlesville sand, which in this area is 420 feet below the top of the Wheeler. With steady development, oil production reached a peak in 1915 of more than 300,000 barrels per day, and a large volume of gas was produced in addition. The 1915 production from this field was 70.7 million barrels; however, only 49 million barrels or about 50 percent of the state's total production was marketed during this year.

During the years of development of the Glennpool and Cushing Fields, search for oil and gas continued in the "Bristow Field" (which apparently included a twelve-township area, Tps. 14-17 N., Rs. 8-10 E.) between the Cushing Field and Glennpool. Gas wells and small oil wells were discovered within the area. Production was found in the Dutcher sand in the area of the present Kellyville Field (sec. 23, T. 17 N., R. 10 E.) in 1912 or 1913, and a well which found oil in the Bartlesville sand discovered the Slick Field in 1913. Oil in the Dutcher sand was found in 1914 in Scott pool (sec. 2, T. 16 N., R. 10 E.) now a part of South Kellyville. In 1915, oil was discovered at Mounds and Depew and in the following year at Bristow, Jennings, and Pickett-Prairie. From the beginning of 1917 to the end of 1927, twenty-four new fields were located, mostly in the southern half of Creek County. These are listed below under the year of discovery: 1917, Iron Post; 1918, North Bristow, Red Bank; 1919, Wilcox; 1920, Deep Fork, Poor Farm; 1921, Olean; 1922, Mannford; 1923, Arno, Southeast Arno, Mercer, Southeast Depew, Walker, Mosquito Creek, Stroud; 1924, Big Pond, Tuskegee, Donnelly, Tibbens; 1925, East Tuskegee, West Kellyville; 1926, Bruce, West Mosquito Creek. Actual development in the "Bristow Field" started in 1920 and reached a peak in 1922. In the *Oil and Gas Journal* (January 23, 1920, p. 52) it is stated that the discovery of the prolific but short-lived production in the Youngstown pool of Okmulgee County in 1918 led to exploration and development of large production in T. 14 N., R. 11 E. and T. 15 N., Rs. 11 and 12 E. in Okmulgee County. This was followed by the opening of the "Dutcher" pool in the Slick Field in T. 15 N., R. 10 E. in Creek County in 1919, which led to the development in 1920 (*Oil and Gas Journal,* Jan. 21, 1921, p. 62) of "Eastern Bristow" (T. 15 N., Rs. 9 and 10 E., and T. 16 N., R. 10 E.). In 1921 the development of the "Continental pool" (Bristow Field of present nomenclature, secs. 26-28, T. 16 N., R. 9 E.) was holding the attention of oil circles. At the close of the year it was making 11,500 barrels per day from 15 wells and was the scene of great drilling and rig-building activity (*Oil and Gas Journal,* January 27, 1922, p. 64).

Annual production in Creek County declined from a high of 55.7 million barrels in 1915 to 19.2 million in 1920. With the development of the "Bristow Field," production rose to 20.9 million barrels in 1921 and to 36.2 million in 1922. This increase in production in 1922 over 1921 was the result of development in the "Greater Bristow" area. Production by districts or by fields in Creek County was not recorded for the years 1918 to 1923, but it must be assumed that production from Glennpool and Cushing Fields continued to decline through these years. In 1924, the Cushing-Glennpool-Sapulpa district produced 12.8 million barrels, while the "Greater Bristow Field" including "Bristow," "Kellyville," "Depew," and "Eastern Bristow," comprising eleven townships, produced 17.2 million barrels. Drilling activity in Creek County declined in 1924 and 1925, but in 1926 the County was the most active area in the state.

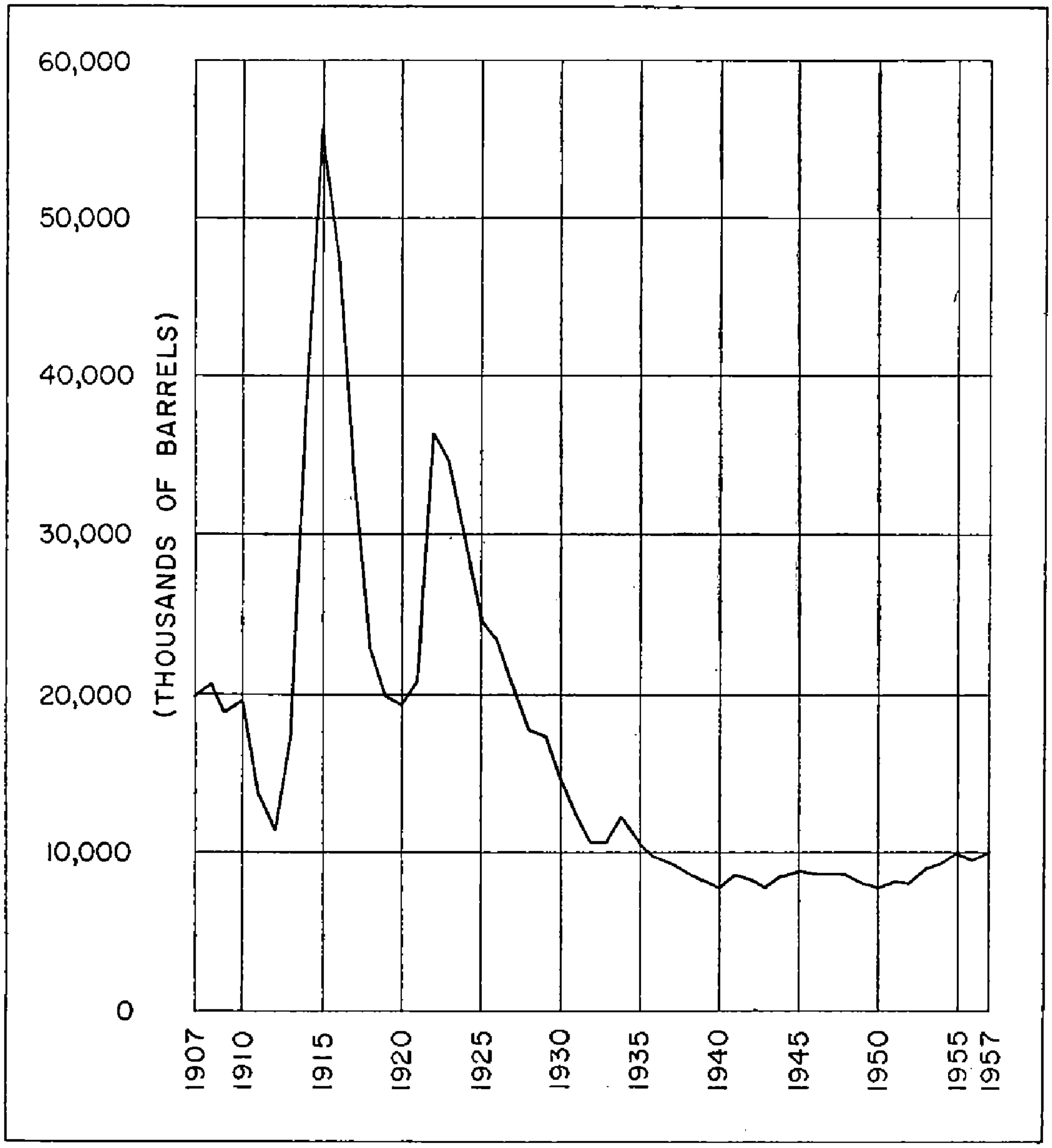

FIGURE 13. Chart of petroleum production in Creek County, 1907-1957.

No new fields were discovered in 1927 or 1928. Fields located since then to the present time are listed below in order of discovery: 1929, West Tuskegee (name changed from Newby in 1947); 1931 or 1932, Olive of present nomenclature; 1932, Lincreek; 1934, West Depew; 1939, West Arno, East Bruce, West Walker; 1940, Edna and East Stroud; 1941, South Bellvue, Milfay, Southeast Poor Farm; 1944, West Big Pond, Northeast Newby; 1945, Southwest Milfay; 1947, Northwest Tibbens; 1948, Southwest Jennings; 1949, Southeast Maramec; 1952, North Olive; 1953, Northwest Depew, Northwest Olive, Southeast Iron Post, South Olive; 1954, North Donelley, Northwest Edna, West Edna, South Edna, West Milfay, West Olean; 1955, South Edna, Forty-four, South Big Pond; 1956, Newby (also called Newby A), Northeast Silver City. None of these fields has been a major producer of oil, but Milfay, West Arno, East Stroud and Northeast Newby are among the more important in accumulative production.

Recent activity in Creek County reached a peak in 1954 when six new fields and five new producing zones in old fields were discovered. Annual production increased about 350,000 barrels over 1953, and over 1 million barrels above 1952 production. The number of producing wells at the end of 1954 increased nearly 500 in the one-year period. Much of this activity is attributed to extensive use of formation fracturing which stimulates flow of oil from most of the sandstone reservoirs of the county. Another important factor is the expansion of successful waterflood projects.

One of the difficulties in reading the early reports on Creek County is that the names of producing areas have changed. In 1935, the Kansas-Oklahoma Nomenclature Committee of the Mid-Continent Oil and Gas Association gave official names to all the oil- and gas-producing areas of the state. Previous to this time, the same name may have been applied to different fields, or the same area may have had two or more names. The official names of producing areas in 1957 are shown on the map of oil and gas fields (Panel I, Plate A). Listed below are the present official names with some of the names which have been used in the past for part or all of a producing area (in parenthesis):

Arno (Kernel)
Big Pond (at one time included in Depew)
Bowden (Oakhurst)
Bristow (Continental), Bristow District or Field at one time included a twelve-township area, Tps. 14-17 N., Rs. 8-10 E.
Bristow, North (at one time included Mosquito Creek, West Mosquito Creek and the area now called North Bristow)
Bruce (Tabor)
Cushing (Drumright, Oilton, Olive, Pemeta, Shamrock)
Depew, Southeast (Pure, at one time included in Depew)
Glennpool (Kiefer)
Independent (Sheridan). Old Independent pool included in Mounds.
Iron Post (Deep Fork, once called Billingslea, and Southeast Arno)
Jennings (Manuel)
Kellyville, South (Scott)
Mannford District (at one time included East Mannford, Southeast Mannford, Cottonwood and House Creek)
Misener (at one time included in Wilcox)
Mosquito Creek (once part of North Bristow)
Mosquito Creek, West (once part of North Bristow)
Olean (once included in Red Bank)
Olive (discovered about 1932, not Olive included in Cushing field)
Pickett Prairie (New York)
Sapulpa (Pumpkin Center)
Slick (Prairie, Eaton, at one time called Eastern Bristow)
Stroud (Key West, Hiett, Hickory Grove)

Tibbens (Sheetz)
Tibbens Northwest (Coppedge)
Tuskegee East (Nuyaka West)
Tuskegee West (Newby)

PETROLEUM PRODUCTION STATISTICS

The history of development of an area is revealed by the amount of crude oil produced and by the number of development and exploratory wells drilled each year. A compilation of the annual crude oil production for Creek County from published sources is shown in Table 4. These statistics are only an approximation, but they do present the important periods in the history of oil and gas development in Creek County. The data for the years 1907 through 1911 are for the Glennpool only and do not include other producing areas such as Sapulpa, Bowden, and Independent. From 1912 through 1917, the figures are the marketed production of Glenn and Cushing Fields. Crude production data from other fields in Creek County were published under the term "Creek district" which included Creek, Okmulgee, Muskogee, Wagoner, Okfuskee, and part of Tulsa Counties. In 1918, the *Oil and Gas Journal* published for the first time the production of counties in this district. The data for the years 1933-1941 and 1950-

TABLE 4

PETROLEUM PRODUCTION IN CREEK COUNTY, 1907-1957

(In thousands of barrels)

1907	19,907	1924	29,594	1941	8,329
1908	20,494	1925	24,502	1942	8,176
1909	18,947	1926	23,419	1943	7,995
1910	19,237	1927	20,552	1944	8,562
1911	13,880	1928	17,817	1945	8,930
1912	11,295	1929	17,108	1946	8,697
1913	17,652	1930	14,573	1947	8,787
1914	30.263	1931	12,281	1948	8,693
1915	55,704	1932	10,862	1949	8,007
1916	47,193	1933	10.887	1950	7,901
1917	34,646	1934	12.008	1951	8,066
1918	22,885	1935	10,881	1952	8,102
1919	19,934	1936	9,907	1953	9,020
1920	19,272	1937	9,341	1954	9,368
1921	20,962	1938	8,837	1955	9,936
1922	36,163	1939	8,266	1956	9,727
1923	34,711	1940	8,057	1957	9,895

TOTAL OF ABOVE FIGURES: 840,232
TOTAL FROM OTHER SOURCES: 891,077

Sources: 1907-1917, Mineral Resources of the United States, *U. S. Geological Survey;* 1918-1932, *Oil and Gas Journal;* 1933-1941, 1950-1951, Oil and Gas Development in the United States, *National Oil Scouts and Landmen's Association,* Yearbook; 1942-1949, 1952-1957, Petroleum Development and Technology, and Statistics of Oil and Gas Development and Production, *Amer. Inst. Mining and Metallurgical Engineers.*

1951 are pipe-line runs from the County. When production figures for a certain year could be found in two sources of information, it was normal that they did not agree. Explanation for this difference may be that production of fields crossing county boundaries may be assigned to one county by one source and to the adjacent county by the other source. Two noteworthy examples are the Glennpool, which extends into Tulsa County. Its production is normally assigned to Creek County. On the other hand, Stroud field production may be assigned to Creek County or to Lincoln County or may be divided between the two counties. This condition is applicable to production data for any of the fields which cross the county boundary. The total production, as shown in Table 4, is 840,232,000 barrels of oil, which is about 50 million barrels less than the aggregate production figure compiled by members of the American Institute of Mining, Metallurgical and Petroleum Engineers. Nevertheless, the data for production by years shown as a graph (Figure 13) indicate that 1908, 1915, and 1922 were important years for Creek County. Annual production has been increasing slightly since 1950, primarily because of production from secondary recovery projects rather than new field discoveries. At the end of 1956, thirty-two waterflood programs on 22,000 acres were recovering oil from Layton, Skinner, Red Fork, Bartlesville (Glenn), Dutcher, and Wilcox reservoirs (Research Oil Reports, 1957). Seventeen waterflood and gas injection projects in the central and south parts of Cushing Field were operating or planned to produce from Bartlesville, Layton, Wheeler, and Prue sands (Riggs and others, 1958, p. 21). Two waterflood projects in the north part of the field produce from the Red Fork reservoir. Similar projects in Glennpool are confined to the Bartlesville (Glenn) sand. Skinner sand under 4,300 acres is being successfully waterflooded in Iron Post (Deep Fork) Field. Secondary oil production is obtained from Dutcher sand in a small area of Slick Field, and from Wilcox sand of Milfay Field (Research Oil Reports, 1957). Secondary recovery has become of prime importance in producing operations in Creek County. At the end of 1957, waterflood projects were in progress or in the planning stage in all but a few fields in the County. One hundred service wells were drilled in 1958, nearly 20 percent of the 525 wells drilled in the County during the year. Table 5 lists oil fields in Creek County alphabetically, gives year of discovery, number of wells producing and production for 1957, and names of oil sands which have produced or are producing in the field. Cumulative production of oil from a field is given if known.

The number of tests drilled for oil and gas each year reveals the history of development of an area. Complete statistics through the years on this phase of activity are not available, but Table 6 shows the annual data for some of the years. No information is available for Creek County previous to 1912, but it is well known that development was high in the Glennpool area in 1907. Peaks of drilling activity which coincide with peaks of annual production of oil are recorded in 1915, when more than 1,070 tests were drilled in Cushing field alone, and in 1922, when 990 tests were drilled. Increased drilling in the early fifties resulted in a slight increase of production in 1955. It is not known how many holes have been drilled for oil in Creek County since exploration and development commenced. About 10,000 logs of wells drilled are filed with the Oklahoma Corporation Commission, but relatively few of the tests drilled previous

TABLE 5

PRODUCTION STATISTICS, PRODUCING SANDS OF OIL FIELDS IN CREEK COUNTY

Field	Year discovery	Wells producing	1957 production (bbls.)	Cumulative production (bbls.)	Producing sands
Arno	1923	8	24,090	716,761	Dutcher, Wilcox
*Arno, SE	1923				(Combined with Iron Post, 1954)
*Arno, W	1939	43	102,952	1,848,956	Prue, Red Fork, Wilcox
Bellvue, S	1941	6	5,217	254,095	Red Fork
Big Pond	1924	81	138,335	------	Jones, Prue, Skinner, Bartlesville, Dutcher, Wilcox
Big Pond, S	1955	2	445	600	Skinner
Big Pond, W	1944	2	1,614	95,516	Prue
Bowden	1906	165	79,935	23,137,297	Bartlesville, Booch, Dutcher, Wilcox
Bristow	1916	91	180,675	------	Bartlesville, Dutcher, Wilcox
Bristow, N	1922	200	221,920	------	Layton, Prue, Skinner, Red Fork, Bartlesville, Wilcox
Bristow, W	1922	13	30,660	------	Dutcher, Wilcox
Bruce	1926	33	24,455	------	Wilcox
Bruce, E	1939	9	1,825	------	Layton
Coppedge	1952				(Name changed to NW Tibbens)
Cushing	1912	1,794	2,706,110	405,487,568	Layton, Jones, Cleveland, Wheeler, Skinner, Red Fork, Bartlesville, Misener, Wilcox (Tucker), Arbuckle
Deep Fork	1920				(Combined with Iron Post, 1953)
Depew	1915	82	271,925	41,361,000[1]	Bartlesville, Dutcher, Wilcox
Depew, NW	1953	19	27,280	237,165	Prue
Depew, W	1934	3	6,205	------	Wilcox
Donnelly	1924	35	42,705	------	Skinner, Bartlesville, Dutcher, Misener, Wilcox
Donnelly, N	1954	2	1,525	13,874	Lower Dutcher
*Edna District	1919	46	27,984	------	Dutcher, Wilcox

*Glennpool	1905	1,817	2,207,862	256,203,837	Oswego, Prue (Perryman), Red Fork, Bartlesville (Glenn), Booch (Taneha), Wilcox, Turkey Mountain (Arbuckle)
*Independent	1908	25	21,535	------	Dutcher, Wilcox
Iron Post	1917	405	955,570	13,041,000[2]	Cleveland, Prue, Skinner, Red Fork, Dutcher, Wilcox
Iron Post, SE	1953	2	1,911	31,134	Dutcher
*Jennings	1916	100	162,060	5,217,894	Skinner, Red Fork, Bartlesville, Booch (Taneha), Burgess, Wilcox
					(Combined with Jennings, 1956)
Jennings, E					
Jennings, SE	1955	35	141,267	141,267	Red Fork
Jennings, SW	1948			114,273	(Combined with Jennings, 1956)
Kellyville	1915	285	253,310	------	Peru, Skinner, Red Fork, Bartlesville (Glenn), Dutcher, Mississippi lime
*Lincreek	1932	21	46,355	396,520	Cleveland, Bartlesville, Mississippi lime, Wilcox
Mannford	1922	471	627,070	11,209,000[2]	Layton, Cleveland, Oswego, Prue, Skinner, Red Fork, Bartlesville, Burgess, Wilcox
Maramec, SE	1949	5	11,680	30,087	Red Fork
Mercer	1923	3	3,860	387,035	Wilcox
Milfay	1941	40	75,952	2,788,084	Wilcox
Milfay, SW	1945	3	2,974	21,864	Skinner
Milfay, W	1954	1	4,259	19,465	Wilcox
Mosquito Creek	1923		0	------	Jones, Prue, Bartlesville, Dutcher
Mosquito Creek, W	1926		0	------	Jones, Cleveland, Prue, Dutcher, Wilcox
*Mounds	1915	49	77,015	------	Red Fork, Bartlesville, Booch (Taneha, Tucker), Dutcher, Wilcox
					(Name changed to West Tuskegee, 1954)
Newby					
Newby A	1956	15	72,428	101,617	Dutcher
Newby, NE	1944	38	67,609	853,690	Skinner
Olean	1921	17	13,870	------	Wilcox
Olean, W	1954	9	37,829	215,666	Misener, Wilcox
Olive	1932?	211	135,415	------	Layton, Cleveland, Red Fork, Bartlesville, Dutcher, Mississippi lime
Olive, N	1952	4	4,231	30,130	Red Fork

Field	Year discovery	Wells producing	1957 production (bbls.)	Cumulative production **(bbls.)**	Producing sands
Olive, S	1953	2	2,574	18,734	Prue
*Pickett Prairie	1916	61	51,100	----	Red Fork, Bartlesville (Glenn), Booch (Taneha), Dutcher, Wilcox
Poor Farm	1920	9	6,205	------	Jones, Prue, Bartlesville, Dutcher, Wilcox
Poor Farm, SE	1941	3	1,086	42,314	Wilcox
Red Bank	1918	29	69,715	------	Bartlesville, Dutcher, Misener, Wilcox
Sapulpa	1909	89	40,515	------	Cleveland, Prue (Perryman), Red Fork, Bartlesville (Glenn), Booch (Taneha), Dutcher, Wilcox
Sapulpa, S	1910	142	79,205	------	Booch (Taneha), Dutcher, Wilcox
Silver City, NE	1956	13	69,907	73,746	Red Fork
Slick	1913	273	656,635	40,104,000[2]	Skinner, Red Fork, Dutcher, Misener, Wilcox
Stroud, E	1940	14	23,827	1,304,452	Prue, Wilcox
Stroud, Hickory Grove sector	1942	14	15,486	293,098	Prue
Stroud, Hiett sector	1948	13	3,856	330,774	Prue
*Stroud, SE sector	1943	90	44,053	3,005,974	Prue, Wilcox
Tibbens	1920	79	74,095	------	Layton, Prue, Skinner, Bartlesville, Dutcher, Wilcox
Tibbens, NW	1952	2	2,317	10,854	Skinner
Tibbens, W	1953				(Abandoned in 1954)
Tuskegee	1924	2	766	------	Dutcher, Wilcox
Tuskegee, E	1925	28	23.116	1,899,014	Dutcher, Misener, Wilcox
Tuskegee, W	1951	7	10,960	87,737	Dutcher
Walker	1923	27	36,135	------	Bartlesville, Dutcher (Gilcrease)
Walker, W	1939	6	1,616	165,313	Bartlesville, Dutcher (Gilcrease)
*Wilcox	1919	67	147,095	5,524,000[1]	Dutcher, Wilcox

* Part of field lies outside of Creek County.
[1] Cumulative production for 1941 plus annual data compiled from *Oil and Gas Journal.*
[2] *Oil and Gas Journal.* Jan. 27, 1958, vol. 56, no. 4, p. 166.
Data compiled from "Statistics of oil and gas development and production": Amer. Inst. Mining. Petroleum Engineers, vol. 12 covering 1957; and "Oil and gas field development in United States and Canada," Yearbook 1958 (review of 1957): National Oil Scouts and Landmen's Assoc., vol. 28.

to 1912 are included and the records for later years are quite incomplete. An estimate of 25,000 tests is probably conservative, as the total number of holes drilled shown in Table 6 is 19,041. Except for records in the Cushing Field, this table does not include data for the County for the years 1905 to 1918 and 1932 to 1950. The number of exploratory and development wells and annual total footage drilled for the eight-year period, 1951-1958, are given in Table 7.

TABLE 6

DRILLED OIL WELLS, GAS WELL, AND DRY HOLES, AND TOTAL PRODUCING WELLS IN CREEK COUNTY, BY YEARS, 1912-1958

Year	Oil Wells Drilled	Gas Wells Drilled	Dry Holes	Producing Wells[3]
1912[1]	737			
1913[1]	836	62	45	
1914[1]	758			
1915[1]	1,003	17	50	
1916[1]	768	41	40	
1917[1]	343	20	30	
1918	205	7	68	
1919	467	38	156	
1920	690	56	115	
1921	606	50	154	
1922	990	57	233	
1923	945	52	300	
1924	515	48	144	
1925	508	56	169	
1926	735	54	200	
1927	548	69	181	
1928	301	42	137	
1929	30	9	19	
1930	244	38	84	
1931	219	35	69	
1932-1949[2]				
1950	230	9	112	
1951	224	6	116	
1952	224	4	168	5,484
1953	418	13	148	5,644
1954	552	14	260	6,161
1955	469	15	268	6,487
1956	386	11	199	6,924
1957	297	6	186	6,971
1958	307	7	100	
	14,554	736	3,751	

Data from *Oil and Gas Journal* annual review issue. [1]Cushing field only; [2]no information; [3]Statistics of oil and gas development and production: *Amer. Inst. Mining and Metallurgical Engineers.*

TABLE 7

DEVELOPMENT AND EXPLORATORY WELLS, AND FOOTAGE DRILLED IN CREEK COUNTY, 1951-1958

Year	Development Wells			Exploratory Wells			Total				
	Oil	Gas	Dry	Oil	Gas	Dry	Oil	Gas	Dry	Total	Footage drilled
1951	221	5	109	3	1	7	224	6	116	346	918,884[2]
1952	222	4	157	2	0	11	224	4	168	396	1,210,813
1953	410	9	119	8	4	29	418	13	148	579	1,414,248
1954	548	13	249	4	1	11	552	14	260	826	2,047,862
1955	467	15	244[1]	2	0	24	469	15	268	752	1,811,271
1956	382	10	189[1]	4	1	10	386	11	199	596	1,438,713
1957	296	6	183[1]	1	0	3	297	6	186	489	1,187,688
1958	306	7	97	1	0	3	307	7	100	525[1]	1,188,678

Data from *Oil and Gas Journal* annual review issue. [1]Includes service wells; service wells not mentioned in previous years. [2]Development figures compiled from data on fields.

STRATIGRAPHY

Rocks penetrated in wells drilled for oil and gas in Creek County range in age from Precambrian to Late Pennsylvanian. Precambrian granite found in several wells in the northern part of the County is overlain by a transgressive sandstone or by carbonate rocks of the Arbuckle group of Late Cambrian or Early Ordovician age. In the southern part of the County, the Arbuckle is succeeded unconformably by Simpson sandstone and shale, Viola-Fernvale limestone, and Sylvan shale of Middle and Late Ordovician age, and Hunton limestone of Silurian or Devonian age. Middle and Upper Ordovician and Silurian-Devonian rocks are beveled northeastward by pre-Woodford erosion and are overlapped by Woodford shale or at places by a basal sandstone member, Misener, of Late Devonian age. Woodford rests upon Hunton limestone in the southwest and upon some part of the Simpson in the north. The Woodford shale is overlain by Kinderhookian or Osagean rocks succeeded by Meramecian and Chesterian units, all of Mississippian age, which are beveled northwestward previous to Pennsylvanian deposition. Morrowan, Atokan, and Desmoinesian units of the Pennsylvanian system successively onlap the Mississippian surface toward the northwest and are overlain by Missourian and Early Virgilian units now exposed at the surface in narrow northeast-trending outcrop bands.

PRECAMBRIAN ROCKS

Precambrian rocks have been penetrated in ten wells in Creek County. Five of the tests are in the Cushing Field area, one in the Mannford District, two in Glennpool, and two in T. 17 N. between the Glennpool and Cushing fields (Table 8). Rock cuttings from a depth of 3,903 to 3,904 feet in Gulf Oil Corporation No. G26S North Glenn Sand Unit 2 were examined by C. A. Merritt who describes the rocks as hornblende granite of medium coarse-crystalline granitic texture containing coarse-crystalline pink feldspar and fine-crystalline anhedral quartz with minor amounts of magnetite and of hornblende altered to chlorite. Red, red-brown or pink granite has been identified by geologists in Central Commercial No. 3 Hay, Woods No. 9 Bartlett, and Gulf No. 1-S Berryhill wells.

Creek County is in the area of regional studies of the Precambrian surface of northeastern Oklahoma made by H. A. Ireland (1955) and A. C. Dillé (1956). Using seven of the wells listed in Table 8, Ireland reconstructs Precambrian topography using isopach lines of estimated original thickness of pre-Simpson strata. Two recently drilled wells in the eastern part of the county penetrated 500 to 600 feet more section that he postulates. Dillé shows by structure contours the present position of the Precambrian surface using eight of the listed wells. He states that Creek County is in an area where the Precambrian surface deepening southwest of Tulsa is interrupted by the "Cushing Ridge." The present position of Precambrian rocks and the apparent thickness of pre-Simpson rocks in the Cushing Field are in part at least the result of (a) post-Morrowan faulting which occurred along a line of adjustment extending from Pottawatomie and Seminole Counties northward through eastern Payne County, (b) of erosion down to the Arbuckle before deposition of Pennsylvanian sediments, and (c) of movement during Pennsylvanian time.

Ordovician System

Rocks of Ordovician age overlie Precambrian granite and consist of the following units (ascending order): Arbuckle dolomite, Simpson group, Viola and Fernvale limestones, and Sylvan shale. The term Arbuckle dolomite is applied to the pre-Simpson, post-Precambrian rock section which at places contains sandstone at the base.

Arbuckle dolomite. Ireland (1944) in a study of pre-Simpson rocks in northeastern Oklahoma states that the 1,073 feet of Arbuckle rocks in the Central Commercial No. 3 Hay is Early Ordovician in age. He subdivides the section into Roubidoux, Jefferson City, Cotter and Powell formations (ascending order) and places 80 feet of arkosic sandstone resting upon granite in the Roubidoux formation. Wells to the east drilled by Gulf Oil Corporation penetrated about 1,400 feet of Arbuckle. (See Table 8.) The upper 900 feet of section is predominantly dolomite ranging from fine- to coarse-crystalline texture, oolitic and cherty in part, and containing occasional thin beds (less than 20 feet) of sandstone or arenaceous dolomite. In Gulf No. 1-S Berryhill where the top of the Arbuckle is at 2,535 feet, medium- to coarse-grained sandstones interbedded with dolomite are present between 3,400 to 3,600 feet. Below this depth occurs about 200 feet of medium- to coarse-crystalline dolomite which is underlain by 100 feet of fine- to very coarse-grained sandstone containing minor amounts of glauconite. This sandstone rests upon five feet of arkose which is underlain by granite. In Gulf No. G26S well, the basal 150 feet of section above the granite is fine- to coarse-grained sandstone interbedded with dolomite containing traces of glauconite. The basal part of this Arbuckle section may be Cambrian in age. The term Reagan or Lamotte is generally applied to the sandstone at the base of the Arbuckle.

Oil accumulated at the top of the Arbuckle dolomite under structural conditions is produced at Cushing Field and at Bowden Field where the dolomite was termed Turkey Mountain sand.

Fernvale-Viola-Simpson. Geologists are not in agreement on the boundary between the Simpson group and the Viola limestone in Creek County. In the southern part of the County, the first limestone penetrated below the Sylvan shale is called Fernvale or Viola, and the underlying sandstones are called "First" and "Second Wilcox." A typical stratigraphic section, from Skelly Oil Company No. 1 Fife (NW¼ NE¼ SE¼, sec. 15, T. 14 N., R. 8 E.), is described below (in feet):

3,730-3,760 Limestone, white to tan, coarse-crystalline with imbedded quartz grains at base. Termed Viola or Fernvale-Viola and considered equivalent to Fernvale limestone.

3,760-3,765 Limestone, buff to brown, lithographic. Termed Viola Dense or Simpson Dense, considered top of Simpson group by some geologists.

TABLE 8

WELLS WHICH PENETRATED PRECAMBRIAN ROCKS IN CREEK COUNTY

Operator, lease location	Elevation in feet	Top of Arbuckle	Top of Precambrian	Top Arbuckle to top Precambrian	Penetration of Precambrian	Year drilled
Cosden Oil & Gas No. 17 Barnett NE NW SE, 22-17N-7E	1,011	3,055	3,670	615	34	1921
Prairie Oil & Gas No. 3 Letts SE SW SE, 23-17N-9E	832	3,685	4,325	640	19	1923
Central Commercial No. 3 Hay SW NW SW, 10-17N-10E	793	3,205	4,278	1,073	4	1937
Gulf Oil Corp. No. 1-S Berryhill SE NW NE, 17-17N-12E	720	2,535	3,925	1,390	4	1955
Cortez Oil Co. No. 4 Gilbra NW SW NW, 2-18N-7E	810	3,692	?3,995	?303	0	1917
Sand Springs Home No. 13 Atkins NE SW NW, 4-18N-7E	825	2,821	3,640	719	171	1925?
Riverside No. 2 Yarhola NW SW SE, 8-18N-7E	748	2,379	3,793	1,414	17	1927
Gulf Oil Corp. No. G26S, N. Glenn Unit 2 SE NW SE, 29-18N-12E	740	2,490	3,898	1,408	6	1956
Magnolia Oil Co. No. 4 Richards NW SE SW, 32-19N-7E	847	3,020	3,887	867	73	1926
Wood Oil Co. No. 9 Bartlett C NE, 18-19N-9E	805	3,074	3,665	594	72	1956

3,765-3,770 Dolomite, light gray to brown, fine-crystalline with imbedded quartz grains at base.

3,770-3,775 Sandstone, white, fine- to medium-grained. Termed "First Wilcox,' considered equivalent to Seminole sand (post-Simpson) by some geologists or to be in the Bromide formation by others.

3,775-3,785 Dolomite, buff, fine-crystalline. Considered top of Simpson group by some geologists.

3,785-3,875 Sandstone, fine- to medium-grained with some rounded, frosted quartz grains. Termed "Second Wilcox."

3,875-3,935 Calcareous sandstone interbedded with green and gray shale. Termed Tyner.

3,935-4,000 Calcareous sandstone interbedded with green and maroon shale. Termed Tyner.

4,000-4,110 Interbedded calcareous or dolomitic sandstone, calcareous arenaceous dolomite, dolomite, and green and maroon shale. At places termed Burgen.

4,110 Top Arbuckle dolomite.

The above sequence of rocks is similar to that found in T. 19 N., R. 7 E. where the section is 300 to 350 feet thick except that normally the "First Wilcox" is absent and the lower part of the Simpson contains less carbonate. The interval from the top of Viola to "Second Wilcox" is about 40 feet.

In the northeastern part of the county, the terms "Hominy" or "Burgen" have been applied to any oil-productive sandstone interbedded with Tyner shale or with the lower carbonate-sandstone-shale unit, and below an uppermost sandstone called "Wilcox." In this area at most places, Woodford shale overlies the "Wilcox," but north of the line of truncation of Viola shown on figure 14, outliers of lithographic limestone and dolomite rest upon "Wilcox." The maximum thickness of Fernvale-Viola limestone in the County is about 30 feet and is found where the unit underlies Sylvan shale.

In Glennpool, the Simpson section ranges from 220 to 270 feet in thickness. Northward in the old Bowden (Oakhurst) Field in sec. 1, T. 18 N., R. 11 E., its thickness is 100 feet or less on top of the structure where Tyner shale underlies Woodford shale. Production was obtained from "Turkey Mountain" (Arbuckle) and "Hominy" pays, and from "Wilcox" on the flanks of this pre-Woodford structure.

The Fernvale-Viola-Simpson sequence thickens regionally to the southwest ranging from 400 feet in sec. 32, T. 14 N., R. 10 E. and 385 feet in sec. 15, T. 14 N., R. 8 E., to 450 feet in sec. 19, T. 15 N., R. 7 E. It is thin over local pre-Woodford structures and absent over the Dropright and Mount Pleasant domes of Cushing Field (figure 15).

Oil production from Simpson sandstones is recorded from West Arno, Big Pond, Bowden, North and West Bristow, Cushing, Depew, Donnelly, Glennpool, Independent, Iron Post, Mannford, Mercer, Milfay, West Milfay, Mounds, Olean, West Olean, Pickett Prairie, Poor Farm, Southeast Poor Farm, Red Bank, Sapulpa, Slick, East and Southeast Stroud, Tibbens, East Tuskegee and Wilcox Fields. Accumulation is related to local small (40 to 80 acre) domes or anticlines in all these fields except Cushing Field.

Oil recovery from Simpson sandstones termed Tucker, Wilcox or Tyner at Cushing Field amounted to 15.3 million barrels for part of the field area at the end of 1955 (Riggs and others, p. 11).

Sylvan shale. The Sylvan is a green-gray fissile shale which is truncated by pre-Woodford erosion along a line trending eastward from T. 17 N., R. 7 E. to T. 16 N., R. 10 E. (figure 14). Its greatest thickness, about 90 feet, occurs in T. 14 N., R. 7 E., the only area in the county where it is overlain by Hunton. The Sylvan is locally thin where overlain unconformably by "Misener" sand.

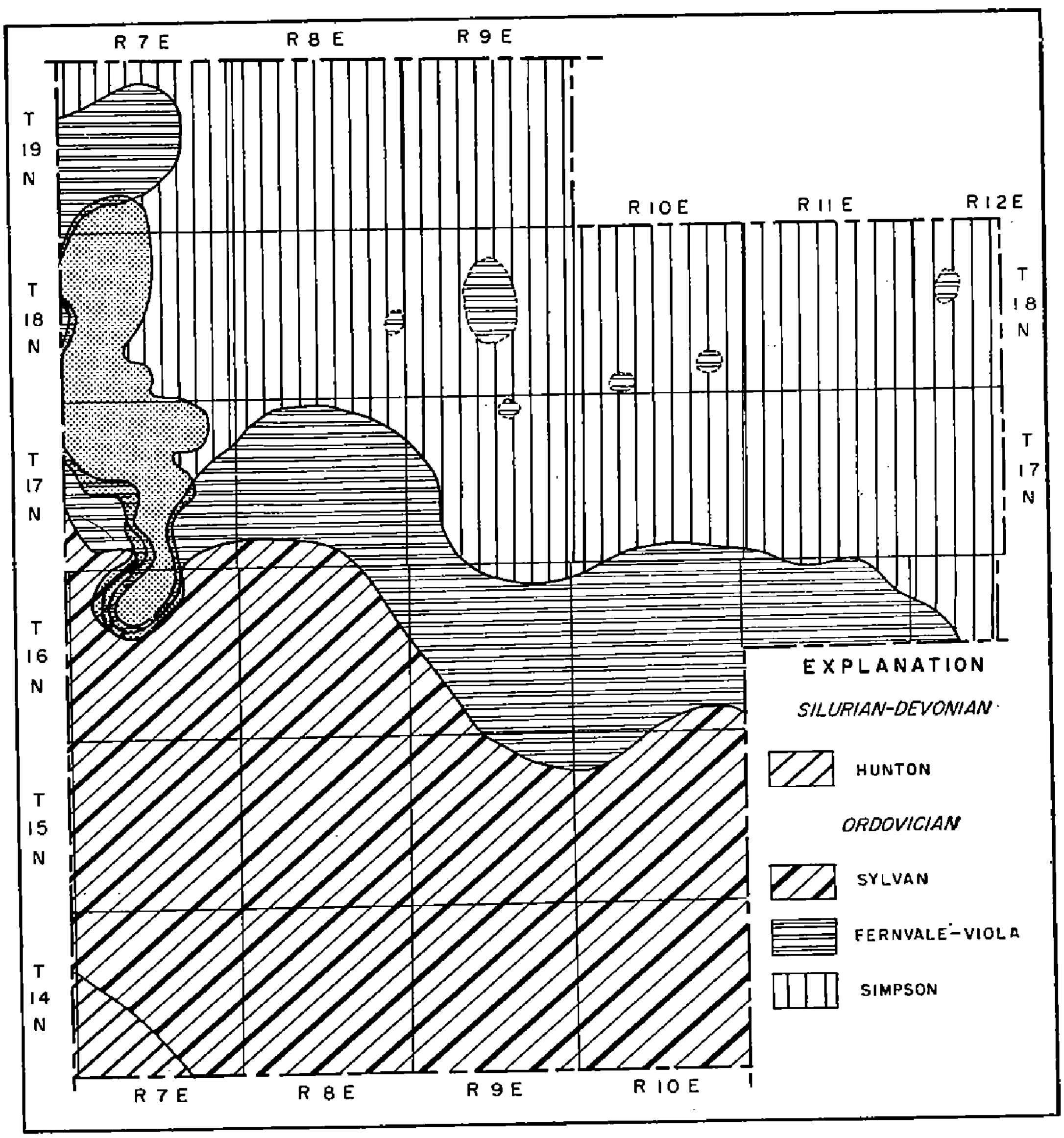

FIGURE 14. Pre-Woodford subcrop map of Creek County. Woodford removed at stippled area from Cushing Field by early Pennsylvanian erosion. In northern part of County isolated areas of Fernvale-Viola are only partly shown.

Silurian Devonian Systems

Hunton group. Rocks which are called Hunton have been penetrated in the southern sections of T. 14 N., R. 7 E. In the Sunray No. 1 Deere (NW¼ NE¼ NE¼ sec. 34, T. 14 N., R. 7 E.) the section termed Hunton consists of 14 feet of brown fine- to medium-crystalline dolomite containing blue-white opaque chert. The thickest penetrated section is reported as 23 feet from a well in the NE corner of sec. 24, T. 14 N., R. 6 E.

Devonian System

"Misener" sand. This term is applied to a variety of rock types—sandstone, dolomitic sandstone, dolomite or chert conglomerate, which underlie locally the Woodford shale and rest unconformably upon older rocks as shown on pre-Woodford paleogeologic map, figure 14. Borden and Brant (1941, p. 446) describe microscopically the lithology of the "Misener' from 50 sets of samples in T. 14 N., R. 10 E. where it lies below Woodford and above Sylvan. In this area the "Misener" ranges in thickness from zero to 60 feet and is thicker in the areas where the Sylvan shale has been eroded more deeply. In Creek County, the "Misener" is best developed south of the line of truncation of the Sylvan shale. However, locally in this area, "Misener" may rest directly upon the eroded surface of Fernvale limestone (Borden and Brant, 1941, p. 448).

"Misener" production is reported from Cushing, Donnelly, West Olean, Red Bank, Slick, East Tuskegee and Wilcox Fields. "Misener" sand is called "Wilcox" in the southeastern part of the county in many of the early drillers logs.

Woodford shale. Woodford (Chattanooga) shale is everywhere present in Creek County except over the Cushing ridge where it was removed by Early Pennsylvanian erosion. It is a brownish-black shale containing *Tasmanites*, conodonts, pyrite nodules, and at places minor amounts of pyritic brown chert. It ranges in thickness from 20 to 30 feet. In the eastern half of the County the Woodford underlies a Kinderhookian limestone and shale unit, and in the western part of the County it underlies a glauconitic dark gray to black argillaceous limestone or calcareous shale unit of basal Osagean age. This basal black shale has been included with the Woodford in many drillers logs. A structure map of the County was made using the base of the Woodford as datum (Panel I, Plate B) because this horizon is readily recognized in drillers logs.

Mississippian System

Mississippian rocks in Creek County thicken regionally in a southeasterly direction from slightly under 250 feet in T. 19 N., R. 8 E. to over 450 feet in T. 14 N., R. 10 E. They are missing over the Cushing structure and are locally thin over pre-Pennsylvanian structures. Folding, southward tilting, and erosion occurred after Mississippian time, and the pre-Pennsylvanian paleogeologic map (Figure 15) shows the resulting subcrop of Chesterian, Meramecian, and Osagean units in the County. Rock units similar in lithology to those which crop out on the surface of northeastern Oklahoma and separable by electrical characteristics have been assigned a Kinderhookian, Osagean, Meramecian, or Chesterian age (ascending order). The maximum thickness of the oldest or Kinderhookian unit is about 50 feet, and that of each of the upper three units is about 250 feet. An angular unconformity exists between the Meramecian and Osagean units, the latter thickening northward as the Meramecian thins by truncation. Evidence also indicates that unconformities are present between the Kinderhookian and Osagean units, and between the Meramecian and Chesterian units.

Mississippian rocks are unimportant as reservoirs of oil and gas in Creek County. Production has been reported from these rocks at Bowden, Bristow, Glennpool, Lincreek, and Sapulpa Fields.

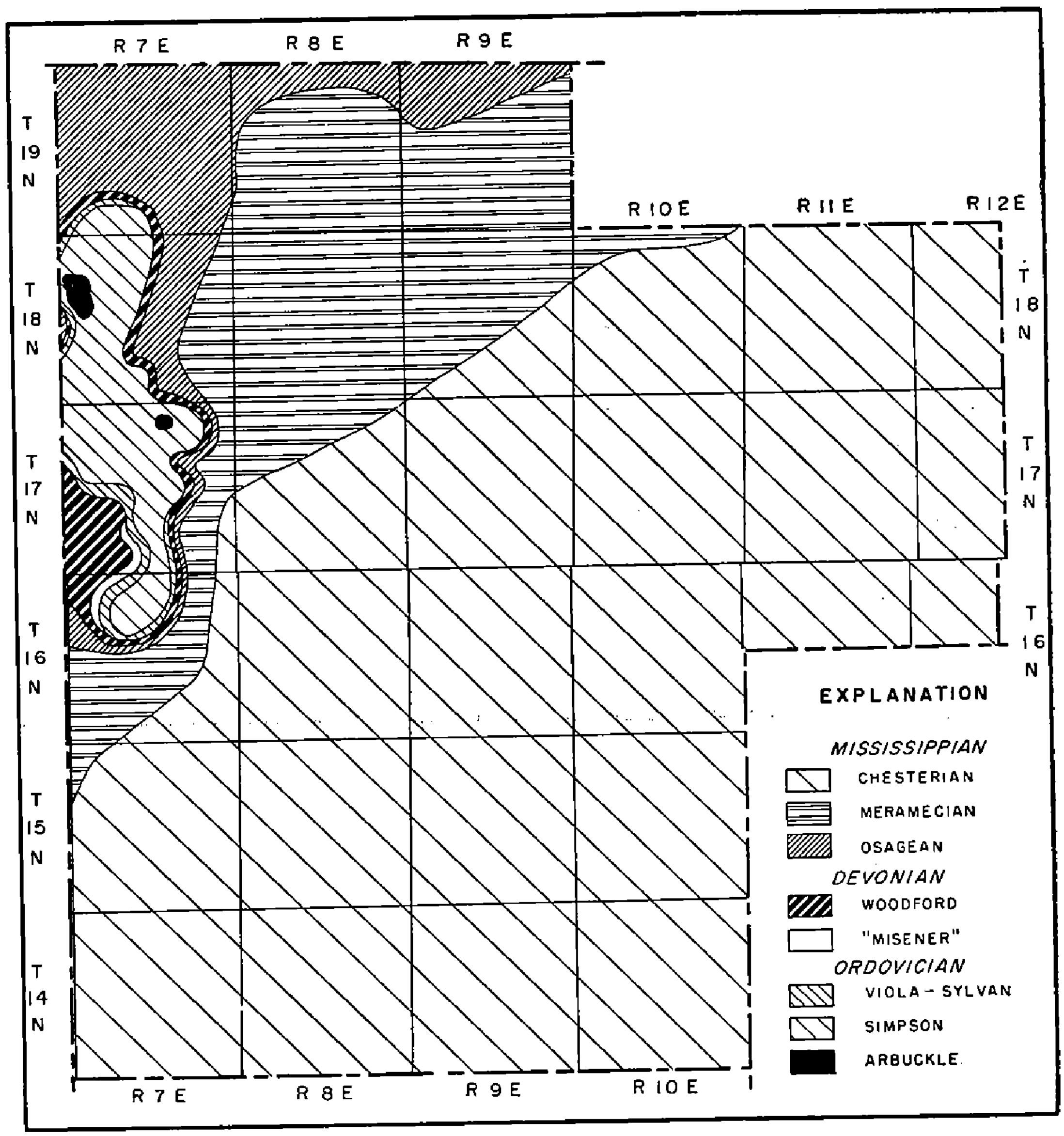

FIGURE 15. Pre-Pennsylvanian subcrop map of Creek County.

KINDERHOOKIAN

Rocks which lithologically resemble those of the surface St. Joe group and are in a similar stratigraphic position occur in eastern Creek County below the basal glauconitic Osagean unit and above Woodford shale. The thickest section, about 50 feet, in T. 17 N., R. 12 E., consists of gray to green shale, brown-gray dolomitic shale, dolomite, and fine-crystalline limestone. *Tasmanites* is reported from both the limestone and shale. This unit is shown in figure 16. The shale exhibits low resistivity resembling the Sylvan electrically, and thins out to the west and south. From an examination of a limited number of electric logs, it is concluded that the unit occurs in Rs. 11 and 12 East, it is probably present but thin in R. 10 East, it extends into Tps. 17 and 18 N., R. 9 E., and may be locally present in T. 19 N., R. 9 E. Borden and Brant (1944, p. 446) mention that traces of green shale and thin granular limestones which they interpret to be Kinderhookian were found at places in East Tuskegee Field (secs. 26, 27, and 34, T. 14 N., R. 10 E.) Krueger (1957, p. 17) in his study of Mississippian rocks in the Tulsa area called this unit Chouteau group, finding a maximum thickness of 50 feet in a cable tool test in sec. 25, T. 17 N., R. 12 E. It consists of 20 feet of tan fine-crystalline limestone, gray and green shale, and 30 feet of gray-brown dolomitic? shale resting upon 23 feet of brown-black Woodford shale. In sec. 22, T. 17 N., R. 11 E., he describes the unit as containing 15 feet of light green and brownish-gray dolomitic shale underlain by 5 feet of gray-brown fine-crystalline dolomitic limestone and 7 feet of brown-gray dolomitic shale resting upon 30 feet of Woodford shale.

OSAGEAN

Rocks assigned an Osagean age overlie unconformably the Woodford shale or Kinderhookian unit where it is present. The Moorefield formation, termed "Mayes" or "Mississippi lime" in Creek County, rests upon the Osagean unit with angular unconformity as shown on Plate D, Panel I. Figure 17 was constructed to show the correlation of Mississippian rock units between wells nos. 18 and 20 on Plate D, Panel I. The unconformity between the Osagean and Meramecian units as herein defined is used as a datum to show that the basal member of the Meramecian unit rests upon a section of rocks which increases in thickness northward. In R. 8 E., the Osagean thickens from about 30 feet in T. 14 N. to 230 feet in T. 19 N. In the eastern part of the County, R. 12 E., the thickness ranges from about 35 feet in T. 16 N. to 110 feet in T. 18 N. The unit increases both by northward thickening of individual beds and by the addition of members both within and at the top of the unit.

Huffman (1958, p. 17) shows southward truncation of Osagean rocks on the surface in northeastern Oklahoma. There the Moorefield rests upon older Osagean formations southward until in sec. 10, T. 13 N., R. 21 E. the Moorefield directly overlies Woodford shale (Huffman, 1958, p. 52). This condition exists also in the subsurface, but south of Creek County near T. 10 N. The eroded Osagean surface may well have exhibited pre-Meramecian relief of 20 to 30 feet such as is found in surface exposures in northeastern Oklahoma, but this is an order of magnitude not readily discernable by a regional subsurface study. However, anomalies in regional thickening suggest that such "knobs" may exist.

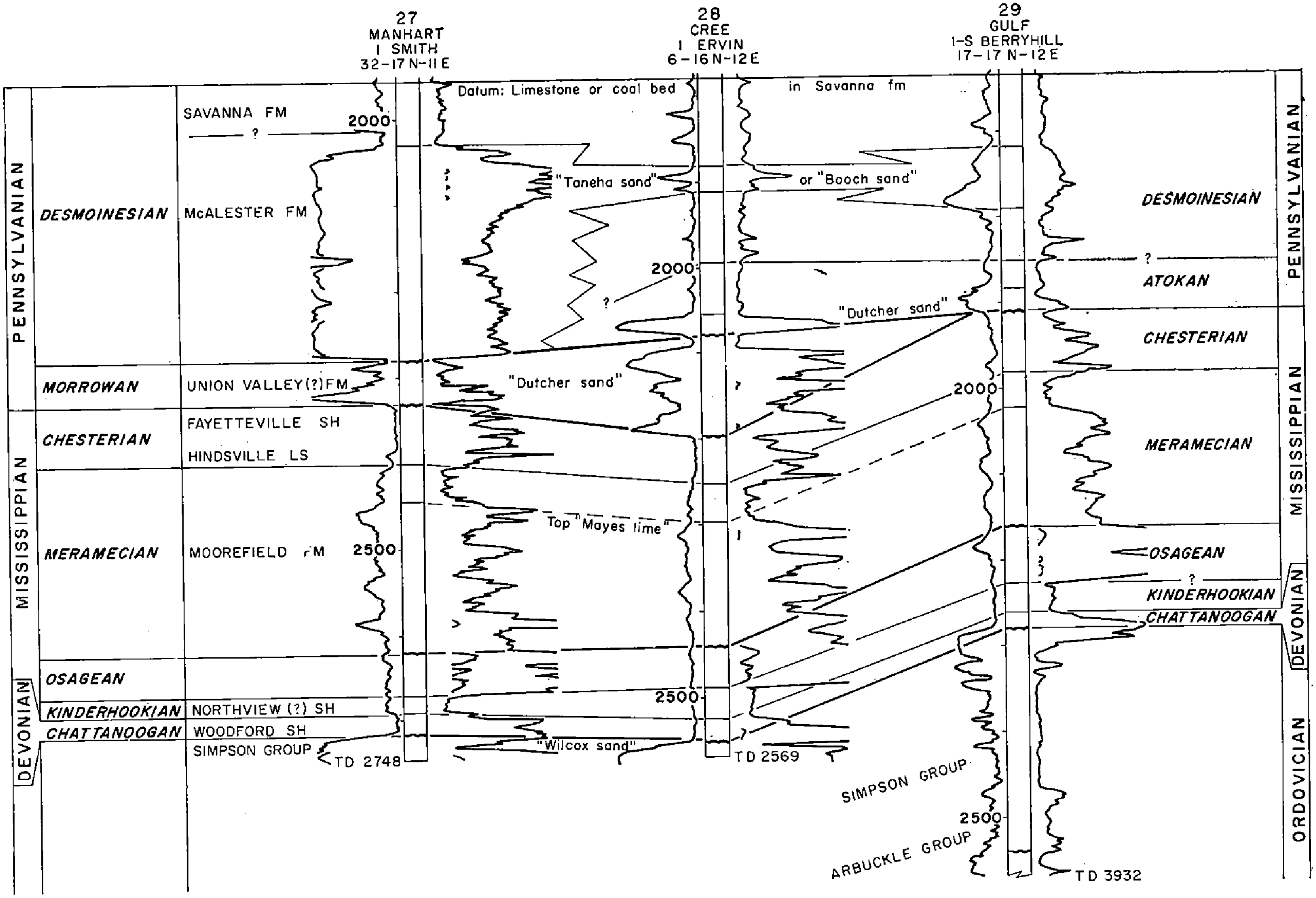

FIGURE 16. Electric log cross section showing correlation and subdivisions of Mississippian system in eastern Creek County and presence of Booch channel in T. 17 N., R. 11 E.

In the south part of the County where the Osagean unit is less than 50 feet thick, it is essentially a black calcareous shale or argillaceous limestone and contains glauconite pellets at the base. As the unit thickens northward, alternating layers become more calcareous until, in general, three relatively light-colored limestone strata are separated by dark calcareous shale. As these limestones increase in thickness, cherty limestone and chert beds occur in the section. Chert was not found south of T. 17 N. in any of the studied well sections. It first appears in the lower limestone member and increases in amount in this member northward. In T. 19 N., chert is locally present in the upper two members (Hyde, 1957, Plate II). These three limestones can be recognized by their negative spontaneous potential curve (leftward excursion of curve on left) in wells nos. 16 and 17, Plate D, Panel I.

MERAMECIAN

Undoubtedly the rocks which have been called "Mayes lime" or at places "Mississippi lime" in central and southern Creek County are equivalent to part of the surface Moorefield formation of northeastern Oklahoma. They lie below the Hindsville limestone where present, or below the Fayetteville shale, and rest unconformably upon the Osagean unit. The upper 20 to 50 feet, termed "False Mayes" is a brownish-gray calcareous silty shale or argillaceous siltstone with lower electrical resistivity than beds above or below. Below this member lies the "Mayes lime" consisting of cyclic thin-bedded strata of gray calcareous siltstone, silty to very fine-sandy limestone and minor amounts of brownish-gray silty calcareous shale. The rock section exhibits a sequence of nearly identical electrical patterns (figure 17) which can be correlated everywhere in the County where the Moorefield is present. The basal unit of the sequence rests with angular unconformity upon rocks assigned an Osagean age. At places this lowermost Moorefield stratum contains glauconite at the base.

The Moorefield formation is about 175 feet thick along the line of truncation of Chesterian rocks in T. 18 N., R. 9 E. and thins out northward and westward as shown on figure 15. Where the Moorefield underlies the Chester, it increases in thickness southwestward from about 180 feet in T. 17 N., R. 12 E. to 260 feet in T. 15 N., R. 7 E. From T. 18 N., R. 9 E. where it is 175 feet thick, it increases southward to 250 feet in T. 15 N., R. 9 E. (figure 17, well no. 20), but decreases to about 210 feet in T. 14 N., R. 10 E. The axis of this small area of thicker Meramecian rocks trends generally westward. The change in thickness appears to be the result of thinning of the upper Meramecian member north of well no. 20 and of all members south to well no. 22 (Plate D, Panel I). Huffman (1958, p. 14) reports a maximum thickness of 100 feet for the Moorefield formation in northeastern Oklahoma.

CHESTERIAN

In southeastern Creek County, Chesterian rocks attain a maximum thickness of at least 225 feet. They are beveled northward by pre-Morrowan erosion and are absent north of the area of subcrop as shown in figure 15. In the areas of maximum thickness, Hindsville, Fayetteville, and Pitkin equivalents (ascending order) and possibly younger Chesterian

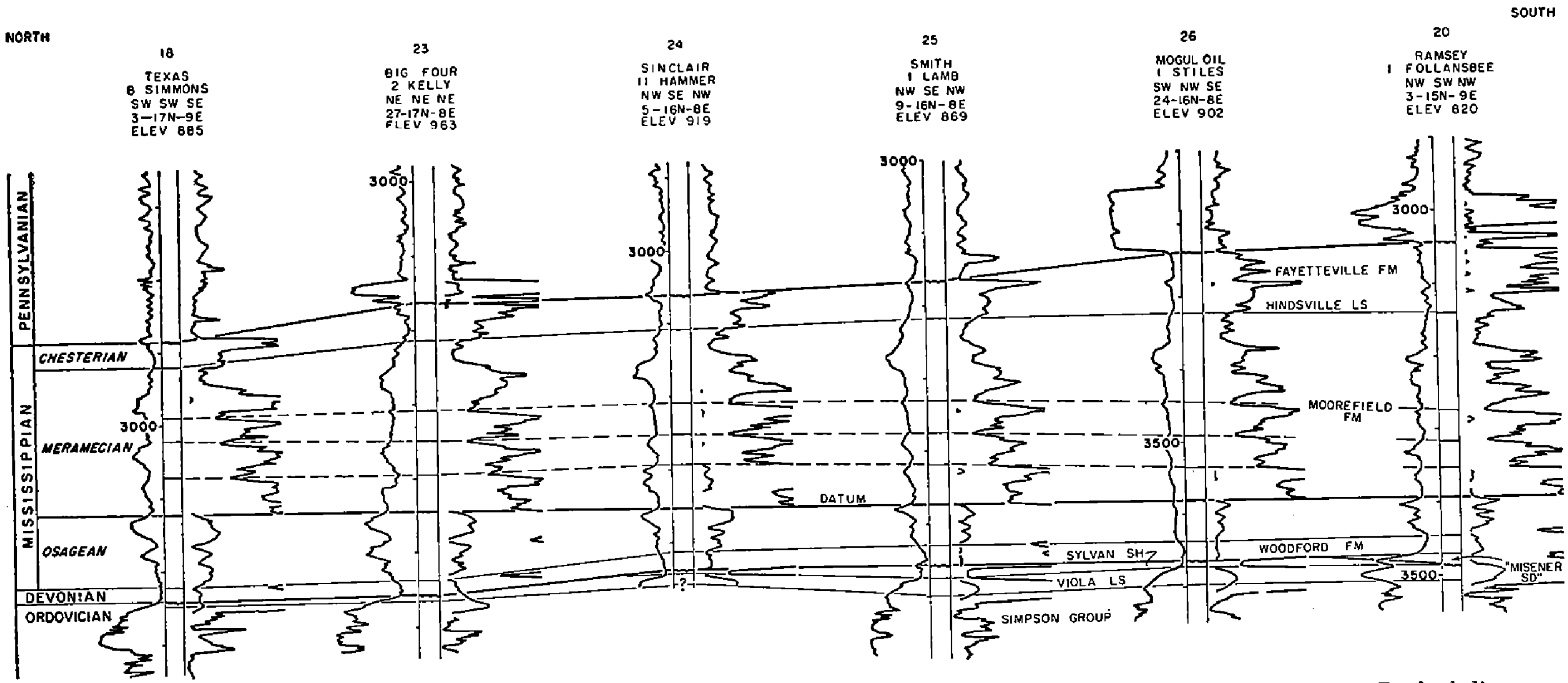

FIGURE 17. Electric log cross section showing relation of Moorefield (Meramecian) to rocks assigned an Osagean age. Dashed lines connect nearly identical electric curves at points which separate Moorefield into units. Basal unit of Moorefield rests upon Osagean rocks which increase in thickness northward. Wells nos. 18 and 20 are used in northwest-southeast cross section, Plate D, Panel I.

rocks are represented. Along the northern boundary of Chesterian rocks in the central and eastern part of the County where most of the Fayetteville has been removed, a light gray limestone averaging 10 feet in thickness, at places bioclastic, has been locally termed "Pitkin." However, this represents either the Hindsville of the surface or a fossiliferous facies at the base of the Fayetteville formation. Southward, the Fayetteville, which is a dark gray to black calcareous shale with thin interbeds of dark lithographic limestone exhibiting relatively high resistivity and positive spontaneous potential in electric logs, reaches a thickness of about 100 feet. This formation is overlain by a section of interbedded dark gray shale and limestone. The limestones are at places light-colored and fossiliferous and may represent the Pitkin facies (well no. 21, Plate D, Panel I).

In southeastern Creek County, the thickness of Chesterian rocks varies locally as much as 100 feet in the relatively short distance of one mile. In the areas where upper Chesterian strata have been removed by pre-Pennsylvanian erosion, Morrowan rocks increase in thickness and indicate that topographic relief of at least 100 feet existed when the Morrowan sea advanced over the area. This relationship of Morrowan and Chesterian rocks is illustrated on Plate D, Panel I by well nos. 21 and 22, and can be studied specifically in secs. 22 and 23, T. 15 N., R. 9 E. and secs. 32 and 33, T. 14 N., R. 10 E.

Pennsylvanian System

Upper Pennsylvanian rocks dip regionally westward at a rate of about 50 feet per mile. The formations crop out in belts of irregular width that strike approximately N. 20 E. An east-west diagrammatic structure section in T. 14 N. (figure 18) shows the general west dip and thickness of Pennsylvanian strata including those of Virgilian, Missourian, Desmoinesian, Atokan, and Morrowan age. A structure section in T. 17 N. (figure 19) illustrates similar regional dip which is interrupted in R. 7 E. by the Cushing ridge. Table 9 gives the stratigraphic section, range in thickness of units, and subsurface names of oil- and gas-productive sands in the County.

The Checkerboard limestone (Early Missourian), youngest formation everywhere recognizable in the subsurface, crops out in eastern Creek County. In the southwest and northwest corners of the County approximately 2,000 feet of younger Pennsylvanian rocks overlies this limestone. The Pennsylvanian thickens southeastward toward the McAlester basin, and thus the 3,700 feet of Pennsylvanian rocks in T. 14 N., R. 7 E. is the thickest section now present beneath the surface of the County. The southeastward regional increase in thickness of Pennsylvanian rocks below the Checkerboard limestone is illustrated in figure 20. The section thickens from 1,000 feet in the northwest corner to 2,500 feet in the southeast corner of the County. Desmoinesian rocks range in thickness from 750 feet in the northwest to about 2,100 feet in the southeast. Atokan and Morrowan rocks deposited by onlapping seas followed by periods of erosion make up the remainder of the section where they are present. The approximate northern extents of Atokan and Morrowan rocks are indicated by dot and

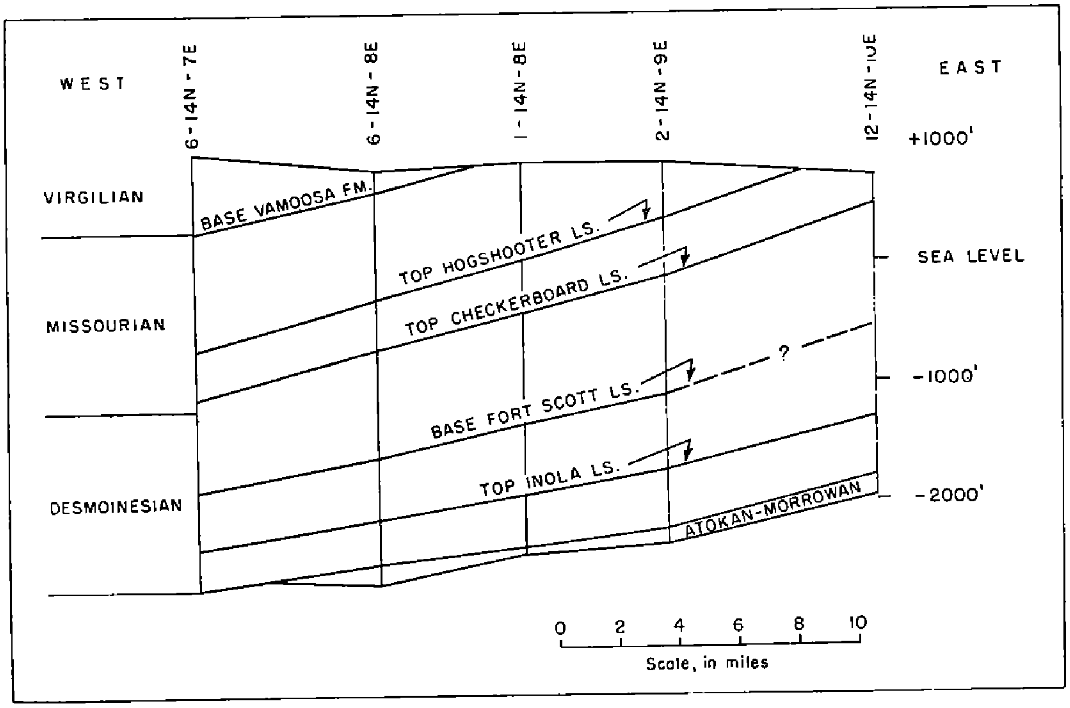

FIGURE 18. Diagrammatic east-west structural cross section in T. 14 N., southern Creek County.

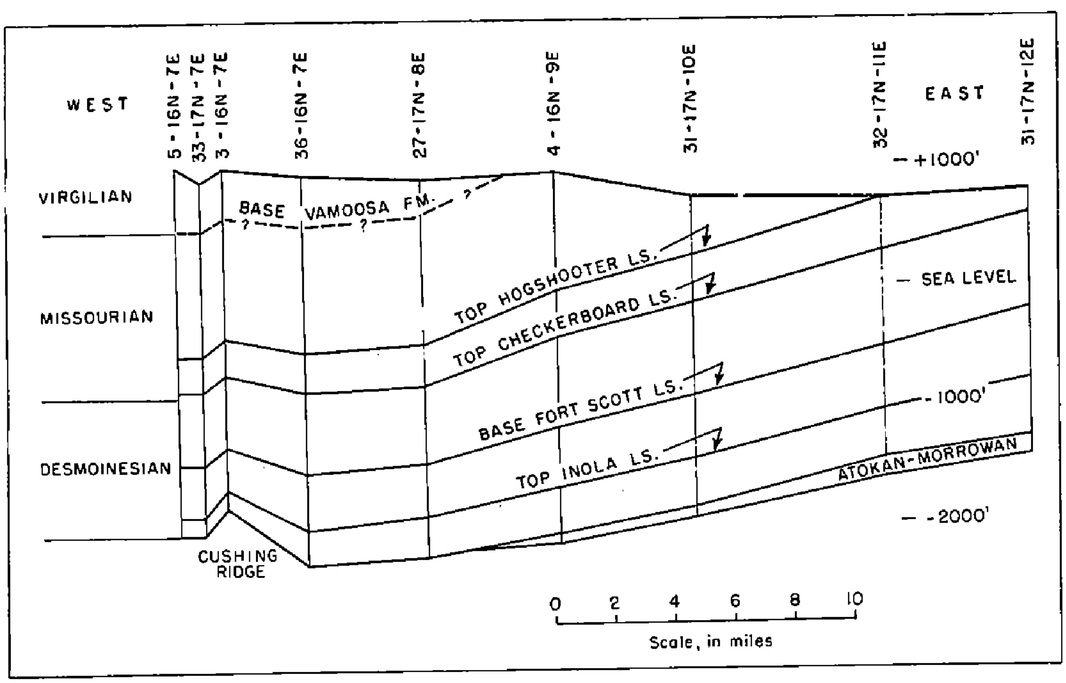

FIGURE 19. Diagrammatic east-west structural cross section in T. 17 N., Creek County, showing regional dip interrupted by Cushing ridge at west.

dot-dash lines respectively on figure 20. These early Pennsylvanian rocks attain a local maximum thickness of about 250 feet in T. 14 N., R. 10 E., but at places in this township they are less than 100 feet thick. With such variability in thickness of this unit at many places in Tps. 14 and 15, Rs. 8 to 10 E., placement of isochore lines depends on selection and location of control points. Scatter control averaging seven wells to a township is used. By using all the available control, it is probable that abrupt increases in thickness would be found in many small areas less than a mile square. Plate D, Panel I is an electric log cross section illustrating correlation and southeastward thickening of Pennsylvanian units.

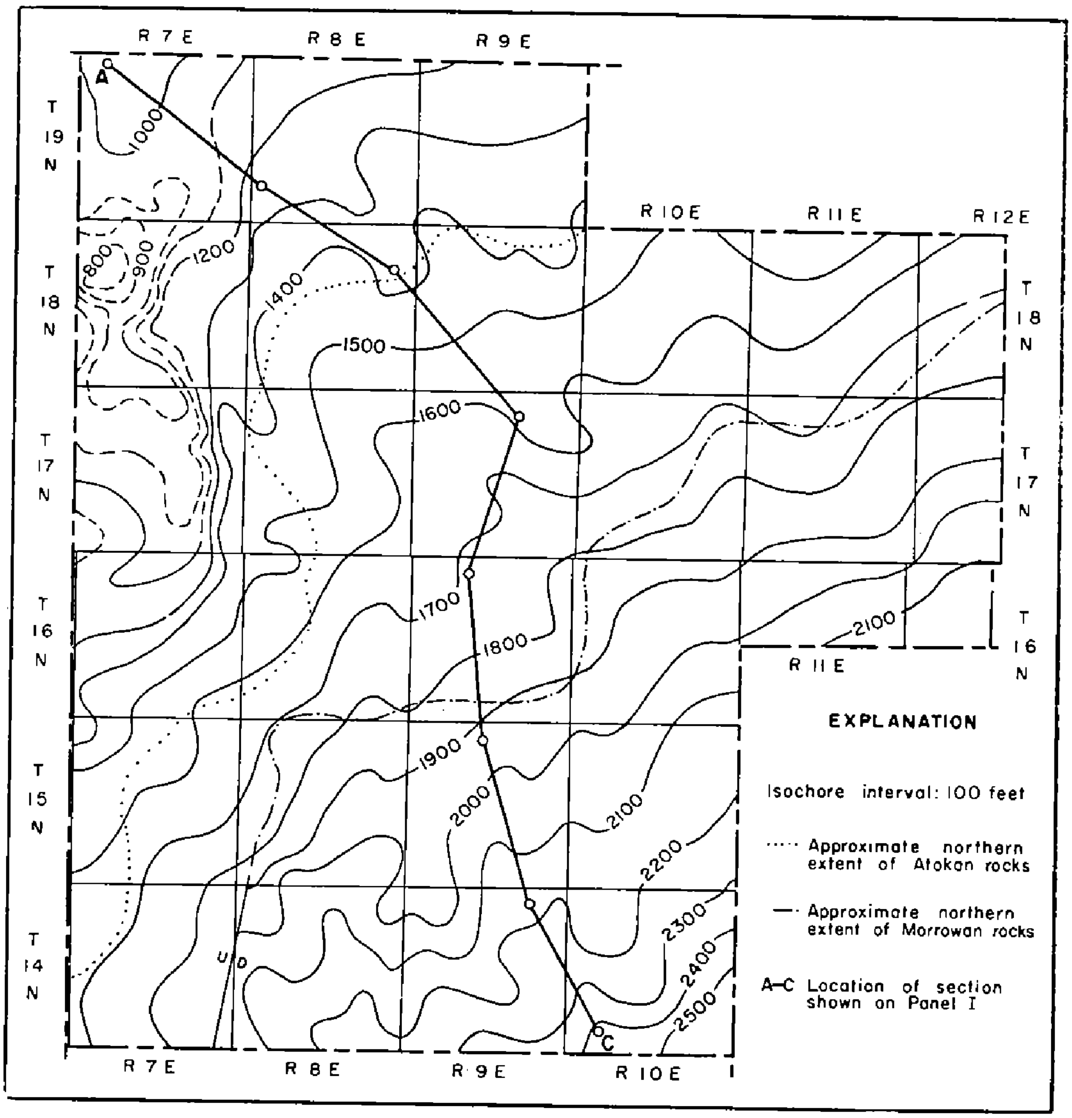

FIGURE 20. Thickness map of rock section from top of Checkerboard limestone to base of Pennsylvanian. Lowest Pennsylvanian strata range in age from Morrowan in southeastern Creek County to Desmoinesian (Boggy) at the Cushing ridge. Regional study based on approximately seven wells per township.

TABLE 9

STRATIGRAPHIC SECTION OF PENNSYLVANIAN FORMATIONS AND NOMENCLATURE OF PRODUCTIVE SANDS IN CREEK COUNTY

Epoch	Group	Outcrop formation names	Subsurface thickness in feet	Subsurface names oil- and gas-productive sands
Virgilian		Pawhuska fm	±50	
		Vamoosa fm	0-700	
Missourian	Ochelata	Tallant fm Barnsdall fm Iola fm Wann fm Chanute fm Dewey fm	1000-1100	
	Skiatook	Nellie Bly fm		
		Hogshooter ls	0-30	
		Coffeyville fm	350-450	Layton
		Checkerboard ls	±5	
		Seminole fm	150-400	Jones, Cleveland
Desmoinesian	Marmaton	Holdenville sh Lenapah ls Nowata sh Oologah ls Labette sh Fort Scott ls	250-500	Wheeler, Oswego
	Cabaniss	Senora fm	250-800	Prue=Prettyman, Skinner, Red Fork,
	Krebs	Boggy fm	150-400	Bartlesville=Glenn
		Savanna fm	0-100	
		McAlester fm	0-100	Booch=Taneha=Tucker*
		Hartshorne fm	0-100	
Atokan			0-100	Dutcher=Gilcrease
Morrowan		Wapanucka sh Union Valley fm	0-200	Dutcher=Cromwell

*Tucker is also used for Simpson sandstone in Cushing Field.

MORROWAN

Rocks of Morrowan age resting unconformably upon the eroded surface of the Mississippian (Chesterian or Meramecian) consist of sandstone, limestone, and shale. This unit attains a thickness of nearly 200 feet in the southeastern part of the county; thins out along the line of northern extent shown on figure 20; and is absent north and west where beveled by pre-Atokan or pre-Desmoinesian erosion.

In Price No. 1 Walker (well no. 22, Plate D, Panel I), 60 feet of finely pyritic green-gray shale termed Wapanucka rests upon 20 feet of glauconitic arenaceous limestone and 50 feet of calcareous glauconitic sandstone referred to the Union Valley formation and called Cromwell or Dutcher sand. However, this rock section is by no means typical as both thickness and lithologic content vary from place to place. In the northern area of distribution, it consists of a glauconitic sandstone, normally calcareous at the top, separated from overlying Atokan sandstone where it is present by a thin bed of shale. At places several sandstone beds or only shale and limestone are present. Relief on the Mississippian surface at the time of deposition of Morrowan sediments, together with later erosion by Atokan seas, account for the relatively abrupt changes in thickness of this unit. Rapid lateral change in facies is reported from one well location to the next.

ATOKAN

Rocks of Atokan age consist essentially of sandstone and shale and attain a maximum thickness of about 100 feet. They unconformably overlie Morrowan rocks where present or Mississippian rocks in the area between the northern extent of Morrowan rocks and the line along which Atokan rocks thin out because of pre-Desmoinesian erosion or possibly non-deposition (figure 20). Neither top nor bottom of the unit is readily defined because it is variable in thickness and in lithologic character, grading from sandstone to shale or to shale and limestone. Merritt and McDonald (1926, p. 41) observed that the lenticular character of the Dutcher sand accounted for many dry offsets to good oil-producing wells. Where a basal sandstone is present, it may rest directly upon Morrowan sandstone or upon a shale less than five feet thick difficult to discern in well cuttings or in electric logs. The electrical characteristics of the overlying Hartshorne-McAlester-Savanna sequence are remarkably consistent from place to place in the County, whereas those of the underlying Atokan unit are variable. This rock section of variable character is placed in the Atokan and is at many places directly overlain by a resistive bed of silty limestone or calcareous siltstone where the Hartshorne formation overlies the unit.

Sandstones in the Atokan as well as those in the Morrowan in Creek County are termed Dutcher. Where Atokan sandstones are clearly separated from Morrowan sandstones as in Price No. 1 Walker (well no. 22, Plate D, Panel I) they may be called Gilcrease. If more than one sand body is present in a well, they are numbered in descending order. Sandstones are fine- to coarse-grained, normally non-glauconitic, micaceous, and argillaceous. Chert pebbles are locally present in the basal part of the sand body. Shales are dark gray and micaceous; limestones are gray to dark gray and microgranular.

Merritt and McDonald (1926, p. 41) report that at most places Dutcher sands yield a showing of oil or gas. They produce from anticlines, terraces, and faulted monoclines. The best productive areas lie in east, central, and southeast parts of the county. Prolific oil production from these sandstones occurred in 1922 and 1923 during development of the Greater Bristow field. One well on the "Poor Farm" structure yielded over 15,000 barrel initial production in 24 hours. Dutcher oil production is reported from Bowden, Bristow, North and West Bristow, Depew, Donnelly, North Donnelly, Edna, Independent, Iron Post, Kellyville, Mounds, Newby A, Olive, Pickett Prairie, Poor Farm, Southeast Poor Farm, Red Bank, Sapulpa, South Sapulpa, Slick, Tibbens, West Tibbens, Tuskegee, East and West Tuskegee, Walker, and Wilcox Fields.

DESMOINESIAN

During Desmoinesian time, many thin stratigraphic units of limestone, shale, sandstone, and coal accumulated on the stable shelf of northeastern Oklahoma within which Creek County lies. Table 10 is a chart showing Desmoinesian formations, important named members, and informal terms used for limestone markers and for oil-productive reservoirs in the subsurface. In the lower two groups of the series, Krebs and Cabaniss, many units are widespread in distribution and represent fairly well-developed cyclical sedimentation. The upper group or Marmaton is largely shale with a few sandstone lenses in the southern part of the County, whereas it is mostly shale and limestone in the northern part of the County. (See Plates C and D, Panel I.)

The base of Desmoinesian rocks can be placed with a certain degree of accuracy above Atokan or Mississippian rocks. The top of the unit in the subsurface is arbitrarily placed at the base of sandstones below the Dawson coal member of the Seminole formation because no recognizable persistent stratum occurs near the top of the series. Sandstones below the Dawson coal range in thickness from 10 to 200 feet (Furlow, 1956, p. 11) and locally appear to have filled channels cut in underlying shale (well nos. 11-13, Plate C, Panel I). Assuming that the top of the Desmoinesian lies approximately 100 feet below the Dawson coal, Desmoinesian rocks thicken southeastward from 750 feet in T. 19 N. R. 7 E., where Hartshorne and McAlester formations both are locally absent, to 2,100 feet in the southeast corner of the County. The thickness of Desmoinesian rocks may be as little as 600 feet on the Cushing ridge where the Boggy formation onlaps hills of Arbuckle limestone.

Krebs Group

The Krebs group consists of four formations, Hartshorne, McAlester, Savanna, and Boggy (ascending order). Three zones of oil-productive sandstones occur as follows: Booch or Taneha in the McAlester, Bartlesville or Glenn and Red Fork in the Boggy formation.

HARTSHORNE-McALESTER-SAVANNA FORMATIONS

The three formations, Hartshorne, McAlester, and Savanna (ascending order) were deposited on the shelf area of the McAlester Basin and consist of thin alternating beds of shale, limestone, coal, siltstone, and sandstone. As the slowly transgressing Desmoinesian seas moved northward and westward, the Hartshorne sea was more limited than the later McAlester and Savanna seas, and the Hartshorne formation thins out at some place within the area of Creek County. Weirich (1953, p. 2033, 2035) considers that the shoreline of deposition of the Savanna formation moved some 25 miles west and 75 miles north of the Atokan shoreline, and therefore it is north and west of Creek County. The Cushing ridge, however, remained as an island or part of a landmass during Hartshorne time. The ridge was gradually covered, but a few small hills remained above sea level during Savanna time since upper Boggy rocks rest upon Arbuckle or Simpson at places in the Cushing Field.

The formations onlapping toward the northwest are 300 feet thick in T. 14 N., R. 10 E., 200 feet thick in T. 14 N., R. 7 E., and 250 feet thick in T. 17 N., R. 12 E. where all are represented. In T. 19 N. where the Hartshorne is thin or absent, the combined thickness is 150 feet or less. Along the Cushing ridge in Tps. 16-18N., R. 7 E., the Savanna formation rests on pre-Pennsylvanian rocks at most places but is absent over some of the domes. A basal sandstone, termed Burgess sand, occurs locally and is oil-productive at the base of whichever Desmoinesian unit that rests upon the pre-Pennsylvanian surface.

The boundaries of these three formations as defined on the surface are difficult to place in the subsurface. Members within the formations are used as geologic markers. Because the electric pattern of thin strata in these formations is remarkably similar throughout the County, these markers are readily followed from well to well. For convenience, subsurface geologists using electric logs consider a persistent coal bed as a marker for the top of the Hartshorne in the southeastern part of the County. The coal bed occurs at 2,945 feet in the Illinois Exploration Co. No. 1 Long (well no. 21, Plate D, Panel I). In this area the Hartshorne formation consists of dark gray shale, siltstone, and coal and is about 100 feet thick, but it is thin or absent in northwestern Creek County.

Overlying the Hartshorne is the McAlester formation, within which occurs the Warner sandstone member, termed Booch, Taneha, or Tucker sand in the subsurface. It ranges in thickness from 5 to 15 feet and is overlain at many places by a coal bed. However, along the boundary of Rs. 10 and 11 E., the Booch sand attains a thickness of about 300 feet where it is deposited in a channel which at places cuts through the normal sequence of Hartshorne and Atokan rocks. An example of thick Booch sand is shown on figure 16 in well no. 27. Busch (1954, p. 9), discussing the McAlester formation in the Seminole district, considers the Booch sand as a deltaic distributary type of deposit with the main channel extending northward into T. 15 N., R. 11 E. Logan (1957, p. 5) shows the channel continuing through Tps. 15-17 N., R. 11 E. in a slightly west of north direction. Furlow (1956, p. 21) reports an approximate western limit of thick Booch along the easternmost three tiers of sections in Tps. 17 and 18 N., R. 10 E. The McAlester formation is approximately 100 feet thick in the southern part of the County and wedges out near the northern boundary of T. 19 N., R. 8 E. (Kirk, p. 20), but extends farther north in ranges to the east.

Oil production from the Booch (Taneha, Tucker) is relatively low as compared with other Pennsylvanian sands and has been found at Bowden, Glennpool, Mounds, Picket Prairie, Sapulpa, and Kellyville Fields in northeastern Creek County and at Wilcox Field in the southeastern part of the

TABLE 10

DESMOINESIAN FORMATIONS, IMPORTANT MEMBERS, AND SUBSURFACE NAMES OF MARKERS AND OIL SANDS

GROUP	FORMATIONS	MEMBERS	Subsurface names of oil sands and markers
MARMATON	Holdenville sh Lenapah ls Nowata sh		
	Oologah ls		Big lime | Wheeler lime and Wheeler sand (Cushing Field)
	Labette sh		
	Fort Scott ls		Oswego lime | Wheeler lime and Wheeler sand (Cushing Field)
CABANISS	Senora fm	Excello sh Breezy Hill ls Iron Post coal Lagonda ss Verdigris ls Croweburg coal ?Morris coal Chelsea ss Tiawah ls Tebo coal U. Taft ss	 Prue (Perryman) sand Henryetta coal Allen or U. Skinner sand Senora lime or coal M. and L. Skinner sand Pink lime U. Red Fork sand
KREBS	Boggy fm	?Wier-Pittsburg coal M. and L. Taft ss Inola ls Bluejacket ss	 M. and L. Red Fork sand Bartlesville (Glenn) sand
	Savanna fm	Doneley ls Sam Creek ls Spaniard ls	Brown limes
	McAlester fm	Coal and shale Warner ss	Booch (Taneha, *Tucker) sand
	Hartshorne fm	Coal, shale, siltstone; Conglomerate at places	

*The term Tucker is also used for Ordovician "Wilcox" in Cushing Field. The term "Stray" is used locally for any oil-productive sand absent in nearby wells, and "Squirrel" is used for pay sand in Prue sand zone or for a pay within the Inola zone or just above. The term "Burgess" is used for any pay sand of Desmoinesian age below the Bartlesville directly overlying Mississippian rocks and not recognized as Booch (Taneha, Tucker). At places in Cushing Field and in western Creek County, the term "Dutcher" is applied to a basal Desmoinesian sandstone.

County. Oil production is obtained locally in the thinner sand bodies and for the most part not in the main channel (Logan, personal communication).

The Savanna formation overlying the McAlester consists of shale, coal, siltstone, and several thin beds of fine-crystalline brown limestone. Three limestone members, named Spaniard, Sam Creek, and Doneley on the surface and called Brown limes in the subsurface, are persistent in the southern and central parts of the County, but are too thin to be recognized in samples or are absent in the northern part of the County. At many places, particularly in northern Creek County, the uppermost beds of the Savanna have been removed by pre-Boggy channelling, and Bartlesville sand has been deposited. Thus geologists normally choose a persistent electric curve within the Savanna formation for local correlation or structural purposes. Kirk (1957, p. 20) states that Savanna rocks maintain a relatively constant thickness from T. 13 N. to T. 22 N. in R. 8 E. This thickness is slightly under 100 feet if the coal bed above the Booch sand is used as top of the McAlester formation.

BOGGY FORMATION

In the subsurface, the Boggy formation consists of the following important units: Bartlesville sand zone, Inola limestone, and Red Fork sand zone (ascending order).

Bartlesville sand zone is defined as the section of rocks above the Savanna formation (Brown lime) and below the Inola limestone. The Bartlesville sand, termed Glenn sand in northeastern Creek County, is considered equivalent to the Bluejacket sandstone member of the surface. It overlies the Savanna formation and is normally separated from the overlying Inola limestone by a section of dark gray to black shale which contains thin limestone. coal beds, and some sandstone (locally oil-productive and called "Squirrel" or "Stray"). This section ranges in thickness from about 10 feet to over 50 feet and might be called the Inola zone. The underlying section in which the Bartlesville sand occurs is locally sandy shale or shale, as it is in parts of the Cushing and Glennpool Fields; or it consists of alternating sandstone and shale beds as in well no. 18 (Plate D, Panel I). At many places,, the section consists of an upper sandy shale and a lower sandstone body, or the unit may be entirely sandstone. Sandstones in the Bartlesville zone do not form a massive blanket but occur as a series of lenses which locally merge and form a thick sand body. Where the percentage of sand in the unit is low, it normally is concentrated at the base of the zone. The Bartlesville zone as defined ranges in thickness from 100 feet in the northern part of the County to slightly over 200 feet in the southern part.

The Bartlesville sand is the most important oil-productive sandstone in the County. It is the major producing zone at Cushing, having produced 160.5 million barrels to the end of 1955 or 79 percent in part of the field as described by Riggs and others (1958, p. 11). Most of the 256 million barrels of oil produced at Glennpool have been from this reservoir, which is being water-flooded at many places. Other fields in which oil has been found in the Bartlesville are Bowden, Bristow, N. Bristow, Depew, Kellyville area, Mannsford, Mounds, Pickett Prairie, Poor Farm, Red Bank, Sapulpa area, Tibbens, Walker, West Walker, and Wilcox.

The *Inola limestone* normally is less than 10 feet thick and overlies the Bartlesville sand zone as defined. This fairly persistent limestone is used for determining structure. At places it is directly overlain by a sandstone which locally is termed Inola sand.

Red Fork sand zone is defined as the rock section above the Inola limestone and below the Tiawah limestone (Pink lime). It is within this unit that an unconformity separates the Boggy formation from the Senora formation. The seas which deposited the Thurman sandstone and Stuart shale, lowermost formations of the Cabaniss group, did not extend into Creek County, and it may be assumed that the area of the County was part of a low-lying land mass at this time. At many places upper Boggy shales are variegated green and red, indicating oxidizing conditions. The shales might better be called sideritic mudstones or claystones to differentiate them from the overlying gray to black thin-bedded or fissile shales. The sand bodies are lensing and as many as three sandstones separated by shale are present. These sandstones are equivalent to the Taft sandstones of the surface. The exact position of the unconformity is uncertain but may lie between the upper and middle sandstone zones as at some places a coal bed, possibly the Wier-Pittsburg, overlies the middle sandstone.

The Red Fork sand zone increases in thickness from about 100 feet in the northern part of the County to over 250 feet in the southeastern corner of the County. Oil production from this zone is obtained from most of the fields in Creek County and is reported as the only productive sandstone at South Bellvue, Southeast Maramec, Northeast Newby, North Olive and Northeast Silver City.

Cabaniss Group

SENORA FORMATION

The Senora formation in the subsurface consists of the following important units (ascending order): Tiawah limestone (Pink lime); Skinner sand zone, divided into an upper and lower division by a coal or limestone bed; Verdigris limestone; and Prue sand zone. These units define neither the bottom nor top of the Senora formation as designated on the surface where the upper Taft sandstone and Tebo coal underlie the Tiawah limestone; and the Iron Post coal, Kinnison shale, Breezy Hill limestone, and Excello shale (ascending order) overlie the Lagonda sandstone (surface equivalent of Prue).

Tiawah limestone (Pink lime), associated black shale, and Tebo coal are persistent thin strata which are readily recognized below the Skinner sand zone and can be traced by use of electric logs or of well samples throughout the County. Normally these units are less than 10 feet thick.

The *Skinner sand zone* overlying the Tiawah limestone is a unit in which lensing sandstones occur in any part of the section. In northeastern Oklahoma, Branson (1954, p. 5) reports seven coal cycles within this zone, in each of which sandstone beds may occur, the Chelsea being the lowest sandstone member. The Skinner sand zone is separated into two divisions by a persistent limestone termed Senora lime in the subsurface or a coal bed possibly equivalent to the Morris coal which occurs 150 feet below the Croweburg coal at the surface in T. 13 N., R. 13 E. (Dunham and Trumbull, 1955, p. 222). The Upper Skinner (called Allen by some) lies above the Senora lime and below the Verdigris limestone and Henryetta-Croweburg coal. Middle and Lower Skinner sands lie below the Senora lime. These same sands would be called Upper and Lower if the term Allen is used for the sand above the Senora lime. The zone thickens from 150 feet in the northern part of the County to 350 feet in T. 14 N., R. 10 E. In this southeastern township the Verdigris is absent at most places, but the underlying coal, Henryetta, is persistent. Sandstone is present in the upper and middle parts of the zone. The three northern wells (nos. 1, 16, 17) on Plate D, Panel I illustrate the section where three sandstones are separated by shale.

Sandstones in the Skinner zone are oil-productive at Southeast Arno, South Big Pond, North Bristow, Cushing, Iron Post (Deep Fork), Jennings, Mannford, Southeast Milfay, Tibbens, Northwest Tibbens, and West Tuskegee Fields.

The *Verdigris* limestone and underlying black shale, and the Croweburg (Henryetta) coal are continuous thin beds within a 20-foot section above the Skinner zone and below the Prue zone. The limestone member grades to shale into the southeastern part of the County, and the Croweburg coal continuing southward is used as a marker in place of the Verdigris (see well no. 22, Plate D, Panel I).

The *Prue sand zone* is defined as equivalent to the Lagonda sandstone, Iron Post coal, and Kinnison shale, named members of the Senora formation of surface nomenclature. Prue sands (also termed Perryman) equivalent to the Lagonda sandstone overlie the Verdigris limestone and at many places are overlain by the Iron Post coal or limestone. Some geologists consider that the Prue sand is equivalent to a lower Calvin sandstone. At some places sandstone occurs above the coal and, if productive, is also called Prue. Sandstones in this zone are lensing and the zone is sandstone and shale in varying proportions. In R. 9 E., the zone increases in thickness southward from 70 feet in T. 19 N. to 130 feet in T. 17 N. (In well no. 18, Plate D, Panel I, the unit is thicker than normal). Kirk (1957, p. 20) observes that the Prue zone is essentially shale south of the vicinity of sec. 19, T. 16 N., R. 8 E.; and that the rock section below the "Oswego" and above the Verdigris limestone thins southward. It is here believed that the Fort Scott limestone has graded to shale within T. 16 N., R. 8 E. and that the limestone beds called "Oswego" in southern Creek County are within the Senora formation.

In the northern part of the County, the Kinnison shale (upper unit of the Prue sand zone as defined) is overlain by the Breezy Hill limestone and Excello shale. These members normally are not over 15 feet in combined thickness and are overlain by the Fort Scott limestone. They are included in the subsurface unit termed Oswego lime. In the southern part of the County none of these units is readily defined.

Oil production from Prue sand zone is reported in the following fields: West Arno, Big Pond, North Bristow, Cushing, Northwest Depew, Glennpool, Iron Post, Kellyville district, Mounds, South Olive, Poor Farm, South Sapulpa, Stroud, and Tibbens. Most of the 5 million-barrels cumulative production of the Stroud Field is from Prue sands. Gas production from this zone is recorded in other fields.

Marmaton Group

In the northeastern part of the County, the surface-named Fort Scott limestone, Labette shale, Oologah limestone, Nowata shale, Lenapah limestone and Holdenville shale (ascending order) form the Marmaton group. At places in this area as well as northwestern Creek County, the upper two units may have been removed by erosion, but even where both are present and not distant from surface outcrop, it is difficult to recognize them in samples or on electric logs, or to place the position of the top of the group. The base of the group is well defined by the base of the Fort Scott limestone. The group is 250 feet thick in T. 19 N., R. 7 E. and 500 feet in T. 18 N., R. 12 E. as shown on Plate C, Panel I.

In the southern part of the County where the Marmaton group is essentially shale with a few sandstone lenses, neither the top nor the bottom is easily placed. The earliest limestone definitely recognizable is normally the Verdigris limestone or associated Croweburg coal of the underlying Cabaniss group. This rock section is divided at the surface into conformably related formations, Calvin, Wetumka, Wewoka, and Holdenville, but these units cannot be defined with any certainty in the subsurface. The group is about 800 feet thick.

FORT SCOTT LIMESTONE

The Fort Scott limestone, called Oswego lime in the subsurface, is about 40 feet thick in the northern part of the County. It grades southward by loss of limestone from the top into thin-bedded siltstone or sandstone and shale, then into shale and disappears as a recognizable unit along an irregular line which crosses T. 16 N. Southward thin limestone beds termed Oswego are in the Senora formation. The Fort Scott is normally a fine- to medium-crystalline fossiliferous limestone. It contains chert at places and is oolitic in parts of the Cushing Field where it is called the Wheeler sand. The initial daily production of some of the early Wheeler producing wells was as high as 2,000 barrels of oil (Riggs and others, 1958, p. 9). From the central and southern parts of Cushing Field (that is, the area south of an east-west line drawn along the northern boundary of sec. 29, T. 18 N., R. 7 E.), cumulative production at the end of 1955 from the Wheeler reservoir amounted to 6,640,000 barrels (1,764 barrels per acre) or 3.26 percent of total production (Riggs and others, 1958, p. 12). Production of gas or oil is reported from Glennpool, Mannford, and Mounds Fields.

LABETTE SHALE

The Labette shale, overlain by Oologah limestone and underlain by Fort Scott limestone, is separable in northern Creek County where both limestones occur. In sec. 5, T. 18 N., R. 12 E. (well no. 15, Plate C, Panel I), the Labette is approximately 100 feet thick, overlying 30 feet of Fort Scott limestone and underlying 50 feet of Oologah (Big lime of drillers). The subsurface Peru sand is in this shale section at places but is not known definitely to produce oil or gas in the County. It is reported that gas was produced from this sand in the Sapulpa field (Mills-Bullard, 1928, p. 141).

OOLOGAH LIMESTONE

The Oologah limestone (Big lime), about 50 feet thick in northern parts of T. 18 N., R. 12 E., consists of an upper and lower limestone separated by shale. This unit grades rapidly into thin lensing beds of sandstone and dark gray and black shale. On Plate C, Panel I the top of the formation is placed at the top of black shale where the upper limestone is absent. In T. 19 N., R. 7 E., the Oologah averages 50 feet in thickness, and consists of a 10-foot limestone overlain by 40 feet of dark gray and black shale with thin (less than 3 feet) limestone beds near the top. Black shale, at places with thin brown fine-crystalline limestone strata, represents some part of the Oologah formation as far south as T. 14 N., in the western part of the County. Black shale at this stratigraphic position does not appear to extend as far south in the eastern ranges.

Regionally the section containing the Nowata shale, Lenapah limestone, and Holdenville shale of surface nomenclature is inseparable into formations in the subsurface, where the Lenapah unit is locally represented by shale or sandstones and the Holdenville contains thin limestone beds and sandstone. This rock section is slightly under 200 feet thick in sec. 6, T. 19 N., R. 8 E. (well no. 4, Plate C, Panel I), about 500 feet in sec. 25, T. 15 N., R. 8 E.,and 300 feet in sec. 5, T. 18 N., R. 12 E. Possible post-Desmoinesian channelling is observable in the cross section, Plate C, in the northeastern part of the County and post-Desmoinesian erosion may have removed the upper part of the three units in the northwestern part of the County.

MISSOURIAN

Rocks assigned a Missourian age cropping out on the surface of Creek County have been described by Oakes in the first part of the bulletin. A cross section, Plate C, Panel I, constructed with the Dawson coal member of the Seminole formation as a datum, attempts to extend the described surface units into the subsurface. It should be noted that the cross section is east-west in T. 19 N., R. 7 E., turns southward at well no. 5, and then is essentially eastward through wells nos. 8 to 15. For the most part, the Checkerboard and Hogshooter limestones are readily recognized in the subsurface. The formations above the Hogshooter consist of lenticular sandstone and shale although locally impure sandy limestone and dolomite strata are present. These formations, Nellie Bly upward through the Tallant, are difficult to follow on the surface according to Oakes, and therefore it is not surprising that their projection into the subsurface is complicated where electric logs and sample logs of wells are used. Normally a recorded electric curve of a formation is two to three miles west of the surface outcrop and the electrical character of the curve may be affected by the presence of fresh water in near-surface sandstones. The resulting correlation of formations above the Hogshooter as illustrated on the cross-section, Plate C, is highly unsatisfactory. Since only minor amounts of oil or gas have been found in formations above the Hogshooter, they will not be discussed in this report. Description and correlation of these upper formations in Creek County are available in the article by M. S. Kirk (1957).

If the base of Missourian rocks is placed at the base of sandstone strata below the Checkerboard limestone, and the top is at the position shown in well no. 1, Plate B, Panel I, Missourian rocks are 1,500 feet thick in sec. 6, T. 19 N., R. 7 E. and 1,580 feet in T. 14 N., R. 7 E. In well no. 1, the Virgilian-Missourian boundary is uncertainly indicated 520 feet below the Lecompton limestone member of the Pawhuska formation, as there is no apparent difference in sandstones in the section. Greig (1957, p. 27, 32, plate 2), uncertain as to the position of the boundary on the surface, assigned the upper 400 feet of rock section to the Vamoosa in Bradshaw No. 1 Sharp (NW¼ SE¼ SE¼ sec. 26, T. 20 N., R. 7 E.). Correlation of the boundary in this well into that of well no. 1 places the base of the Vamoosa about 100 feet above that indicated on Plate B. In T. 14 N., R. 7 E. chert conglomerate in the base of the Vamoosa formation overlies Missouran beds. The Vamoosa, overlain by Lecompton limestone, is about 700 feet thick in the subsurface of southwestern Creek County.

Skiatook Group

Early Missourian rocks subdivided into Seminole, Checkerboard, Coffeyville, and Hogshooter formations (ascending order) are discussed below. Thickness of these combined units ranges from 500 to 600 feet, locally greater where all sandstones below the Checkerboard are included in the Seminole formation.

SEMINOLE FORMATION

The Seminole, basal formation of the Skiatook group, is conformably overlain by the Checkerboard limestone and rests upon the eroded surface of Desmoinesian rocks. At most places, the formation is divisible into an upper and lower section by the Dawson coal, a level which may be represented also by a thin limestone bed less than five feet thick. Sandstones in the upper unit are termed Upper Cleveland or Jones sand, and in the lower unit, Lower Cleveland or Cleveland, but these names are variously applied depending on the number of separate sand bodies locally present above the Fort Scott limestone. In some fields, as in Cushing, the term Cleveland is applied to sandstones probably in the Desmoinesian section (Riggs and others, 1958, p. 6).

Sandstones in the lower unit locally appear to fill channels which have been cut into underlying Desmoinesian shale in the northern part of the County (see wells nos. 11 and 13). At places on the surface of northeastern Oklahoma, Seminole shale is found to rest in channels upon Desmoinesian shale; limestones and sandstones are present in the Holdenville formation. A clue to the problem of placement of the base of the Seminole formation was found in a well drilled by cable tools in sec. 16, T. 18 N., R. 9 E., where a 200-foot rock section below the Checkerboard limestones contained four sandstone beds each 20 to 30 feet thick, separated by shale beds of comparable thickness. Chert fragments found in the second sandstone from the top may be an indication that the base of the Seminole should be placed at its lower boundary. It is conceivable that these lenticular sandstones merge to form one lens, and that the Desmoinesian-Missourian boundary is within one sand body. Thus in areas where a bed of sandstone below the Checkerboard is as much as 200 feet thick, channel fill is not necessarily represented. The pre-Missourian erosion of Desmoinesian rocks in the area of Creek County may be of minor magnitude, and northward thinning of rocks of the Marmaton group may be more the result of deposition than of erosion. In the southwestern part of the County, the Cleveland sand zone is in part an oolitic limestone.

Seminole sandstones called in the subsurface Jones (Upper Cleveland) or Cleveland (Lower Cleveland) are reported as productive of oil or gas in the following fields in Creek County: North Bristow, Cushing, Mannford, Poor Farm, Red Bank, and Walker.

CHECKERBOARD LIMESTONE

In northeastern Creek County, near the surface outcrop of Checkerboard limestone, two limestones each less than five feet thick and separated by 15 feet of shale, were found by Williams (1941, plate) at a depth of 60 feet in Sooner No. 1 Willie Lee (SW¼ SW¼ NW¼ sec. 17, T. 18 N., R. 12 E.). These two limestones present in well no. 15 (Plate C) are indicated by two high-resistivity peaks on the electric log. The upper unit of high resistivity normally represents a dark fine-crystalline limestone and black shale or black shale. The lower limestone is the one called Checkerboard by most geologists in northern Creek County because it is more persistent as a cream to white fossiliferous limestone. It is continuous into southern Creek County, maintaining a relatively constant position below markers in the overlying formations whereas the upper unit appears to rise in the Coffeyville section (Kirk, 1957, p. 9). It also is correlative with the continuous limestone called Checkerboard in eastern Creek County which has been traced to the type locality of the Checkerboard of the surface in sec. 22, T. 15 N., R. 11 E.

COFFEYVILLE FORMATION

The Coffeyville formation consists of interbedded shale and sandstone. Sandstone normally occurs in the upper and middle parts of the formation and is termed Layton sand in the subsurface. At many places a coal bed is present near the top of the formation. A second coal or a black shale occurs just above a sandstone zone at places termed Lower Layton sand which is in the middle part of the rock section. In the northern part of the County, a black shale or a dark brown microcrystalline limestone near the base of the formation exhibits high electric resistivity or gamma ray intensity and may be mistaken for the Checkerboard limestone. (See Plate C.) In the southern part of the County two limestones in a 20-foot section occur in shale between the Upper and Lower Layton sands. Examples of this limestone zone are found below 1,270 feet in Sunray No. 1-A Deere (NE¼ SE¼ NE¼ sec. 34, T. 14 N., R. 7 E.) and below 1,300 feet in General American No. 1 Keeling (NW¼ SE¼ SW¼, sec. 33, T. 16 N., R. 8 E.). The Coffeyville formation ranges in thickness from 330 feet in T. 19 N., R. 7 E. to 400 feet in T. 18 N., R. 10 E.; and in T. 14 N. from 400 feet in R. 7 E. to 480 feet in R. 10 E.

Oil production from the Layton sand is reported from North Bristow, East Bruce, Cushing, Kellyville, and Tibbens Fields. In the central and south parts of Cushing Field, Layton oil production by the end of 1955 amounted to over 16 million barrels or eight percent (Riggs and others, 1958, p. 12). The Layton also has yielded an unknown but large amount of gas.

HOGSHOOTER LIMESTONE

Near the surface in northeastern Creek County, the Hogshooter is a dolomitic limestone averaging 30 feet in thickness. It overlies the Coffeyville formation and is directly overlain by a basal sandstone of the Nellie

Bly formation. (See Plate C, Panel I.) In most of the subsurface of Creek County, the Hogshooter is overlain by shale and is the highest limestone in the Missourian section which can be traced with some assurance throughout the County. In the northwestern part of the County, the formation is less than three feet thick, or is absent locally. At some places, however, the limestone termed Hogshooter in the subsurface does not remain at the same stratigraphic level, as illustrated by well nos. 6-9, Plate C, Panel I. A change of 40 feet in stratigraphic position occurs within a distance of less than one-half mile in sec. 2, T. 18 N., R. 8 E.

STRUCTURE MAP

The structure map of the Woodford shale (Plate B, Panel I) is based mainly on drillers logs filed with the Oklahoma Corporation Commission, but data from the relatively few electric logs available in the area have been utilized. As the Oklahoma Geological Survey has no file of plotted well logs, the conclusion was reached that the most reliable structural datum obtainable from available sources is the base of the Woodford (Chattanooga) shale. No Pennsylvanian stratum continuous throughout the County can be ascertained with any degree of certainty in such logs because strata which are persistent and indicate structure are normally less than 10 feet in thickness and may or may not be recorded in a log. In the northern and eastern parts of the County the Fort Scott (Oswego) limestone where 20 to 30 feet thick might be used, but this bed is at places confused with the Oologah (Big lime) or Verdigris limestone in the logs.

Most of the drilling for "Wilcox" oil production was done before 1925. Drillers were looking for the black shale of the Woodford as a lithologic marker above "Wilcox" sand and recorded its base with a fair degree of accuracy. As at some places basal Mississippian strata are also black, the top of the Woodford is not reliable in drillers logs. In the southeastern part of the County, early logs record "Wilcox" erroneously for "Misener" sand. Where density of tests is low in an area, all available control is used, but where many tests are drilled as in pool areas of "Wilcox" or "Misener" production, control on the map is limited to about 25 percent of the tests drilled, and selection of control points is based on outlining the pool area. In old field areas, exact location of a test and its elevation are problematical at many places. Where few control points are shown in some pools, contours are based on unpublished maps from various sources. Reliability of contours is also dependent upon accuracy of surface elevations which have been obtained from various sources and have not been checked. The 100-foot contours shown on Plate B, Panel I have been taken from a map made originally by 20-foot contours. Indicated lines of faulting are only approximately placed and may represent zones of faulting. No area on the map should be considered contoured with the degree of accuracy necessary to delineate prospects for oil and gas.

Present structure of the Woodford in Creek County is the result of all movements that have modified its originally comparatively flat surface. Post-Mississippian, pre-Desmoinesian orogenic movements folded Mississippian rocks and formed to the west a broad arch related probably to an ancient positive element. East of the Cushing Field feature, faults that strike north-northeastward may have been initiated in Mississippian rocks at this time, but movement along the fault zone certain during post-Morrowan, pre-Desmoinesian time during the Wichita orogeny continued into Middle Desmoinesian. Early Virgilian rocks, cropping out at the surface in the Cushing Field area reveal structure of the underlying beds, and minor en echelon northwest-trending faults occur predominantly in the areas overlying the deeper NNE-trending fault zones. General tilting of the Woodford surface, southwestward in Creek County, may have reached a maximum in Permian time but has been modified by later epeirogenic movements.

The regional structure map, Plate B, Panel I, shows a general southwest-dipping homocline interrupted by faults normally downfaulted to the east, and by the large Cushing structure from which Mississippian rocks and Woodford shale as well as older rocks have been removed by several episodes of pre-Pennsylvanian and early Pennsylvanian erosion. Excepting the Cushing faulted anticline, structural contours of 100-foot interval show in general southwest-trending noses normally having less than 100 feet of closure but locally having more than 200 feet.

Most of the subsurface faults are in the western and southern parts of Creek County. The throw of these faults ranges from less than 100 feet to as much as 500 feet, and for most faults it is 100-200 feet.

The two major faults of the County lie between Shamrock and Bristow. Maximum indicated displacement is along the fault on the southeast boundary of Cushing and Lincreek Fields. Along this fault, in the central part of T. 16 N., R. 7 E., the throw is shown as 500 feet. Then in the northwestern part of T. 15 N., R. 7 E. at Lincreek, the throw is shown as 800 feet, but some doubt has been cast on the reliability of the samples in the critical well in the NE¼ sec. 7. This same fault or fault zone is extended by geologists southwestward through Lincoln County into central Pottawatomie County.

The longest fault shown on the map trends north-northeast between Depew and Bristow. Within Creek County it has a mapped length of about 25 miles. Geologists working in this region extend this fault or fault zone southwestward through Okfuskee County into northern Seminole County, connecting it with the Keokuk fault. In southern Creek County, the Keokuk fault is downthrown eastward and has a normal displacement of 100-200 feet. The throw diminishes northward and the fault dies out in T. 17 N., R. 8 E., where the direction of displacement is reversed and the east side is upthrown.

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APPENDIX

MEASURED STRATIGRAPHIC SECTIONS IN CREEK COUNTY

TOWNSHIP FOURTEEN NORTH

1. Sec. 9, T. 14 N., R. 7 E. Measured along road about one-fourth mile south of the NW cor.

VANOSS FORMATION	
Shale: gray, weathers brown; not measured.	
PAWHUSKA FORMATION	
Lecompton limestone member:	
Limestone: gray, weathers brown; many vugs lined with calcite; fossiliferous	0.8
Shale: weathers reddish brown	7.0
Limestone: gray, weathers brown; fossiliferous	0.6
VAMOOSA FORMATION	
Shale: gray, weathers brown; not measured.	

2. Sec. 1, T. 14 N., R. 8 E. Measured from foot of escarpment 2,000 feet west of SE cor. west to top of hill.

TALLANT FORMATION	
Covered: probably nonresistant sandstone; extends west to top of hill	7.0
Sandstone: white, speckled with black, weathers brown to red; medium-grained	5.0
Shale: weathers reddish brown; silty	8 0
Sandstone: white, speckled with black, weathers brown; fine-grained	10.0
BARNSDALL FORMATION	
Unnamed shale member:	
Covered: probably shale; not measured.	

3. Sec. 2, T. 14 N., R. 8 E. Measured from SW cor. west to top of hill.

VAMOOSA FORMATION	
Sandstone: medium-grained, contains chert pebbles one inch long, maximum, and beds of chert conglomerate 2 feet thick, maximum; extends to top of hill	20.0
TALLANT FORMATION	
Shale: gray, weathers brown; silty	11.0
Sandstone: gray, speckled with black, weathers brown; fine-grained, massive	7.0
Covered: probably shale	15.0

4. Sec. 12, T. 14 N., R. 8 E. Measured from 1,500 feet east of W¼ cor. westward to base of conglomeratic sandstone.

VAMOOSA FORMATION

Sandstone: conglomeratic with chert fragments; not measured.

TALLANT FORMATION

Covered: probably shale	25.0
Sandstone: weathers brown; medium-grained	25.0

BARNSDALL FORMATION

Unnamed shale member:

Covered: probably silty shale	15.0

Okesa sandstone member:

Sandstone: weathers brown; fine-grained	10.0
Shale: weathers red; silty; contains thin bands of siltstone 2 to 5 inches thick	35.0
Sandstone: weathers red; silty	2.0
Shale: weathers red; silty	8.0

Sandstone: top exposed in bed of stream; not measured.

5. Sec. 9, T. 14 N., 9 E. Measured from the alluvium 2,200 feet east of SW cor. westward to top of hill.

CHANUTE FORMATION

Shale: weathers brownish red; extends to top of hill	5.0
Sandstone: weathers brownish red; fine-grained	3.0
Covered: shale	4.0
Sandstone: weathers brown; fine-grained	3.0
Covered: shale	3.0
Sandstone: weathers brown; fine-grained	2.0

DEWEY FORMATION

Shale: weathers red	10.0
Sandstone: light gray, weathers light brown; silty	1.0
Shale: weathers red	1.0
Sandstone: light gray, weathers light brown; silty	2.0
Shale: weathers red	3.0
Sandstone: gray, weathers light brown; fine-grained to silty	15.0

NELLIE BLY FORMATION

Shale: maroon; not measured.

TOWNSHIP FIFTEEN NORTH

6. Sec. 20, T. 14 N., R. 9 E. Measured from escarpment 2,000 feet east of SW cor. east to top of hill.

BARNSDALL FORMATION	
Okesa sandstone member:	
Covered: probably shale	7.0
Siltstone: white	2.0
Covered: probably shale and nonresistant sandstone	5.0
IOLA FORMATION (representatives)	
Sandstone and shale, interbedded: sandstone is white, weathers brown; beds one-half to one foot thick and at least one contains fusulinid molds; the shale weathers red and is silty	4.0
Shale: weathers red	3.0
Siltstone: white, weathers brown; sandy; contains fusulinid molds	6.0
CHANUTE FORMATION	
Covered: probably shale	40.0

7. Sec. 4, T. 15 N., R. 7 E. Measured in vicinity of SW cor.

PAWHUSKA FORMATION	
Unnamed beds:	
Sandstone: gray, weathers brown; fine-grained; nonresistant	18.0
Shale: weathers red; silty	6.0
Sandstone: gray, weathers brown; silty; calcareous; fossiliferous in lower part	6.0
Covered: shale	4.0
Lecompton limestone member:	
Limestone: gray, weathers brown to red; fossiliferous	1.5
VAMOOSA FORMATION	
Shale: not measured.	

8. Sec. 4, T. 15 N., R. 7 E. Measured in vicinity of the center.

PAWHUSKA FORMATION	
Unnamed beds:	
Covered: probably sandy shale	20.0
Sandstone: gray, weathers brown; silty; calcareous; thin wavy bedding	5.0
Shale: weathers brown; silty	3.0
Lecompton limestone member:	
Limestone: gray, weathers brown to red; sandy, silty	1.5
VAMOOSA FORMATION	
Shale: not measured.	

9. Secs. 4 and 9, T. 15 N., R. 7 E. Measured north from Turner Turnpike, one-fourth mile south of NE cor. sec. 9 to top of hill south of E¼ cor. sec. 4.

PAWHUSKA FORMATION	
Unnamed beds:	
Shale: weathers brownish red; thin-bedded; silty; top eroded	6.0
Lecompton limestone member:	
Limestone: white, weathers brownish red; sandy, silty	1.5
VAMOOSA FORMATION	
Shale: weathers brownish red; silty	15.0
Sandstone: white, weathers brownish red; fine-grained, silty; nonresistant	4.0
Shale: weathers red; silty	12.0
Sandstone: gray, weathers reddish brown; fine-grained; massive; middle part nonresistant	35.0
Shale: weathers red; silty; not measured.	

10. Sec. 5, T. 15 N., R. 7 E. Measured in SW¼.

VANOSS FORMATION	
Shale: sandy; not measured.	
Sandstone: weathers brown; fine-grained; thin-bedded	10.0
Covered: probably shale	6.0
PAWHUSKA FORMATION	
Turkey Run Limestone member:	
Limestone: gray, weathers brown; silty	1.5
Unnamed beds:	
Covered: probably silty shale	12.0
Sandstone: weathers brown; fine-grained; massive	10.0
Covered: probably sandy shale	3.0
Sandstone: weathers brown; fine-grained; massive	14.0
Shale: gray	6.0
Lecompton limestone member:	
Limestone: weathers brown; sandy and silty	1.0
Silty sandstone and sandy shale	5.0
Limestone: gray, weathers red; sandy and silty	1.0
Sandstone and shale: gray; silty	5.0
Limestone: weathers red; sandy and silty	1.0
VAMOOSA FORMATION	
Shale: weathers red; not measured	

11. Sec. 6, T. 15 N., R. 7 E. Measured along south line of SE¼ from alluvium west to top of hill.

PAWHUSKA FORMATION	
Unnamed beds:	
Covered: probably nonresistant sandstone and sandy shale	20.0
Sandstone: gray, weathers brown; medium-grained; massive	6.0
Shale: gray; silty	18.0
Lecompton limestone member:	
Limestone: gray, weathers brown to red; sandy; fossiliferous	1.0
Shale: gray; silty	4.0
Limestone: gray, weathers brown to red; sandy; fossiliferous	1.0
Shale: gray	1.5
Limestone: gray, weathers brown to red; sandy; fossiliferous	1.0
VAMOOSA FORMATION	
Shale: weathers red; silty	17.0
Sandstone: base not exposed	5.0

12. Sec. 1, T. 15 N., R. 8 E. Measured from culvert 1,300 feet east of SW cor. west to top of hill.

TALLANT FORMATION	
Shale: weathers red; sandy	8.0
Sandstone: gray, weathers brown: medium-grained; massive	15.0
Shale: weathers red; sandy	5.0
Sandstone: gray to maroon; fine-grained; thin-bedded	9.0
Shale: weathers red; silty to sandy	11.0
Sandstone: gray to red, weathers reddish brown; fine-grained; massive	6.0
Shale: weathers red	8.0
Sandstone: gray to white; weathers brown; medium- to coarse-grained; massive	12.0
BARNSDALL FORMATION	
Unnamed shale member:	
Covered; probably shale	5.0

13. Sec. 9, T. 15 N., R. 9 E. Measured from 2,000 feet west of SE cor. west to top of hill.

BARNSDALL FORMATION	
Okesa sandstone member:	
Shale: weathers red; contains thin sandstone beds	12.0
IOLA FORMATION (representatives)	
Sandstone: light gray to white, weathers brown; medium-grained to silty; massive; lightweight; permeable; probably leached calcareous sandstone	30.0
Shale: weathers brown	7.0
Shale and siltstone: alternating beds one-half inch to 30 inches thick; shale is silty and weathers brown; siltstone is gray to white and weathers brown; near top is a bed of white siltstone that contains molds of fusulinids	9.0
Shale: weathers brown	4.0

14. Sec. 33, T. 15 N., R. 9 E. North of SW cor. extends to top of hill.

BARNSDALL FORMATION	
Okesa sandstone member:	
Covered: probably silty shale and thin silty sandstone beds	10.0
IOLA FORMATION (representatives)	
Sandstone: white, weathers brown; medium- to fine-grained; a minor amount of silty shale, silty sandstone, and siltstone; generally massive and lightweight; probably leached calcareous sandstone and siltstone	30.0
Shale: not measured.	

15. Sec. 34, T. 15 N., R. 9 E. Measured from base of sandstone 1,000 feet north of SW cor. north to top of hill.

BARNSDALL FORMATION	
Okesa sandstone member:	
Sandstone: weathers brown; medium-grained	13.0
Covered: probably silty shale and nonresistant sandstone	10.0
Sandstone: light gray, weathers brown; fine-grained	6.0
Shale: maroon	3.0
Sandstone: light gray, weathers brown; fine-grained	7.0
Shale: maroon	11.0
Sandstone: buff, weathers brown; fine-grained	5.0
IOLA FORMATION (representatives)	
Shale: weathers reddish brown	10.0
Sandstone: light gray, weathers brown; medium- to fine-grained	11.0
Shale: gray, weathers brown	12.0
Sandstone: medium-grained	8.0

16. Sec. 36, T. 15 N., R. 9 E. Measured from a point east of the SE cor. to the top of the hill west of that corner.

NELLIE BLY FORMATION (upper part)

Sandstone: weathers brown; medium- to fine-grained; interspersed with silty shale	15.5
Shale: weathers buff to brown	7.0
Sandstone: weathers brown; medium- to fine-grained	2.0
Shale: weathers buff to brown; silty	7.0
Sandstone: poorly exposed; weathers buff; thin-bedded	6.0
Shale: dark blue, weathers gray to brown	8.0
Sandstone: weathers buff to brown; medium- to fine-grained; fossiliferous-molds	5.0
Shale: base not exposed	15.0

TOWNSHIP SIXTEEN NORTH

17. Sec. 13, T. 16 N., R. 9 E. Measured along road over high escarpment east of SW cor.

WANN FORMATION

Covered: shale; not measured.	
Sandstone: weathers brown; fine-grained	6.0
Sandstone: gray, weathers brown; thin-bedded; fine-grained; silty	5.0
Siltstone: gray; thin-bedded	6.0
Sandstone: gray, weathers brown; fine-grained	1.5

IOLA FORMATION (representatives)

Shale: gray; silty	5.0
Shale: maroon	12.0
Shale: gray; silty; contains a few siltstone beds about 2 inches thick	11.0
Covered: probably silty shale	40.0

18. Secs. 15 and 16, T. 16 N., R. 9 E. Measured from the railroad trestle in the NW¼ of the NW¼ sec. 15 to the sandstone outcrop 1,700 feet east of the NW cor. sec. 16.

TALLANT FORMATION

Sandstone: not measured.

BARNSDALL FORMATION

Unnamed shale member:

Shale: gray, weathers red	10.0
Sandstone: weathers brown; not well exposed	10.0
Shale: weathers red; sandy, contains a few sandstone beds each about one foot thick	40.0

Okesa sandstone member:

Sandstone: gray to white, weathers reddish brown; exposed in road cut near the center of the NE¼ sec. 16; thickness indicates a channel sandstone	40.0
Covered; probably sandy shale	6.0
Sandstone: weathers brown; coarse-grained; massive	2.0
Shale: sandy	1.0
Sandstone: weathers red; calcareous	1.0
Covered: probably sandy shale	4.0
Sandstone: weathers reddish brown; medium- to fine-grained	19.0
Covered: probably sandy shale and nonresistant sandstone	11.0
Shale: weathers red; sandy	11.0
Sandstone: weathers red; medium- to fine-grained; massive	10.0

WANN FORMATION (probably the lower part)

Covered: probably shale and nonresistant sandstone	10.0

19. Sec. 26, T. 16 N., R. 9 E. Measured in the vicinity of the SE cor. and westward to top of hill.

WANN FORMATION

Sandstone: light gray to white, weathers red; medium- to fine-grained; profoundly weathered	12.0
Shale: weathers red	6.0

IOLA FORMATION (representatives)

Sandstone: white to light gray, weathers brown; medium-grained to silty; contains much highly porous lightweight siltstone, probably leached calcareous siltstone	40.0
Covered: probably shale	25.0

20. Secs. 6 and 7, T. 16 N., R. 10 E. Measured from bridge 2,000 feet west of SE cor. sec. 6 west along road to top of hill and thence southwest to base of sandstone that caps high hill in the NW¼ sec. 7.

WANN FORMATION

Sandstone: not measured.

IOLA FORMATION (representatives)

Sandstone: not measured.

Covered: sandy shale with a few sandstone beds in lower part	about 20.0

CHANUTE FORMATION

Covered: sandy shale	about 85.0
Sandstone: weathers brown to buff; fine-grained; beds one to 2 feet thick	10.0

DEWEY FORMATION

Shale: weathers brown	18.0
Sandstone: weathers brown; fine-grained; massive	20.0

NELLIE BLY FORMATION

Covered: probably shale; not measured.

21. Sec. 28, T. 16 N., R. 10 E. Measured on the hillside immediately east of the SW cor.

DEWEY FORMATION	
Shale: top eroded	3.0
Sandstone: weathers brown; poorly exposed but rubble indicates that it is fine-grained and contains interbedded shale	6.0
NELLIE BLY FORMATION	
Shale: partly covered; contains thin-bedded silty sandstone	30.0
Sandstone: weathers brown; thin-bedded; silty and contains interbedded silty shale	17.0
Shale: dark gray; silty and contains a few silty sandstone beds less than one foot thick	23.0
Sandstone: weathers brown; fine-grained; silty	1.5
Shale: gray; silty	6.0
Sandstone: gray; silty	1.0
Shale: gray, weathers brown	15.0
Covered; probably shale; not measured.	

TOWNSHIP SEVENTEEN NORTH

22. Sec. 15, T. 17 N., R. 7 E. Measured in the vicinity of the center.

PAWHUSKA FORMATION	
Unnamed beds:	
Sandstone: weathers brown; coarse- to fine-grained; massive; top eroded	5.0
Covered: probably shale	15.0
Lecompton limestone member:	
Limestone: gray, weathers brown; fossiliferous ..... about	3.0
VAMOOSA FORMATION	
Covered: probably shale	2.0
Topographic bench: probably indicates sandstone ... about	2.0
Covered: probably shale	80.0
Sandstone: gray, weathers brown; medium- to fine-grained; massive	25.0
Shale: base not exposed	20.0

23. Secs. 17 and 20, T. 17 N., R. 7 E. Measured southwestward up hill in the SW$\frac{1}{4}$ of sec. 17 and the NW$\frac{1}{4}$ of sec. 20.

VANOSS FORMATION	
Sandstone: weathers reddish brown; medium-grained; massive; top eroded	10.0
Shale: greenish gray	10.0
PAWHUSKA FORMATION	
Turkey Run limestone member:	
Limestone: weathers brown; sandy; fossiliferous .... about	3.0
Unnamed beds:	
Covered: probably shale	10.0
Sandstone: weathers reddish brown; medium-grained; massive	5.0
Covered: probably shale	15.0

Sandstone: weathers reddish brown; medium-grained; resistant	7.0
Covered: probably shale	10.0
Shale: weathers greenish tan	12.0
Lecompton limestone member:	
Limestone: white, weathers brown; fossiliferous	4.0
Shale: weathers greenish tan	6.0
Limestone: white, weathers brown; sandy; fossiliferous	1.0
VAMOOSA FORMATION	
Covered: probably shale	5.0
Sandstone: weathers brown; fine-grained; resistant	2.0
Covered: probably sandy shale and nonresistant sandstone	20.0
Sandstone: weathers brown; medium-grained	10.0
Covered: probably nonresistant sandstone	6.0
Sandstone: weathers brown; medium-grained	32.0
Covered: probably nonresistant sandstone	6.0
Sandstone: weathers brown; medium-grained; base not exposed	5.0

24. Sec. 5, T. 17 N., R. 9 E. Measured in road immediately west of SE cor.

TALLANT FORMATION	
Sandstone: gray, weathers reddish buff; fine-grained; contains minor beds of silty shale	35.0
Shale: weathers red; silty	5.0
Sandstone: gray, weathers purple; silty; beds less than one foot thick interbedded with silty shale	10.0
BARNSDALL FORMATION	
Unnamed shale member:	
Shale: gray, weathers red; silty and contains a minor amount of siltstone	10.0
Sandstone: gray, weathers brown yellow and red; fine-grained; beds about one foot thick; base not exposed	5.0

25. Secs. 8 and 9, T. 17 N., R. 9 E. Measured from cross roads 500 feet east of the SW cor. sec. 9 westward to top of hill 1,000 feet west of that corner.

TALLANT FORMATION	
Sandstone: weathers red; medium-grained; massive	10.0
BARNSDALL FORMATION	
Unnamed shale member:	
Shale: weathers red	1.0
Sandstone: weathers red; fine-grained to silty; massive	2.0
Shale: maroon; silty	11.0
Sandstone: gray, weathers brown; thin-bedded; silty	2.0
Shale: gray; silty	17.0
Sandstone: gray, weathers brown; medium- to fine-grained	6.0
Shale: gray; silty	5.0
Siltstone	2.0

Sandstone: medium-grained; massive	4.0
Shale: silty	5.0
Covered: probably shale	6.0

26. Sec. 13, T. 17 N., R. 9 E. Measured in the south part, from the high water mark in the emergency spillway of Lake Heyburn to the S¼ cor.

WANN FORMATION

Sandstone: gray, weathers brownish red; medium- to fine-grained; thin-bedded; extends to top of hill	6.0
Shale: silty	2.0
Sandstone: weathers reddish brown; medium-grained; beds about one and one-half feet thick	5.0
Covered: probably silty shale	15.0
Sandstone: gray, weathers reddish brown; medium-grained; beds 2 inches to 2 feet thick	8.0
Covered: probably silty shale	20.0

IOLA FORMATION (representatives)

Siltstone: weathers reddish brown; sandy, lightweight, permeable; contains molds of fusulinids; probably leached calcareous siltstone	18.0
Shale: dark	1.0
Limestone: gray, weathers brown; fossiliferous	1.0
Shale: dark gray; contains oval concretions about 1 inch in diameter which weather dark brownish-red	40.0

27. Secs. 21 and 22, T. 17 N., R. 9 E. Measured from the alluvium west of the N¼ cor. of sec. 22 westward along the road to a point 1,250 feet south and 1,800 feet west of the NE cor. of sec. 21.

BARNSDALL FORMATION

Unnamed shale member:

Silty shale and silty sandstone: not tree-bearing; not measured here, but in the south part of sec. 21	60.0

Okesa sandstone member:

Sandstone: gray, weathers brown; fine-grained; beds about one foot thick	6.0
Shale: weathers brownish red; silty	30.0
Sandstone: gray, weathers brown; fine-grained; silty	2.0
Shale: gray, weathers red; silty	15.0
Sandstone: gray, weathers brown; fine-grained; silty; massive	6.0
Shale: gray, weathers brownish red	6.0
Sandstone: white, weathers brownish red	1.0
Shale: weathers brownish red; silty	1.5
Sandstone: white, weathers brownish red; fine-grained to silty	5.0
Shale: weathers brownish red; silty	6.0
Sandstone: white, weathers brown; fine-grained; massive	5.0
Shale: weathers red	11.0
Siltstone: gray	1.0
Shale: weathers red	36.0

28. Secs. 27 and 34, T. 17 N., R. 9 E. Measured from a point in stream bed 500 feet west and 500 feet north of the SE cor. sec. 27 west to road and thence along road southwestward to a point 2,700 feet north and 1,200 feet east of SW cor. sec. 34.

BARNSDALL FORMATION	
Unnamed shale member:	
Shale: not measured here but in center of sec. 27	60.0
Okesa sandstone member:	
Silty sandstone and silty shale beds, alternating	20.0
Sandstone: gray, weathers brownish red; medium- to fine-grained; a bed at top 2 feet thick and another at base, also 2 feet thick, are resistant and weather out as ledges, other parts not well exposed; shale flakes in lower part	15.0
Shale: weathers dark red; silty and sandy; contains a few sandstone lenses, each less than one foot thick; not well exposed	30.0
Sandstone: weathers lavender to brownish red; fine-grained; contains sandy shale partings	8.0
Shale: weathers dark red; silty to sandy	10.0
Sandstone: weathers red; fine- medium- and coarse-grained; shale pebbles in basal part	18.0
Shale: weathers brownish red	4.0
Sandstone: weathers brownish red; fine- medium- and coarse-grained; shale pebbles in basal part	20.0
WANN FORMATION (lower part)	
Covered: probably silty shale	6.0
Sandstone: weathers brown; fine-grained	2.0
Covered: probably silty shale	7.0
Sandstone: white, weathers brown; massive	3.0
Shale: weathers red	6.0
Sandstone: white, weathers brown; fine-grained; massive	2.0
Shale: weathers brownish red	2.0
Sandstone: white, weathers brown; fine-grained to silty	1.0
Shale: weathers brownish red	20.0
Sandstone: white, weathers brownish red; fine-grained	5.0
Covered: probably shale; extends down to bed of stream	15.0

29. Sec. 29, T. 17 N., R. 9 E. Measured from stream bed 1,500 feet east of SW cor. sec. 29 west to that corner.

VAMOOSA FORMATION

Sandstone: not measured.

TALLANT FORMATION

Shale: weathers brownish red; silty	15.0
Sandstone: white, weathers brownish red; medium- to fine-grained; coarse sandstone and shale fragments in lower part	18.0
Shale: weathers red; silty	12.0
Sandstone: white, weathers brown; medium- to fine-grained; weathers to deep sandy soil, springs along base	30.0

BARNSDALL FORMATION

Unnamed shale member:

Covered: probably shale; not measured.

30. Sec. 4, T. 17 N., R. 10 E. Measured along west side from foot of escarpment northward to top of hill, where road turns west.

WANN FORMATION

Sandstone: weathers brown; medium-grained; extends to top of hill	3.0
Shale: gray, weathers brown; sandy	2.0
Sandstone: weathers brown; coarse-grained; massive	1.0
Covered: probably shale	7.0

IOLA FORMATION (representatives)

Sandstone: gray, weathers brown; calcareous	4.0
Covered: probably shale	6.0
Limestone: light gray, weathers brown; sandy to silty; dense	2.0
Covered: probably shale	4.0
Limestone: light gray, weathers brown; sandy to silty; dense	10.0
Covered: probably nonresistant sandstone	4.0
Sandstone: weathers brown; fine-grained to silty; contains interbedded silty shale; lightweight; contains molds of fusulinids	20.0
Covered: probably shale	10.0

31. Sec. 9, T. 17 N., R. 10 E. Measured along west line, vicinity of W¼ cor.

WANN FORMATION

Sandstone and sandy shale: not well exposed; extends to top of hill	10.0

IOLA FORMATION (representative)

Sandstone: weathers brown to red; medium- to fine-grained; contains fossil plant fragments, and molds of brachiopods and fusulinids	15.0

Covered: probably silty shale and silty nonresistant sandstone	6.0
Sandstone: light gray, weathers brown; fine-grained	2.0
Sandstone: weathers brown; silty; contains fossil brachiopods, crinoids and molds of fusulinids	1.0
Shale: gray, weathers brown; silty	2.0
Siltstone: weathers red; calcareous and ferruginous; contains molds of brachiopods, crinoids, and fusulinids	2.0
Covered: probably shale	25.0

32. Sec. 15, T. 17 N., R. 10 E. Measured from the lake in the SW part of sec. 15 west to top of hill.

NELLIE BLY FORMATION (in the upper part)

Sandstone: weathers brown; fine-grained; caps hill; not measured.	
Shale	2.0
Limestone: dark, weathers brown to yellow	1.0
Shale: weathers buff	6.0
Sandstone: weathers brown to buff; fine-grained	2.0
Covered: shale	6.0
Sandstone: weathers brown; fine-grained	6.0
Covered: shale	8.0
Limestone: gray, weathers brown; sandy and silty	3.0

33. Sec. 15, T. 17 N., R. 10 E. Measured from stream near S¼ cor. eastward to top of hill.

NELLIE BLY FORMATION (in upper part)

Shale: weathers dark reddish brown; extends to top of road cut	6.0
Siltstone, weathers brown to buff	1.0
Shale: gray, weathers brown	11.0
Limestone: gray, weathers brown; sandy to silty	3.0
Covered: shale	5.0
Limestone: gray, weathers brown; sandy to silty	3.0
Covered: shale	5.0
Sandstone: weathers brown; fine-grained and silty; calcareous	2.0
Covered: probably silty shale	6.0
Sandstone: brown; fine-grained	2.0
Shale: dark; silty	2.0
Sandstone: dark; fine-grained; fossiliferous; beds one to 2 feet thick	6.0
Covered: probably silty shale	5.0
Sandstone: brown, weathers buff; fine-grained to silty	2.0
Covered: probably shale	9.0

34. Sec. 28, T. 17 N., R. 10 E. Measured in road cut and quarry on north side of U. S. Highway 66, near E¼ cor.

NELLIE BLY FORMATION (upper part)

Sandstone: weathers buff; medium-grained to silty; beds one-half to one foot thick; extends to top of hill	5.0
Shale: silty	4.0
Sandstone: silty	1.0
Silty shale and sandstone	11.0
Sandstone: silty; calcareous	1.0
Shale: gray; silty — about	2.0
Sandstone: weathers buff; beds one-tenth to one foot thick with silty shale partings between — about	10.0
Shale: maroon	11.0
Siltstone: gray, weathers brown; sandy; cemented with calcium carbonate; weathered in spots, especially along joint cracks, weathered material soft and friable, unweathered parts hard and durable as limestone, boundaries between weathered and unweathered parts sharp	10.0 to 12.0
Shale: silty with siltstone beds less than one-half foot thick spaced about 3 feet apart	28.0
Sandstone: weathers buff to brown; fine-grained; beds about one foot thick with sandy silty shale partings between	10.0
Shale: dark; sparingly fossiliferous; contains siltstone beds a few inches thick, some of which are calcareous	22.0

TOWNSHIP EIGHTEEN NORTH

35. Sec. 13, T. 18 N., R. 7 E. Measured from SE cor. west to top of hill.

PAWHUSKA FORMATION

Unnamed beds:

Sandstone: light tan, weathers brown; fine-grained; silty; nonresistant	10.0
Shale: gray; silty	6.0

Lecompton limestone member:

Limestone: weathers brown; sandy; thin wavy bedding; fossiliferous	10.0

VAMOOSA FORMATION

Shale: weathers red; silty	20.0
Sandstone: light gray, weathers brown; medium-grained; massive	25.0
Shale: gray, silty; contains widely spaced sandstone beds one to 3 feet thick; not well exposed	60.0
Covered: probably shale; not measured.	

36. Sec. 35, T. 18 N., R. 7 E. Measured in vicinity of tower, north side of highway, in SW¼.

PAWHUSKA FORMATION

Unnamed beds:	
Covered: probably sandy shale and sandstone	12.0
Sandstone: gray, weathers brown; medium-grained; massive	10.0
Covered: probably shale	10.0
Lecompton limestone member:	
Limestone: blue gray, weathers brown; sandy; fossiliferous	6.0

VAMOOSA FORMATION

Covered: probably shale	28.0
Limestone: weathers brown; sandy	1.0
Shale: weathers red	23.0
Sandstone: gray, weathers brown; fine-grained; massive	20.0
Covered: probably shale	17.0
Sandstone: gray, weathers brown; fine-grained	2.0
Covered: probably shale; not measured.	

37. Sec. 7, T. 18 N., R. 9 E. Measured from floor of bridge 1,000 feet north and 1,500 feet west of SE cor. along road northwestward to top of spur and thence westward to top of hill.

VAMOOSA FORMATION

Sandstone: gray, weathers reddish brown; massive; gnarly	3.0
Covered: probably silty shale and siltstone	24.0
Shale: weathers red; includes a few gray siltstone beds, each less than one foot thick	17.0
Sandstone: weathers brown; fine-grained	11.0

TALLANT FORMATION

Sandstone: silty	6.0
Sandstone: weathers brown; fine-grained; massive	11.0
Covered: probably shale	5.0

38. Sec. 7, T. 18 N., R 9 E. Measured from stream 900 feet south of NE cor. southwestward along road to top of hill.

VAMOOSA FORMATION

Shale: gray, weathers red; extends to top of hill in road and up higher ground westward	17.0
Sandstone: gray, weathers brown; silty; thin-bedded; contains a minor amount of silty shale	17.0
Sandstone: not well exposed; nonresistant and probably silty	9.0
Shale: gray; silty	2.0
Sandstone: gray, weathers brown; fine-grained; massive; resistant	8.0

TALLANT FORMATION

Silty shale and siltstone	11.0
Sandstone: gray; silty	2.0
Shale: gray, weathers buff; silty	4.0

Sandstone: gray, weathers brown; fine-grained	6.0
Shale: dark gray	2.0
Sandstone: gray, weathers reddish brown; fine-grained	11.0
Shale: dark gray	5.0
Sandstone: weathers brown; fine-grained	5.0
BARNSDALL FORMATION	
Unnamed shale member:	
Shale: dark, weathers brown to red; base not exposed	5.0

39. Secs. 7 and 18, T. 18 N., R. 9 E. Measured from floor of bridge 1,000 feet north and 1,500 feet west of SE cor. sec. 7 along road southwestward to top of spur in north part of sec. 18.

VAMOOSA FORMATION	
Sandstone: buff, weathers brown; fine-grained	18.0
Nonresistant sandstone and silty shale	6.0
Covered: probably silty shale	5.0
Sandstone: weathers reddish brown; medium-grained	3.0
Shale: gray to red; silty; contains a minor amount of siltstone	5.0
Sandstone: gray; fine-grained	6.0
Shale: gray; silty	7.0
Sandstone: gray, weathers brown; fine-grained	5.0
Nonresistant silty sandstone and shale	22.0
Sandstone: buff, weathers reddish brown; medium-grained; massive	40.0
TALLANT FORMATION	
Shale: buff, weathers red	17.0
Sandstone: base not exposed	2.0
Covered	4.0

40. Sec. 20, T. 18 N., R. 9 E. Measured from NE cor. west to top of hill.

TALLANT FORMATION (upper part)	
Covered: probably shale; not measured.	
Sandstone: gray, weathers brown; fine-grained; massive to thin-bedded	10.0
Shale: gray, weathers red	6.0
Sandstone: gray, weathers brown	4.0
Shale: weathers red; contains sandstone beds in middle part, each less than one foot thick	21.0
Sandstone: gray, weathers reddish brown; fine-grained	4.0
Shale: weathers red	11.0

41. Sec. 20, T. 18 N., R. 9 E. Measured in SE¼ of SE¼.

TALLANT FORMATION (upper part)	
Sandstone: weathers reddish brown; coarse-grained; massive	10.0
Covered: shale	8.0
Sandstone: poorly exposed	3.0
Covered: shale	11.0
Sandstone	4.0
Covered: probably shale	4.0
Sandstone: gray, weathers brown; fine-grained; massive	5.0
Covered: shale; weathers red	28.0

42. Secs. 28 and 29, T. 18 N., R. 9 E. Measured from a point in stream 400 feet east and 2,200 feet north of SW cor. sec. 28, westward to top of ridge in sec. 29 and thence north along top of ridge 1,000 feet.

VAMOOSA FORMATION	
Sandstone: not well exposed; top eroded	5.0
TALLANT FORMATION	
Covered: probably shale	11.0
Sandstone: gray, weathers brown; fine-grained; probably contains silty shale partings	5.0
Shale: gray, weathers red; silty	10.0
Sandstone: gray, weathers brown; fine-grained	16.0
Covered: probably silty shale and thin silty sandstone beds	21.0
Sandstone: gray, weathers pink; fine-grained; beds one to 6 inches thick	11.0
Shale: weathers mottled, gray and reddish brown	4.0
Sandstone: weathers brown; medium- to fine-grained; massive	20.0
BARNSDALL FORMATION	
Unnamed shale member:	
Covered: probably silty shale; not measured.	

43. Sec. 30, T. 18 N., R. 9 E. Measured from the base of sandstone 2,100 feet east of the SW cor. west to that corner.

VAMOOSA FORMATION	
Sandstone: weathers brownish red; coarse-grained; massive; contains soft white grains which suggest devitrified chert; top eroded not measured.	
Shale: weathers maroon; silty	6.0
Sandstone: weathers brownish red; medium to coarse-grained; massive; contains, in lower part, dull gray to white fragments one-sixteenth inch long and shorter which suggest devitrified chert, also shale fragments one-half inch long	25.0
TALLANT FORMATION	
Covered: probably silty maroon shale	6.0
Sandstone: weathers brown; fine-grained; not well exposed	6.0
Covered: probably silty shale	4.0
Sandstone: white; fine-grained to silty	5.0
Shale: maroon; silty	2.0
Silty maroon shale and siltstone, interbedded	5.0
Sandstone: white; fine-grained; cross-laminated	2.0
Shale: maroon; silty	2.0
Sandstone: white; fine-grained to silty	2.0
Shale: maroon; silty; contains siltstone layers one inch thick	1.0
Siltstone: white	1.0
Shale: maroon; silty	2.0
Sandstone: white; fine-grained; silty	2.0
Shale: weathers maroon	1.0
Siltstone: white, weathers brown	2.0
Covered: probably shale; not measured.	

44. Secs. 35 and 26, T. 18 N., R. 9 E. Measured from SE cor sec. 35 along trail northward to top of sandstone 1,000 feet south and 400 feet east of NE cor. sec. 26.

BARNSDALL FORMATION

Okesa sandstone member:

Sandstone: weathers reddish brown; fine-grained; massive	20.0
Shale: weathers light tan; sandy and silty; contains a few silty sandstone beds each less than 2 feet thick	17.0
Sandstone: weathers reddish brown; fine-grained	6.0
Shale: weathers maroon; silty	26.0
Sandstone: weathers reddish brown; fine-grained; silty; thin-bedded	6.0
Shale: sandy and contains thin beds of nonresistant sandstone	23.0
Sandstone: weathers light brown to reddish brown; fine-grained; thin-bedded to massive	4.0
Silty sandy shale and nonresistant sandstone	11.0
Sandstone: dark brown; thin-bedded to massive	10.0
Sandy shale and nonresistant sandstone; not well exposed	5.0
Sandstone: weathers brown; medium- to fine-grained; massive; shale conglomerate at base	19.0

WANN FORMATION

Covered: probably nonresistant sandstone and sandy shale	12.0
Sandstone: weathers brown; fine-grained; massive; base not exposed	18.0

45. Sec. 4, T. 18 N., R. 10 E. Measured from draw 2,200 feet west of SE cor. westward to top of hill.

BARNSDALL FORMATION

Okesa sandstone member:

Sandstone: weathers brown to red; fine-grained; extends westward to top of hill; not measured.	
Shale: dark red; contains several beds of fine-grained sandstone, each about one foot thick	22.0
Sandstone: weathers reddish brown; fine-grained	11.0
Sandstone: weathers brown; coarse- to fine-grained; contains many shale pebbles, a few as long as 2 inches	2.0

WANN FORMATION

Sandstone: weathers reddish brown; fine-grained	16.0
Shale: weathers dark red	5.0
Sandstone: weathers buff; fine-grained; soft	11.5
Sandstone: weathers reddish brown; fine-grained	12.0
Sandstone: weathers buff; fine-grained; soft	11.0
Shale: weathers dark red	8.0

Sandstone: weathers reddish brown; medium- to fine-grained	14.0
Sandstone: reddish brown; medium- to coarse-grained	3.0
Shale: covered; not measured.	

46. Sec. 31, T. 18 N., R. 10 E. Measured from a point 150 feet east of SW cor. north along top of ridge 1,000 feet.

BARNSDALL FORMATION	
Okesa sandstone member:	
Sandstone: weathers gray; fine-grained	2.0
WANN FORMATION	
Shale: weathers red; silty	15.0
Sandstone: weathers brownish red; fine-grained; massive; cross-bedded	20.0
Topographic bench: indicates silty sandy sandstone probably about	3.0
Sandstone: gray, weathers brown; medium- to fine-grained; massive; cross-bedded	40.0
Covered: probably sandy shale	10.0
Sandstone: weathers light gray to brown; medium-grained; massive	23.0
Covered: probably shale; not measured.	

47. Sec. 33, T. 18 N., R. 10 E. Measured in new and old road cuts 800 feet west of SE cor.

WANN FORMATION	
Sandstone: at top of cut; weathers brown; massive	3.0
Shale: sandy	0.5
Sandstone: weathers buff to brown	0.5
Siltstone: pink	1.0
Shale: pink; silty	1.4
Sandstone: gray; fine-grained	0.5
Shale: dark gray	1.3
IOLA FORMATION (representatives)	
Siltstone: pink; calcareous	0.2
Shale: pink	1.0
Siltstone: pink; calcareous; sparingly fossiliferous	1.0
Shale: brown; silty	2.5
Siltstone: white, weathers brownish red; calcareous; fossiliferous	1.0
Shale: dark gray	6.0
Sandstone: commonly white, weathers brown; medium- to fine-grained; leached in old cut; abundant fossil shell fragments and molds of fusulinids	24.0
Covered: probably shale; not measured.	

48. Sec. 34, T. 18 N., R. 10 E. Measured from stream 1,300 feet west of SE cor. westward to top of hill.

CHANUTE FORMATION

Sandstone and sandy shale; extends to top of hill	15.0

DEWEY FORMATION

Covered: probably silty shale	20.0
Sandstone: weathers buff to brownish red; fine-grained; rudely bedded	10.0
Shale: dark, weathers gray; silty	7.0
Siltstone: weathers gray; soft but stands vertical; fossiliferous	3.0
Siltstone: weathers gray; calcareous; fossiliferous, molds and casts	5.7

NELLIE BLY FORMATION

Shale: gray, silty; base not exposed; not measured.

49. Sec. 35, T. 18 N., R. 10 E. Measured from 500 feet west of SE cor. west to top of hill.

NELLIE BLY FORMATION (upper part)

Covered to top of hill: probably shale	6.0
Sandstone: weathers buff to brown; thin-bedded	3.0
Sandstone: weathers buff to brown; fine-grained; massive; hard; calcareous	3.0
Sandstone: weathers buff; fine-grained; massive; hard	3.0
Shale: gray, lavender band 4 inches thick 2 feet below top; contains siltstone beds a few inches thick	5.7
Sandstone: white to brown or buff; fine-grained; massive; soft	3.5
Siltstone: buff; shaly	2.0
Shale: gray	3.7
Sandstone: weathers reddish brown; fine-grained; hard; calcareous; fossiliferous	1.0
Sandstone: weathers reddish brown; fine-grained; soft; nodular; calcareous; fossiliferous	1.0
Shale: gray	3.0
Sandstone: weathers buff; fine-grained	2.0
Shale: gray; silty	1.5
Sandstone: weathers yellowish brown	1.0
Shale: gray; silty	1.0
Sandstone: weathers brown; fine-grained	0.5
Shale: gray; blocky; little silt	2.2

Covered: probably shale; not measured.

50. Sec. 35, T. 18 N., R. 10 E. Measured from about 1,000 feet east of SW cor. west to top of hill and thence north about 300 feet.

CHANUTE FORMATION	
Sandstone: not measured.	
DEWEY FORMATION	
Covered: probably silty shale	15.0
Sandstone: weathers buff to reddish brown, much of it mottled with brown; fine-grained; massive beds one to 3 feet thick	7.0
Shale: gray; silty	4.0
Sandstone: weathers brownish buff; fine-grained; fossiliferous, many molds; probably leached calcareous sandstone	0.8
NELLIE BLY FORMATION	
Shale: weathers brownish red; silty	4.0
Covered: probably silty shale; not measured.	

51. Sec. 35, T. 18 N., R. 10 E. Measured from NW cor. south up hill.

CHANUTE FORMATION	
Shale and nonresistant sandstone: extends to top of hill	20.0
Sandstone: white; fine-grained	5.0
DEWEY FORMATION	
Shale: gray; silty	5.0
Sandstone: weathers brown; fine-grained; calcareous	2.0
Shale: gray; silty	5.0
Sandstone: gray; fine-grained	1.0
Shale: gray; silty	3.0
Sandstone: weathers brown; fine-grained; upper 7 feet calcareous; quarried east of road	15.0
NELLIE BLY FORMATION	
Covered: probably shale	2.0
Sandstone: weathers brownish yellow	5.0
Shale: gray	5.0
Siltstone: weathers buff; sandy; fossiliferous, many molds; fresh rock is probably gray calcareous siltstone	1.3
Siltstone: weathers brown; shaly; nonresistant; fossiliferous, many molds	5.0
Shale: dark gray	25.0
Limestone: gray, weathers brown; silty; fossiliferous	2.0
Shale	5.0
Sandstone: weathers buff to brown	4.5
Sandstone: weathers buff; shaly	6.0
Sandstone: weathers brown; fine-grained	10.0
Covered: probably shale	17.0
Sandstone: weathers brown; fine-grained; cross-bedded; ripple marked; fossiliferous in upper part, molds; base covered by water below ford	4.0

52. Sec. 7, T. 18 N., R. 12 E. Measured up the southeast flank of the hill in the NW¼ of the SW¼, from Turner Turnpike to the top of the hill ear the W¼ cor.

COFFEYVILLE FORMATION (upper part)

Sandstone: weathers brown; fine- to medium-grained; top eroded	5.0
Covered: sandy shale	18.0
Sandstone: weathers brown; fine-grained; massive	1.5
Covered: shale	35.0
Topographic bench: covered by sandstone rubble from above; probably shaly siltstone about	5.0
Covered: shale	65.0
Topographic bench: covered by rubble from above; probably shaly siltstone about	5.0
Covered: shale	30.0
Topographic bench: covered by rubble; probably shaly sandstone	2.0
Covered: shale	40.0

53. Sec. 8, T. 18 N., R. 12 E. Measured from stream 2,200 feet east of W¼ cor. westward up hill.

COFFEYVILLE FORMATION

Shale: not measured.	
Sandstone: weathers reddish brown; fine-grained	5.0
Shale: weathers yellowish gray	17.0

CHECKERBOARD LIMESTONE

Limestone: not well exposed; generally dark bluish-gray; dense; massive about	2.5

SEMINOLE FORMATION

Covered: probably sandy shale; not measured.

TOWNSHIP NINETEEN NORTH

54. Sec. 7, T. 19 N., R. 7 E. Measured south from bridge 2,100 feet north of SE cor.

VANOSS FORMATION

Shale: weathers dark red; silty; extends to top of hill	2.0
Sandstone: weathers brown; fine-grained; massive	8.0
Shale: weathers dark red; silty; not well exposed	10.0
Limestone: gray, weathers brown; thin-bedded; sandy; fossiliferous	10.0
Covered: probably silty shale	18.0
Sandstone: weathers brown; fine-grained	2.0
Covered: probably silty shale	20.0
Sandstone	30.0

55. Sec. 8, T. 19 N., R. 7 E. Measured from 1,200 feet east of NW cor. west to that cor.

VANOSS FORMATION

Limestone: weathers brown; sandy; fossiliferous	1.0
Sandstone: gray, weathers brown; medium- to fine-grained	3.0
Covered: probably silty shale	3.0
Limestone: gray, weathers brown; fossiliferous	8.0
Shale: weathers red; silty	5.0
Sandstone: gray, weathers brown; fine-grained; massive	5.0
Shale: gray, weathers brown; silty	20.0
Limestone: dark blue, weathers brown; sandy; fossiliferous	2.0
Covered: probably silty shale	12.0
Sandstone: gray, weathers brown; fine-grained; base not exposed	2.0

56. Secs. 2 and 3, T. 19 N., R. 8 E. Measured up east end of hill in the vicinity of the E¼ cor. sec. 3.

VAMOOSA FORMATION (middle part)

Covered: probably silty shale; extends to top of hill	15.0
Sandstone: weathers yellow to brown; medium- to fine-grained; several beds are massive	22.0
Shale: weathers yellow; silty to sandy	50.0
Sandstone and silty shale beds	5.0

57. Sec. 11, T. 19 N., R. 8 E. Measured up hillside from water's edge, north side of Cimarron River, about one-fourth mile west of cor.

VAMOOSA FORMATION (lower part)

Covered by sandstone debris; probably shale	2.0
Shale: weathers yellow	6.0
Sandstone: weathers brown; medium-grained; massive	5.0
Covered by sandstone blocks: probably silty shale	20.0
Covered: lodgment terrace of sandstone blocks; probably represents silty sandstone about	2.0
Covered: probably silty shale and nonresistant sandstone	90.0
Covered: lodgment terrace of sandstone blocks; probably represents silty sandstone about	2.0
Covered: probably silty shale and silty sandstone beds	28.0
Covered: lodgment terrace of sandstone blocks; probably represents silty sandstone about	2.0
Covered: probably silty shale and nonresistant sandstone	34.0

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