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GEOLOGY AND MINERAL RESOURCES OF HUGHES COUNTY, OKLAHOMA

BY

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GEOLOGY AND MINERAL RESOURCES
OF
HUGHES COUNTY, OKLAHOMA

By O. D. Weaver, Jr.

ABSTRACT

The primary purposes of this investigation were: (1) to study in detail the character, distribution, and thickness of the rock formations and to prepare a detailed areal geologic map; (2) to trace northward formations already mapped to the south and west of Hughes County and correlate them with the formations of northeastern Oklahoma and southeastern Kansas; (3) to study the fossils present in the various formations and make a faunal and floral range chart; (4) to determine the age and correlation of several producing oil sands that crop updip to the east of Hughes County; (5) to map the faults in the area; (6) to locate and describe mineral deposits of possible economic value.

The surface rocks in Hughes County are of Pennsylvanian and Quaternary age and were mapped in detail. The Pennsylvanian rocks include ten formations which range in age from the Boggy formation of middle Desmoinesian age up to the Coffeyville formation of lower Missourian age. The Quaternary deposits include high level gravels, drape deposits, terrace deposits, the Gerty sand, and flood plain deposits. Sixty-five units of sandstone, conglomerate, shale, and limestone, as well as all formational contacts, were mapped by the writer and appear on the geologic map.

Wewoka Creek and Little River show evidence of having played a much more important role in the drainage of the county in the past. Broad flood plains and extensive terrace deposits testify to the past size and extent of these streams. Muddy Boggy, Sand, Panther, and Caney Boggy Creeks drain the south part of the county and flow southward into the Red River. They have high gradients and are actively enlarging their drainage basins to the north at the expense of the South Canadian River. The South Canadian River once flowed southeastward from the vicinity of Allen across southern Hughes, northeastern Coal, and central Pittsburg Counties and rejoined its present channel just south of Eufaula in southern McIntosh County. The Gerty sand of Hughes and adjoining counties roughly outlines the past course of this stream. An abrupt change from southeast to northeast that occurred just southeast of Hughes County was caused by the Ashland anticline in northeastern Coal County. Little River was an important tributary to the South Canadian River at that time and flowed across Hughes and northern Pittsburg Counties in the channel now occupied by the South Cana-

dian River. A tributary of Little River worked its way southward from the vicinity of Atwood and cut into the channel of the South Canadian River, diverting it northward into its present channel.

A distinct change occurs in the character of the beds lying above the Boggy formation. Coarse chert conglomerates are common in the Thurman and succeeding formations, and the shale intervals separating the successive sandstone units become thinner. Coarse chert conglomerates do not occur in Hughes County north of a northwest-trending line through the central part of the county. These conglomerates typically do not thicken toward the south but grade laterally to finer-grained sediments both to the northeast and the southwest. This indicates a southeastern or possibly a southern source of these gravels.

Numerous sandstone and siltstone tongues are present at the base of the Calvin sandstone. These tongues wedge out to the northeast along the strike of the beds and to the northwest in the subsurface. The presence of these tongues and certain other physical properties of this unit indicate that the condition of deposition was that of a large delta, with the streams that deposited the tongues shifting irregularly across its surface.

The Homer and the Sasakwa limestones of the Holdenville formation are not present north of the vicinity of Spaulding in the west-central part of the county. The limestone that occurs on the fair grounds at Holdenville is not the Homer limestone but is a thin limestone near the base of the Holdenville formation. Surface mapping indicates that the contact between the Des Moines and Missouri series is conformable in Hughes County. The Coffeyville formation of northeastern Oklahoma and southeastern Kansas was traced southwest across Hughes County and found to be the equivalent of the lower part of the Francis formation as mapped in the Stonewall quadrangle. The Checkerboard limestone, which lies immediately below the Coffeyville formation in Okfuskee County to the north, is not present in Hughes County. The DeNay limestone, the basal unit of the Francis formation as mapped to the southwest of Hughes County, is not present north of the west-central part of the county. This limestone occupies the same stratigraphic position as that of the Checkerboard limestone to the north and is considered to be its equivalent.

Though most of the fossils occurring in the Pennsylvanian rocks in Hughes County are long ranging, the forms *Mesolobus mesolobus*, *"Marginifera" muricatina* and *Delocrinus granulosus* appear to be limited to the Des Moines series.

Deposits of volcanic ash present in the Dustin area are associated with high terrace deposits of the North Canadian River and are probably of Quaternary age.

The southeast edge of the central Oklahoma uplift or platform, a subsurface feature, trends northeastward across the central and northeastern parts of Hughes County. The McAlester basin lies to the south and includes the southeastern part of the county. The oldest Pennsylvanian rocks present beneath the county are of Morrowan age. The Morrowan and the overlying Atokan rocks are very thick to the southeast of Hughes County but thin rapidly across central Hughes County as they pass northwest out of the McAlester basin. An important unconformity is present at the base of the Atoka series in the subsurface of this area. The upper part of the Wapanucka shale is truncated, and the Wapanucka lime is not present northwest of the north-central part of the county. The Des Moines series overlies the Atoka series unconformably in the subsurface. This unconformity cuts out the entire Atoka section to the northwest of Hughes County. Formational contacts and many of the individual units of the formations that crop out in Hughes County can be traced accurately into the subsurface. Changes in thickness and character of the units may be interpreted. The exposed formations thin to the west in the subsurface and at places grade into shale. The "Senora limestone" of the subsurface crops out across northeastern and east-central Hughes County. This limestone lies near the top of the lower Senora sandstone unit of the surface. The oil produced at about 1,700 feet in the Olympic field of northwestern Hughes and southern Okfuskee Counties is from sandstones which occur in the upper part of the lower Senora sandstone of the surface. The "Calvin sandstone", which produces oil in the subsurface of western Hughes, Seminole, and Okfuskee Counties, is equivalent to only the lower part of the Calvin sandstone of the surface. The "Wetumka shale" of the subsurface is a silty shale zone within the Calvin formation of the surface. Oil fields in Hughes County are limited to the area north and west of the outcrop of the lower part of the Calvin sandstone. This belt trends northeast across the county and roughly coincides with the southeastern edge of the central Oklahoma uplift. Gas production is obtained to the east of this zone, however. The change from basin to shelf environment occurs in this "hinge zone," and the occurrence of oil and gas is directly affected by the change.

INTRODUCTION

Scope and Purpose of the Work

This report presents the results of a detailed study of the rocks of Pennsylvanian age that crop out in Hughes County, Oklahoma.

The primary purposes of this investigation were: (1) to study in detail the character, distribution, and thickness of the rock formations and to prepare a detailed areal geologic map; (2) to trace northward formations already mapped to the south and southwest of Hughes County and to correlate them with the formations of northeastern Oklahoma and southeastern Kansas; (3) to study the fossils in the various formations and determine ranges of species; (4) to determine the age and correlation of several producing oil sands that crop out updip to the east in Hughes County; (5) to map the faults in the area; and (6) to locate and describe mineral deposits of possible economic value.

Location of the Area

The area of this report includes all of Hughes County, an area of approximately 810 square miles located in the east-central part of the state. All the county is included in Townships 4 to 9 North and Ranges 8 to 12 East. Figure 1 shows the county outline and its relations to other Oklahoma counties.

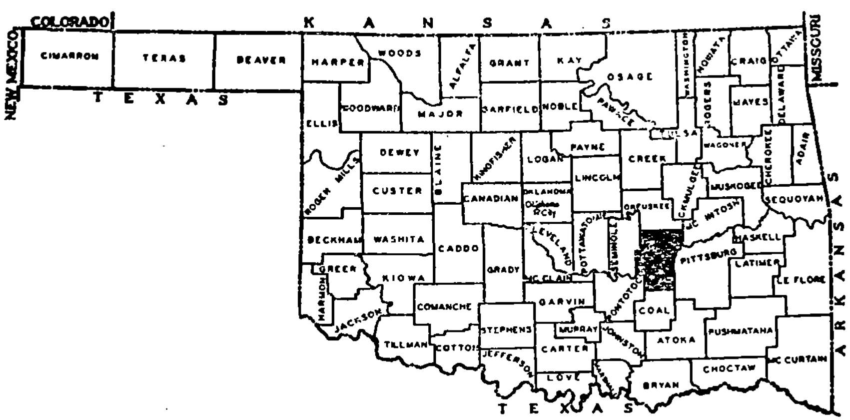

FIG. 1. Index map of Oklahoma showing location of Hughes County.

Accessibility of the Area

The area is easily accessible from most directions by paved roads. U. S. Highway No. 270 trends southeast through Holdenville, Calvin, and Stuart, and U. S. Highway No. 75 passes from north to south through Wetumka and Calvin. State Highways 9, 12, and 68 cross the county.

Equally important locally is an excellent network of section line and farm-to-market roads which, except where they cross certain shale beds, are passable in all weather. Actual accessibility of any particular part of the county is largely controlled by the character of the rock that crops out in that area. Thus, the rugged outcrops of the thick Calvin sandstone and of the lower sandy member of the Senora formation directly limit the feasibility of road construction and offer little to encourage settlement in those areas. The complete road network on the outcrop of the Wetumka shale, for example, contrasts sharply with the incomplete network on the underlying Calvin sandstone.

Three railroads serve Hughes County. The Chicago, Rock Island and Pacific Railroad passes through Holdenville, Calvin, and Stuart. The St. Louis and San Francisco Railroad serves Spaulding, Holdenville, Yeager, and Wetumka. The Kansas, Oklahoma, and Gulf Railroad serves Atwood, Calvin, Lamar, and Dustin.

Previous Investigation

In 1895 and 1896 topographers of the United States Geological Survey mapped three quadrangles[1,2,3] in east-central Oklahoma which among them included all of Hughes County. In 1898, Drake's regional report was published.[3a] Following this work, Taff[4] mapped and named the formations in the southern part of the county but did most of his work farther south and east. In 1910 Gould, Ohern, and Hutchison[5] studied the grouping of the Pennsylvanian rocks of eastern Oklahoma. Gould[6] and Snyder[7] in 1911,

1 "Canadian quadrangle topographic sheet", 1901. *U. S. Geol. Survey.*
2 "Coalgate quadrangle topographic sheet", 1901. *U. S. Geol. Survey.*
3 "Wewoka quadrangle topographic sheet", 1901. *U. S. Geol. Survey.*
3a Drake, N. F., 1898. *Amer. Phil. Soc., Proc.*, v. 36, p. 326-419.
4 Taff, J. A., 1901. *U. S. Geol. Survey, Geol. Atlas, Folio* No. 74.
5 Gould, C. N., Ohern, D. W., and Hutchison, L. L., 1910. *Univ. Okla., Research Bull.* No. 4.
6 Gould, C. N., 1911. *Okla. Geol. Survey, Bull.* 5, p. 153.
7 Snider, L. C., 1911. *Okla. Geol. Survey, Bull.* 8, p. 171.

mentioned the possible economic value of the sandstones, shales, and clays of the county. In the same year Snider[8] discussed the stratigraphy of Hughes and surrounding counties and mentioned further the value of the clays of the area.

The volcanic ash deposits in the Dustin area were discussed by Buttram[9] in 1914, and in 1915 G. H. Girty[10] made a comprehensive study of the fauna of the Wewoka formation.

Information of a general nature about the county and its geographic setting was included by Snider[11] in his "Geography of Oklahoma", published in 1917.

In 1925 a brief stratigraphic review in which the lithologies were described and the characteristic fossils of all the formations that crop out in the county were listed was published by Gould and Decker.[12]

The discovery of oil stimulated other investigations in the county. In 1924 Lockwood[13] published the first report on the Papoose oil field, and in the following year Dwyer[14] discussed the newly developed Fuhrman pool. Bunn and Roark[15] compiled a paper concerning the petroleum geology of the Papoose oil field that presented an excellent summary of the petroleum production methods of the time. Included was a chapter on the geology of the area by Roark.

The year 1924 marked the publication of Morgan's[16] study of the Stonewall quadrangle, an area immediately southwest of Hughes County. This paper added considerably to the knowledge of the adjacent area and served, along with Taff's work to the south, as a background for the present work.

In 1926 Miser's[18] "Geologic Map of Oklahoma" showed the areal geology of the county on a scale of 1:500,000.

8 Snider, L. C., 1911. *Okla. Geol. Survey, Bull.* 7, p. 227.
9 Buttram, Frank, 1914. *Okla. Geol. Survey, Bull.* 13.
10 Girty, G. H., 1915. *U. S. Geol. Survey, Bull.* 544.
11 Snider, L. S., 1917. *Okla. Geol. Survey, Bull.* 27.
12 Gould, C. N., and Decker, C. E., 1925. *Okla. Geol. Survey, Bull.* 35.
13 Lockwood, C. D., 1924. *Oil and Gas Journal*, vol. 23, no. 27, pp. 23, 110.
14 Dwyer, J. L., 1925. *Oil and Gas Journal*, vol. 24, no. 27, pp. 24, 137.
15 Bunn, J. R., and Roark, Louis, 1926. *Okla. Geol. Survey, Bull.* 36.
16 Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2.
18 Miser, H. D., 1926. *U. S. Geol. Survey.*

The article "Paleogeography of Oklahoma" by Wilson,[19] which appeared in 1927, served to place the county in its proper paleogeographical setting. In the same year Redfield,[20] in discussing the mineral resources of Oklahoma, mentioned two volcanic ash deposits in the northern part of the county and summarized data on the oil and gas fields in the area. A more complete review of these fields is contained in the "Digest of Oklahoma Oil Fields"[21] which appeared in 1928. Also in 1928 came Dwyer's[22] article on deep drilling in the Allen-Sasakwa field.

A micropaleontological study by Warthin[23] appeared in 1930, as did a handy summary by Boyle[24] of the geology of the surface and subsurface formations of the county. In 1932 Swindell's[25] paper on the Fish pool was published. A bibliography of oil and gas pools by Alan G. Shelton[26] in 1942 contained reference data on all fields in Hughes County.

The most significant recent works on the area are by Sarles[27] and Ries.[28] Sarles traced the DeNay limestone into the county from Seminole County on the west, and Ries carefully traced the Sasakwa limestone into the county farther to the south. Ries' work also included the faunal study of this limestone.

In 1949 Burwell[29] included the analysis of samples of volcanic ash from the Dustin area in his work on cellular products from Oklahoma volcanic ash.

Much detailed structural mapping has been done by major oil companies in Hughes County in years past, but most of this information is not available to the general public.

19 Wilson, Roy A., 1927. *Okla. Geol. Survey*, Bull. 41.
20 Redfield John S., 1927. *Okla. Geol. Survey, Bull.* 24, p. 113.
21 *Okla. Geol. Survey*, 1928. *Bull.* 40, Vol. 1.
22 Dwyer, J. L., 1928. *Oil and Gas Journal*, Vol. 26, No. 64, pp. 91, 97.
23 Warthin, A. S., 1930. *Okla. Geol. Survey, Bull.* 53.
24 Boyle, J. Phillip, 1930. *Okla. Geol. Survey, Bull.* 40-XX.
25 Swindell, Floyd, 1932. *Oil Weekly*, Vol. 67, No. 11, p. 41.
26 Shelton, Alan G., 1942. *Okla. Geol. Survey, Bull.* 63.
27 Sarles, J. E., 1943. *Univ. of Okla.* Unpublished Master of Science Thesis.
28 Ries, E. R., 1943. *Univ. of Okla.* Unpublished Master of Science Thesis.
29 Burwell, A. L., and Ham, William E., 1949. *Okla. Geol. Survey, Circ.* 27.

Present Investigation

Preparation

Aerial photographs of Hughes County were obtained from the Agricultural Adjustment Administration. Transparent cellulose acetate sheets were attached to alternate pictures in each flight line, and pictures were numbered and indexed for ready reference. The acetate covers served both as work sheets on which to include geological data and notes and as a protection for the photographs when in use in the field. Thus, no geological or cultural data were put on the pictures themselves. Section lines or corners were almost everywhere identifiable, and all sections were numbered and section corners indicated on the photographs in colored ink. A base map was then constructed by tracing drainage, roads and other cultural features on transparent acetate township plats whose scale was the same as that of the photographs, approximately 3.24 inches per mile. Roads and other cultural data were later checked in the field and corrections made. The photographs were fairly uniform in scale, but where certain pictures deviated slightly, adjustments were made to the section corners.

Careful stereoscopic study of the photographs in the laboratory began when the base map was completed. All possible structural and stratigraphic data, as well as drainage and cultural features, were traced onto the acetate cover sheets. Later the drainage and cultural data were transferred to the township plats, which were photographed and taken into the field as work sheets.

Field Procedure

The field work consumed a total of seven months and was completed during the summers of 1950 and 1951. Mapping was started in the southeast part of the county where the oldest formations are exposed. Township plat base maps were carried into the field, as were such aerial photographs as were needed to cover the area being worked. Prior to each day's field mapping, a complete stereoscopic study was made of the photos of the area to be covered. Formations were traced along the outcrop where feasible and contacts and outcrops were located by the use of the photos directly or pacing or automobile traverse.

Fossil collections were made at intervals throughout the section and along the strike of the beds in the same horizons. Collections from mineral deposits of possible economic value were made if it seemed advisable. Detailed sections were measured at many places.

Laboratory Procedure

Although identification of many of the fossils was made in the field or immediately after the collecting, all of the collections were later cleaned, sorted, and identified in the laboratory. A faunal and floral chart was then compiled.

Thin sections were made of several of the limestones in the area, as well as of some of the Gerty gravels.

In compiling the measured sections, electric logs were studied and used to check the computed thicknesses in areas of low dip and poor exposures.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to the Oklahoma Geological Survey for sponsoring this project. Mr. Malcolm C. Oakes of the Survey checked the field work and offered valuable suggestions on many occasions. Dr. William E. Ham made important contributions during the preparation of the various plates.

Professor Charles E. Decker checked the fossil identifications.

Mr. W. D. McBee of the Carter Oil Company carefully checked the electric log cross section and furnished electric logs and other field data as needed.

Dr. Edward R. Ries spent two days in the field with the writer in the summer of 1951 in order to assure correlations of formations that crop out across Hughes and Okfuskee Counties.

Dr. William F. Tanner, who mapped the geology of Seminole County, worked several days with the writer on joint boundary problems and later made helpful suggestions during the preparation of the manuscript and the plates.

Final drafting of the Geologic Map (Plate I) was done by Dwight H. Ford of the Oklahoma Geological Survey, and most of the outcrop photographs were taken by Myron E. McKinley, Assistant Geologist, Oklahoma Geological Survey.

GEOGRAPHY

Topographic Features

In his "Geography of Oklahoma" Snider[30] included all but the extreme eastern part of Hughes County in the Sandstone Hills physiographic province. The east-central and northeast part of the county he classified as a part of the Prairie Plains region, and the extreme southeast part was included in the Lower Arkansas Valley region. However, Morris[31] in an unpublished manuscript places the entire county in the Sandstone Hills province. According to Fenneman[32] the county lies regionally in the Central Lowland physiographic province.

A series of northeast trending cuestas characterizes the topography of Hughes County. These cuestas are capped by resistant sandstones, siltstones, or conglomerates which are underlain by softer shales, argillaceous siltstones, and thin limestones of Pennsylvanian age. These ridges or escarpments overlook broad shale valleys to the southeast and slope gently to the northwest at about 1°. The consolidated beds are now blanketed locally by alluvial deposits of present streams or by Quaternary terrace deposits.

The sequence of sandstones and shales was deposited in essentially horizontal position. At a much later date the beds were tilted into their present position. Streams flowing east from the Rocky Mountain area eroded and leveled the area by beveling off most of the higher topographic features and filling those areas which were lower. The streams were at grade and meandered over this broad plain, which stood at about the level of the highest hills present in the county today. There is today a rough accordance of ridge tops throughout the area, and gravel, sand, and clays of Quaternary age cap some of the highest cuestas and buttes. These earlier streams did not follow the same courses as those of today but flowed in the same general direction.

30 Snider, L. C., 1927. *Okla. Geol. Survey, Bull. 27*, p. 80.
31 Morris, John W., January, 1952. *Personal Communication.*
32 Fenneman, Nevin M., 1938. *Physiography of the Eastern United States*, p. 616.

Later the major rivers crossing the area were rejuvenated and began actively cutting down through the blanket of Quaternary sand, gravel, and clay previously deposited. With this renewed downcutting, tributary streams began cutting back into the softer shale zones between the newly exposed resistant sandstone beds. These tributaries became subsequent streams paralleling the strike of the tilted beds and creating the broad shale plains present today at the base of each cuesta. As erosion continued, the escarpments retreated gradually to the northwest, largely by undercutting in the shale beneath the caprock. Differential erosion produced re-entrants and promontories, and when headward erosion of obsequent and subsequent tributaries proceeded far enough, portions of the main escarpments were isolated, forming buttes.

The height of the various southeast-facing cuestas or buttes depends primarily upon the thickness of the shales that underlie the sandstone caps. Also important are the amount of dip and the resistance of the successive caprocks. Most escarpments are between 50 and 100 feet high.

Typical of the general topography of the county is the broad, grass-covered shale plain just southwest of Dustin which slopes gently to the west. This is on the upper shale member of the Senora formation. On the west it is bounded by a steep escarpment capped by the lower Calvin sandstone. Heavy timber covers the rough country atop this escarpment. To the east of the prairie plain the grassland merges into the heavily wooded dip slope of the lower Senora sandstone member.

Some of the escarpments extend across the county with few breaks, and other ridges gradually become lower and disappear to the north where the sandstones wedge out. The topography is locally modified by faults which have tilted small blocks at irregular dips.

There are two major river valleys in the county. The Canadian River cuts almost directly across the many escarpments and divides the county into northern and southern parts. The North Canadian River valley swings southward from central Okfuskee County and its alluvium covers a small area immediately north of Wetumka.

Of special interest is a broad eastward-sloping belt of stream laid sand, clay, and gravel which trends across the south half of the county. The town of Gerty lies on these ancient stream deposits, and Taff[33] applied the name of Gerty sands to these and other related deposits in nearby counties. These river deposits are intermediate in age between the upland terrace cover described above and the high terrace materials deposited by the present rivers. The Gerty surface provides an abrupt change from the rough, timbered topography to the north and south of the area. Loose sands have been driven by eolian action into large barren dunes over much of the area. (See "Quaternary Stratigraphy.")

According to data on the topographic maps[34] the highest point in Hughes County, approximately 1,150 feet above sea level, is in sec. 3, T. 7 N., R. 11 E. The lowest point,[35] between 550 and 600 feet above sea level, is in the bed of the Canadian River where it flows out of the county in sec. 24, T. 8 N., R. 12 E. The maximum relief in the county is about 550 feet. The average altitude of the county is between 850 and 900 feet above sea level.

Drainage

Hughes County is drained by the North Canadian and Canadian Rivers in its northern and central portions respectively, and by numerous smaller creeks which flow southward from the south part of the area to the Red River.

The North Canadian River rises in New Mexico and flows across Oklahoma in an east-southeast direction. It enters Hughes County northeast of Wetumka by making a tight meander southward from Okfuskee County. It serves as the main drainage artery for the northwest, north-central, and a small area in the northeast part of the county. Wewoka Creek is the most important tributary and there is evidence that it played a much more important role in the drainage pattern of the past. The North Canadian River has an average gradient of 2.43 feet per mile,[36] is choked with sands and clays, and has numerous meander scars and oxbow lakes along its broad flood plain.

33 Taff, J. A., 1901. *U. S. Geol. Survey*, Geol. Atlas, Folio No. 74, p. 4.
34 "Wewoka Quadrangle topographic sheet", 1900. *U. S. Geol. Survey.*
35 "Canadian Quadrangle topographic sheet", 1900. *U. S. Geol. Survey.*
36 Ries, Edward R., 1952. *Okla. Geol. Surv., Bull.* 71, in press.

The central and eastern parts of the county are drained by the Canadian River and its tributaries. It roughly parallels the North Canadian River in its course across the state and merges with it east of Eufaula in McIntosh County. Little River is the most important tributary, and drains the west-central part of the county. Both of these rivers have broad, oversized flood plains punctuated with oxbow lakes and bordered with high terrace deposits. The gradient of the Canadian River in Hughes County is approximately 3.1 feet per mile.[37]

The southern part of the county is drained by Muddy Boggy, Sand, Panther, and Caney Boggy creeks, which flow to the southeast and merge in central Coal County before flowing south into the Red River. These streams have high gradients and are actively enlarging their drainage basins as they encroach upon that of the South Canadian River. Muddy Boggy Creek, in the extreme southwest part of the county, has an average gradient of more than 7 feet per mile.[38]

Most of the minor tributaries, especially in the central and northern part of the county, are subsequent streams. These are streams which parallel the strike of the various beds because they follow the softer shale beds. The major rivers trend across the strike of hard and soft beds, but do show numerous local deviations owing to resistant formations such as the Calvin sandstone. Major streams cross the more resistant beds at right angles at most places and meander across the softer shales. In the western half of T. 8 N., R. 10 E., Grief Creek crosses the ridges of the lower Wewoka sandstones where the sandstones are thin or absent and the beds consist mostly of less resistant shales. Many streams cross the escarpments at places where the sandstones grade to shale. It is at these weaker zones where stratigraphic details are cut away or covered, making exact correlations more difficult.

Vegetation

The sandstone and siltstone scarps are generally covered with post oak (*Quercus stellata* Wang), *blackjack* (*Quercus marylandica* Muench), and hickory (*Carya cordiformis* Koch). The prairie grasslands are areas of low relief underlain by shales. These are

37 "Coalgate Quadrangle topographic sheet", 1901. *U. S. Geol. Survey.*
38 *Ibid.*

the areas of pasture and general farming. Cottonwood (*Populus sargentii* Dode), black willow (*Salix nigra* March), pecan (*Carya pecan* English and Graebn), and black walnut (*Juglans nigra* Linnaeus) typically cover the alluvial bottoms.

Climate

Regionally, eastern Oklahoma has a warm, humid, continental type of climate, typified by long, hot summers and mild, brief winters.[39] Daily ranges in temperature are small for a continental type of climate, and summer nights are warm. Average relative humidity is moderate, ranging from 60 to 70 percent.

Rainfall

The average annual precipitation[40] as measured at the Holdenville, Oklahoma, station over a period of 38 years is 37.83 inches. Table I following shows the average monthly precipitation in Hughes County for the same period. There is a primary maximum rainfall in April, May, and June, and a secondary maximum during September. On the whole rainfall is fairly well distributed throughout the year.

TABLE I

AVERAGE MONTHLY PRECIPITATION OF HUGHES COUNTY

Month	Inches
January	2.26
February	1.82
Ma·ch	2.99
April	3.74
May	5.35
June	3.91
July	2.70
August	3.15
September	4.02
October	3.35
November	2.47
December	2.07

Temperature

The average annual temperature at the Holdenville station in Hughes County is 61 degrees. The maximum recorded temperature is 118 degrees, and the minimum recorded is 12 degrees below zero. January averages 40 degrees and the average temperature in July

39 Blair, Thomas A., 1942. *Climatology*, pp. 219-220.
40 "Climate and Man", 1941. *U. S. Dept. of Agri.; Yearbook*, p. 1067.

is 82.1 degrees. The length of the growing season is approximately 225 days, a figure computed from the average dates of the last killing frost in Spring, March 26, and the first to occur in the Fall, November 26.

Soils

Hughes County lies in the western portion of an area of red and yellow podzolic soils which cover much of the southeast part of the United States.[41] These soils are typically acid, strongly leached, and are low in organic matter and plant nutrients.

Locally the soils of the county are divided into three main groups by soil scientists.[42]

1. *Cherokee Prairie or Eastern Oklahoma Prairie.*—This is a typical prairie soil with natural grass cover well shown in the northeast part of the county in the Dustin-Carson area. In this area the parent rock is the upper shale member of the Senora formation. Soil of this type is also present in the west-central and northwest parts of the county where the source-rocks are the shales and sands lying above the Calvin sandstone. Some 35 per cent of the county is covered by soils of this type. Although the soil needs fertilizer and a planned conservation program, over 85 per cent of the area is suitable for cultivation. Average depth of the virgin topsoil is 15 inches and the annual erosion rate or soil loss is low. This soil is well-adapted to corn, grain sorghums, pasture crops, peanuts, and cotton. Though generally deficient in calcium and phosphorus, a well organized fertilization program yields splendid crop returns.[43] The area is excellent for the pasturing of beef and dairy cattle. Size of farms and towns in this soil group area is well above the average for the county, and this area has the densest population.

2. *Cross Timbers.* These areas are characterized by shallow, sandy, youthful soil derived mainly from the sandstones and siltstones of the Thurman, Stuart, Senora, and Calvin formations. With the exception of the Dustin-Carson area and certain bottom-

41 "Soils and Man", 1938. *U. S. Dept. of Agri.*
42 Long, Roscoe M., July, 1951. *Personal Communication.*
43 Kellog, Charles E., 1949. *The Soils That Support Us*, The Macmillan Company.

land soils along present streams, all the northeast part of the county east of the contact between the Wetumka shale and the Calvin sandstone is covered by soil of this type, as is most of the county south of the Canadian River. These soils cover some 60 per cent of the county.

The soils are classified as poor and stony, and only some 35 per cent of the area is under any type of cultivation. The area is rugged and covered largely with black jack, post oak, and hickory. As these are essentially youthful, residual soils, they directly reflect the parent material underlying them. When a detailed geologic map is compared with a soil map in the area, interesting and worthwhile correlations may be made. The more mature the soils, of course, the more they are disassociated from the parent materials.

Small farms typify this area, and 3 to 5 acres of land under cultivation by one farmer might be considered the average. The standard of living is appreciably lower than in the surrounding, more fertile, prairie areas. Some cotton, grain, and peanuts are grown, but the land is best fitted for light pasture and timber.

3. *Alluvial Plains or Bottomlands.*—These are deep, coarse textured, well-drained, sandy soils well adapted for many types of farm crops. This type of soil covers some 10 percent of the county, on the flood plains and alluvial terraces of the present rivers. Garden truck, peanuts, corn, and alfalfa are common crops. Over 90 per cent of this land is under cultivation. Much of the soil is low in organic matter, but it needs far less soil management than do the other soil groups of the county. Farms are small in these areas, but yields are large and profitable.

Population and Economic Development

In 1856 the area that is now Hughes County became a part of the old Creek Indian Nation. The county was organized in 1907 and had a population then of 19,945.[44] The population grew steadily, reaching 29,189 by 1940. However, World War II drained the county of much of its manpower, as many of the inhabitants moved to larger cities for war work. Too, the sagging

44 "The Natural Resources of Hughes County", 1948. *Engineering Experiment Station, Okla. A., and M. College,* Research Project No. I, Stillwater, p. 24.

cotton market and depleted soils caused many tenant farmers to move to other areas. In 1950 the population was 20,648,[45] or approximately 25 persons per square mile. Some 20 per cent of the people are colored, and almost 15 per cent are Indians. More than 90 percent of the Indians are Creeks, but there are also Seminoles, Cherokees, and Choctaws in the county.

More than 80 per cent of the population is rural. The greater part of the total population lives on the prairie areas west of the outcrop of the Calvin sandstone. This essentially is also the area where the Cherokee Prairie type soils are present. Average farm size is 157 acres and is increasing annually as the number of tenant farmers decreases. There has been a decided drop in the number of acres under active cultivation in recent years as worn out cotton land is converted to grazing lands.

Holdenville, with a population of approximately 6,000, is the county seat, and Wetumka, Dustin, and Calvin are important centers.

Farming, stock raising, oil production, and oil field maintenance are the chief industries of the county. Cotton production was for years the chief source of farm income but now has given way to a more diversified farm economy. Much former cotton acreage is now devoted to peanuts, and in 1950 19,000 acres produced over 9 million pounds of peanuts.[46] A large per cent of the acreage in peanut production is located on the outcrop of the Gerty sand. Annually over 650 wells in the county produce almost 2 million barrels of oil. Although oil and gas are the main mineral resources of the county, volcanic ash is mined at Dustin, and several gravel pits are worked in the south part of the county.

45 *Rand McNally Commercial Atlas and Marketing Guide,* 1951. 81st Edition, Rand McNally and Company, New York.

46 Davis, Frank E., July, 1951. *Personal Communication.*

SURFACE STRATIGRAPHY

Introduction

More than 3,800 feet of Pennsylvanian strata crop out in Hughes County. This thick sequence includes rocks ranging in age from the upper part of the Boggy formation of lower Des Moines age to the upper part of the Coffeyville formation of lower-middle Missouri age. At many places the bedrock is covered by surficial deposits of Quaternary(?) clay, sands, and gravel.

TABLE II

SUBDIVISIONS OF THE DES MOINES AND MISSOURI SERIES IN HUGHES COUNTY

- Missouri series
  - Coffeyville formation
  - Seminole formation
- Des Moines series
  - Holdenville formation
  - Wewoka formation
  - Wetumka shale
  - Calvin sandstone
  - Senora formation
  - Stuart formation
  - Thurman sandstone
  - Boggy formation

The Pennsylvanian rocks consist largely of alternating thick sandy shales and fine to medium-grained sandstones, and a few thin limestones. Though the shale zones comprise the largest proportion of this sequence, the more resistant sandstones crop out over a much wider area and give a rough, stony appearance to much of the landscape.

The oldest rocks exposed in the area are the shales of the upper part of the Boggy formation, which crop out in the southeast corner of the county. Owing to the northeast strike of the overlying formations and their gentle northwest dip, younger formations are exposed in successive broad valleys and cuestas across the county to the northwest. The youngest Pennsylvanian rocks exposed are the sandstones of the upper-middle part of the Coffeyville formation, which crop out in the northwest corner of the county.

Hughes County is on the southeast edge of the central Oklahoma uplift, an important subsurface structural feature north of the Arbuckle Mountains. It is bounded on the east and southeast by the McAlester basin, a prominent structural feature in east-central Oklahoma. Thick deposits of Atoka and lower Des Moines age were deposited in a shallow sea covering this basin. The overlying rocks of Desmoinesian and Missourian age in Hughes County represent near-shore facies deposited as the southern shoreline as this sea moved to the north and west. The intertonguing relations, lensing, channelling, and highly contorted form of many of the sandstone units suggest this type environment, as do the fossils of many of the units.

The Geologic Map

Sixty-five mappable units were traced across Hughes County. The upper and lower contacts of all these units were mapped as accurately as possible, though many of the boundaries are gradational. Especially difficult to trace were the tops of the sandstone units. These boundaries are shown as solid lines on the geologic map, although many of them had to be arbitrarily drawn because of their gradational nature.

Difficulty arose in the mapping of many of the units of the Thurman, Senora, and Calvin formations. In these and a few other formations the units mapped as "shale" might better be termed "argillaceous siltstone." This attempt at subdivision was made in the hope of adding to the broader picture of the stratigraphic relations of these units and to their environmental history.

Pennsylvanian System

Des Moines Series

Rocks in the middle and upper parts of the Des Moines series, one of the major divisions of the Pennsylvanian system in the Mid-Continent region, crop out in Hughes County. This sequence has a total thickness of about 2,600 feet and includes rocks of the upper part of the Boggy formation and of the Stuart, Thurman, Senora, Calvin, Wetumka, Wewoka, and Holdenville formations.

Though the base of the Des Moines series is not exposed in Hughes County, the series rests unconformably on the Atoka formation in the subsurface of this general area. The series is bounded at the top by the base of the Seminole formation. Though this contact is unconformable in parts of the Mid-Continent region, there is no apparent structural discordance along the contact in Hughes County, Faunal evidence offers some aid. The diagnostic Des Moines forms *Mesolobus* and *Delocrinus granulosus* are apparently limited to this series.

It should be emphasized that this contact is irregular, as are many of the other sandstone-shale contacts across the county. Absence of any marker bed in the uppermost part of the Holdenville shale makes it difficult to determine the exact nature of its contact with the overlying Seminole sandstone.

Rocks of the Des Moines series crop out in a broad, north-northeast trending belt that covers all but the northwest and west-central parts of the county. Strike of the beds is to the northeast, and they dip to the northwest at about one degree.

Boggy Formation.

First Reference: J. A. Taff, 1899.

Nomenclator: J. A. Taff, 1899.

Type Locality: Although Taff did not designate a specific type locality for the Boggy formation, it is probable that he named the formation from extensive outcrops along Clear and Muddy Boggy Creeks in Pontotoc, Coal, and Pittsburg Counties.

Original Description: Taff[47] first discussed the Boggy in the McAlester-Lehigh area as follows:

> There is a mass of shale and sandstone above the Savanna sandstone nearly 3,000 feet thick. Throughout a part of this field it is possible, and would be desirable, to separate these beds and map them as two or more series of beds from both stratigraphical and structural points of view. In other parts of the field, however, it is not possible to trace or map beds of sandstone or shale in separate collections of strata . . . . . In the Boggy shale there are probably not less than sixteen beds of sandstone, ranging in thickness from 20 to 150 feet, separated by shale from 100 to 600 feet thick. One coal bed, about 2 feet 6 inches thick, has been located and worked to a small extent, though now abandoned. This coal bed is about 400 feet above the base of the Boggy shale. . . . .
>
> The shales of this series are exposed to a very slight extent. In the few hill slopes and stream cuttings where observed, the shales are bluish fissile clay containing ironstone concretions, thin wavy sandstone plates, and shaly sandstone strata. The sandstones . . . . vary but little in minor detail of texture. They are generally brownish or gray and some beds are quite ferruginous . . . . All the sandstones are fine-grained and were without doubt deposited under very similar conditions.

[47] Taff, J. A., 1899. *U. S. Geol. Survey*, 19th Annual Report, Part 3, pp. 438-439.

Other Descriptions: George D. Morgan,[49] after mapping the Boggy formation in the Stonewall quadrangle to the southwest of Hughes County noted that the formation is mainly shale, with sandstones prominent near the top. Near Franks, the Boggy contains sandstones, fine-grained conglomerate, and limestone conglomerate. A limestone with abundant *Caninia torquia* occurs near the top.

After mapping the Boggy in the Lehigh district immediately south of Hughes County, Knechtel[50] wrote that it consists largely of blue and gray shale with a few sandstone beds and a few local thin limestone lenses. Many of the sandstones contain abundant chert pebbles. Marine and continental beds occur. The thickness was estimated as from 1,250 to 1,500 feet.

History of Usage: Use of the term Boggy formation has followed the precedent set by Taff.

Distribution: The Boggy formation crops out over much of the north and west portions of the McAlester Coal Basin. It is present in eastern Pontotoc County and extends north and east across Coal, Hughes, Pittsburg, Latimer, Haskell, LeFlore, McIntosh, and Muskogee Counties to the Arkansas River. The Boggy formation has been traced into northeastern Oklahoma where it is equivalent to the lower part of what was formerly called Cherokee shale.

In Hughes County the Boggy formation crops out over an area of 3 square miles in the southeast corner of T. 4 N., R. 11 E.

[49] Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, pp. 77-80.
[50] Knechtel, M. M., 1937. *U. S. Geological Survey, Bull.* 874-B, p. 107.

Though the siltstones in the top part of the Boggy are discontinuous, they appear to have approximately the same dip as the overlying Thurman sandstone beds. In this part of the county the regional dip of the beds is approximately 1° NW, and the strike is N. 45° E.

Stratigraphic Position: In Hughes County only the upper shales of the Boggy formation crop out. However, Hendricks[52] reported that in the McAlester area east of Hughes County the Boggy formation overlies the Savanna sandstone with apparent conformity. The contact between the Boggy and the overlying Thurman sandstone is exposed over only a small area in Hughes County, and the exact structural relationship of the two units could not be accurately determined. Further discussion of the nature of this contact is included in the section concerning the stratigraphy of the Thurman sandstone.

Paleontology: Prolific faunas have been reported from the Boggy formation. Such typical Des Moines forms as "*Marginifera*" *muricatina* and *Mesolobus mesolobus* are common. The conularid *Paraconularia crustula* is especially abundant. Sixty-one species of invertebrates were collected and identified by the writer.

Fossils identified from the Boggy formation in Hughes County:

Anthozoa
- Lophophyllidium sp.
- Pleurodictyum eugeneae (White)
- Stereostylus ? radicosus (Girty)

Conularida
- Calloconularia holdenvillae (Girty)

Echinoidea
- Echinocrinus megastylus (Shumard)

Bryozoa
- Fistulipora carbonaria (Worthen)
- Polypora elliptica Rogers
- Rhombopora lepidodendroides Meek

Brachiopoda
- Lindstroemella patula (Girty)
- Lingula carbonaria Shumard
- Petrocrania modesta (White and St. John)
- Chonetes granulifer Owen
- Chonetes granulifer armatus Girty
- Cleiothyridina orbicularis (McChesney)
- Composita subtilita (Hall)
- Composita trilobata Dunbar and Condra
- Condrathyris perplexa (McChesney)
- Crurithyris planoconvexa (Shumard)

52 Hendricks, T. A. *U. S. Geol. Survey, Bull.* 874-A, p. 22.

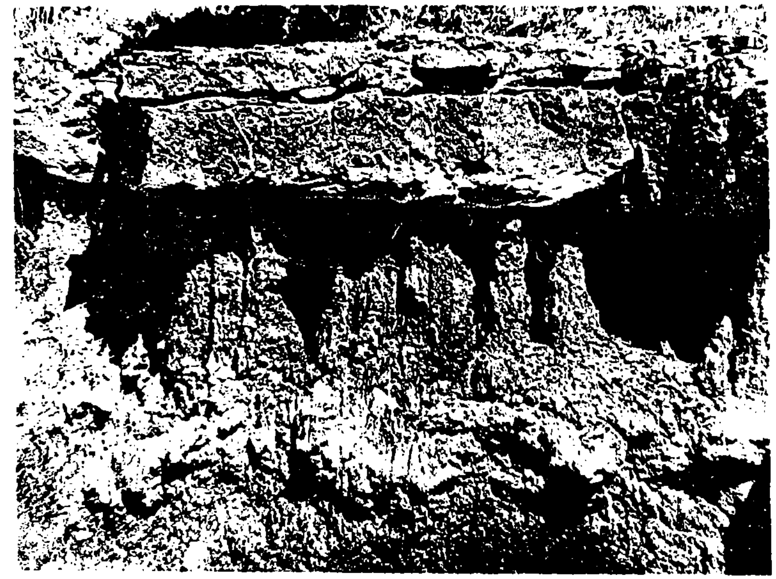

Figure 2. Sandstone lens in the Boggy formation in creek bed just west of road at center of E. line, sec. 26, T. 4 N., R. 11 E.

Figure 3. Minor channeling in a sandstone of the Thurman formation (IPth-2) near center of the SW¼ sec. 13, T. 4 N., R. 11 E.

Derbyia crassa (Meek and Hayden)
Juresania nebrascensis (Owen)
Linoproductus prattenianus (Norwood and Pratten)
Marginifera splendens (Norwood and Pratten)
"Marginifera" muricatina Dunbar and Condra
Mesolobus mesolobus (Norwood and Pratten)
Mesolobus mesolobus decipiens (Girty)
Mesolobus mesolobus euampygus (Girty)
Neospirifer cameratus (Morton)
Nudirostra rockymontanum (Marcou)
Punctospirifer kentuckiensis (Shumard)

Pelecypoda
Anthraconeilo taffiana Girty
Astartella concentrica (Conrad)
Aviculopecten occidentalis (Shumard)
Aviculopinna peracuta (Shumard)
Edmondia gibbosa McCoy
Limipecten texanus (Girty)
Nucula anodontoides Meek
Nuculana bellistriata (Stevens)
Promytilus swallovi (McChesney)
Schizodus affinis Herrick
Yoldia glabra Beede and Rogers

Gastropoda
Amphiscapha catilloide (Conrad)
Bellerophon crassus wewokanus Girty
Cymatospira montfortiana (Norwood and Pratten)
Euphemites vittatus (McChesney)
Glabrocingulum grayvillense (Norwood and Pratten)
Meekospira choctawensis Girty
Pharkidonotus percarinatus (Conrad)
Strobeus brevis White
Worthenia tabulata (Conrad)

Nautiloidea
Metacoceras cornutum Girty
Pseudometacoceras sculptile (Girty)

Ammonoidea
Gastrioceras hyattianum Girty

Trilobita
Griffithides parvulus Girty

Chondrichthyes
Petrodus occidentalis (Newberry and Worthen)

Plantae
Calamites sp.

Age and correlation: The Boggy formation is in the lower part of the Des Moines series of the Mid-Continent region. It is correlated with the middle part of the Cherokee shale of Iowa, Nebraska, Missouri, and Kansas, and with the middle part of the Deese formation of the Ardmore basin in southern Oklahoma.

Thickness and Character: Only the upper 200 feet of the Boggy formation is exposed in Hughes County. This part of the formation consists of gray, sandy to silty, fossiliferous shale with numerous discoid limonite concretions in irregular zones. The shale of the upper 40 feet of the Boggy contains numerous siltstone lenses. (See Figure 2.) Some of these lenses contain fine white chert specks which give the otherwise gray to brown siltstones a somewhat mottled appearance. These specks average less than a millimeter in diameter and occur commonly as flakes. The chert particles signify the beginning of a rapid change in environmental conditions that is further recorded by the deposition of the overlying coarse sands and chert conglomerates of the Thurman sandstone.

Good exposures of the Boggy are found beneath a steep, southeast-facing escarpment capped by the massive Thurman sandstone. This escarpment trends across the southeastern part of the county and is easily traced eastward into Pittsburg County and southward into Coal County.

The Campophyllum-bearing limestone reported by Morgan from the Stonewall quadrangle to the southwest was not found in Hughes County, although certain zones near the top of the formation do carry abundant fossils.

(See measured stratigraphic sections 35 and 36 for further details of the lithology of the upper part of the Boggy formation.)

Thurman Sandstone.

First Reference: J. A. Taff, 1899.

Nomenclator: J. A. Taff, 1899.

Type Locality: The town of Thurman in the Canadian quadrangle.

Original Description: Concerning the Thurman sandstone in the McAlester district to the east of Hughes County, Taff[54] wrote as follows:

> This rock overlies the Boggy shale and has an exposure of about 200 feet within the McAlester quadrangle. The lower part, constituting 50 feet or more of strata, is a conglomerate composed of angular or little rounded chert fragments in a brown sandstone matrix. Brown sandstone and shaly beds occur above the conglomerate as far as exposed within the McAlester quadrangle. These beds

[54] Taff, J. A., 1899. "The Geology of the McAlester-Lehigh Coal Field," p. 439.

> occur in the flat-top hills north of Coal Creek and in the table-land in the northwest corner of the McAlester quadrangle. They lie in a nearly horizontal position, and the conglomerate and sandstone form cliffs and steep slopes where they crop on the brinks of the hills.

Other Descriptions: Taff later studied and mapped the Thurman sandstone across the Coalgate quadrangle. This area includes the southern part of Hughes County. The present writer found his original mapping of the base and top of the formation to be generally accurate and could add only minor refinements. However, in the central part of the outcrop of the Thurman across Hughes County the writer was able to divide the formation into four major sandstone units with three intervening silty shale beds. Concerning the Thurman sandstone in the northern part of the Coalgate quadrangle, Taff wrote:[55]

> The Thurman sandstone represents the beginning of a marked change in the character of the sediments which were brought into the sea and spread across this region in Carboniferous times. Shales and fine sandy sediments of the Boggy shale are followed by coarse pebbles of white chert mixed with coarse quartz sand forming the Thurman sandstone. After the deposition of this conglomerate, which reached a thickness of about 50 feet in the eastern half of the area now occupied by the Thurman sandstone in the Coalgate quadrangle, finer sands were deposited until a maximum depth of more than 200 feet was attained.
>
> In the northeastern corner of the quadrangle, the whole formation is about 250 feet thick, while in the western portion it does not exceed 80 feet. This decrease in thickness is gradual and is accompanied by a similar change in the texture of the sandstone. The conglomerate which in places is 50 feet thick at the east is at the west a mere ledge of pebble rock or may be entirely absent. The sandstone beds in the upper part of the formation, while becoming finer and thinner in texture westward, include beds of shale, and near the border of the quadrangle there are thin beds of impure, fossiliferous limestone.

After tracing the Thurman sandstone southwest from the Coalgate quadrangle into the Stonewall quadrangle, George D. Morgan[56] stated that the Thurman is about 100 feet thick. He found several beds of conglomerate near the base. Some of the

[55] Taff, J. A., 1901. "Coalgate Folio," p. 4.
[56] Morgan, G. D., 1924. *Okla. Bureau of Geology, Bulletin* 2, pp. 84-85.

pebbles are chert; others are limestone which resembles the "pink crinoidal" member of the Chimney Hill.

Hendricks[57] mapped the base of the Thurman sandstone across the McAlester district, east of Hughes County. He, too, reported a massive, conglomeratic sandstone at the base of the formation.

Dane, Rothrock, and Williams[58] mapped the Thurman sandstone across northwestern Pittsburg County, an area immediately east of Hughes County and north of the McAlester district mentioned above. They reported an average thickness of between 290 and 335 feet for the formation and mentioned a coarse chert pebble conglomerate that occurs at the base. The writers attributed the northward thickening of the formation to the presence of irregularly occurring sandstones above the approximate zone of the top of the Thurman as mapped by Taff in the Coalgate quadrangle. These sandstones probably are equivalents of the lower part of the overlying Stuart formation, they reported.

History of Usage: Use of the name Thurman sandstone has followed Taff's original description.

Distribution: The Thurman sandstone extends in a narrow belt from east-central Pontotoc County northeastward across Coal, Hughes, and Pittsburg Counties. The formation is not definitely recognizable north and east of T. 7 N., R. 14 E. in Pittsburg County, and projections of the formation to the north across the Canadian River are largely conjectural.[59]

In Hughes County the Thurman sandstone crops out in a band about 4 miles wide which trends northeastward across the southeast part of the county.

The strike of the Thurman sandstone changes gradually as the formation crosses the southeast part of the county. In the southwest corner of T. 4 N., R. 11 E. the strike of the formation is approximately N. 60° E. and the dip about 1° NW. Farther to the northeast, in the east-central part of T. 4 N., R. 11 E., the formation strikes approximately N. 60° E. and dips about 1° NW. Accurate

57 Hendricks, T. A., 1937. *U. S. Geol. Survey, Bull.* 874-A.
58 Dane, C. H., Rothrock, H. E., and Williams, James Steele, 1938. *U. S. Geol. Survey, Bull.* 874-C, p. 166.
59 Dane, C. H., 1938. *U. S. Geol. Survey, Bull.* 874-C, p. 166.

dip determinations are difficult owing to the irregular nature of the sandstones.

This change of strike, from the northeast and east-northeast in the southern part of Hughes county to north-northeast in the northwestern part of Pittsburg County, is typical of the overlying Pennsylvanian formations as well. Thus the outcrops of the bases of the Thurman, Stuart, Senora, and Calvin formations, which approximate their strike, trend almost east-west in southwest Hughes and northern Coal Counties. There is a pronounced change in their strike on the north side of the outcrop of the Gerty sand belt in the south-central part of the county. North of this belt the strike of the Thurman, Stuart and Senora formations is more toward the north, reaching about N. 45° E. in the central part of T. 5 N., R. 10 E. Generally speaking, the strike of each succeeding bed is a little more toward the north, and the average strike of the beds above the Calvin sandstone north of the Canadian River is N. 30° E.

Stratigraphic Position: In Hughes County the Thurman sandstone overlies with apparent conformity the Boggy formation and is overlain conformably by the Stuart formation. The area of observation of the Boggy-Thurman contact is small and further studies to the northeast will be necessary to determine the exact relationship.

The contact is gradational, and the coarse chert pebbles of the Thurman sandstone are preceded by smaller chert flakes in the upper part of the Boggy shales. The contact is not one that can be followed precisely, however, for the lower sandstones of the Thurman are not continuous along the scarps. Thus, the base of the "zone" of the Thurman sandstones was mapped across the county.

Dane, Rothrock, and Williams,[60] after mapping the Boggy-Thurman contact in the Quinton-Scipio district east of Hughes County, reported a sharp contact and local erosional irregularity. They believed the contact in that area to be unconformable.

Paleontology: Morgan[61] reported meager collecting possibilities

60 Dane, C. H., et al, 1938. *U. S. Geol. Survey, Bull.* 874-C, p. 167.
61 Morgan, G. D., 1924. *Okla. Bureau of Geology,* Bull. 2, p. 85.

from outcrops of the Thurman sandstone to the southwest, but Williams[62] listed 41 species collected from the formation in the Quinton-Scipio district to the east of Hughes County. He reported mainly marine species, with pelecypods the most abundant group.

The present writer identified 26 species from the formation, most of which are articulate brachiopods and pelecypods. Almost all the gastropods are represented by internal molds and are difficult to identify. Many of the sandstones contain fossils, but they were difficult to collect owing to the irregular resistance of the beds.

Fossils identified from the Thurman sandstone in Hughes County:

Anthozoa
- Lophophyllidium sp.

Conularida
- Calloconularia holdenvillae (Girty)

Bryozoa
- Fistulipora carbonaria Ulrich
- Prismopora lobata Warthin

Brachiopoda
- Lindstroemella patula (Girty)
- Chonetes granulifer Owen
- Composita subtilita (Hall)
- Derbyia crassa (Meek and Hayden)
- Hustedia mormoni (Marcou)
- Linoproductus insinuatus (Girty)
- "Marginifera" muricatina Dunbar and Condra
- Mesolobus mesolobus decipiens (Girty)

Pelecypoda
- Allorisma terminale Hall
- Astartella concentrica Conrad
- Aviculopinna americana Meek
- Limipecten texanus (Girty)
- Schizodus affinis Herrick

Gastropoda
- Bucanopsis meekiana Swallow
- Euphemites vittatus (McChesney)
- Strobeus brevis White
- Trepospira depressa (Cox)

Nautiloidea
- Pseudorthoceras knoxense (McChesney)

Ammonoidea
- Gastrioceras hyattianum Girty

Age and Correlation: According to Moore[63] and others, the Thurman sandstone is of lower Allegheny age. It is in the middle part of the Des Moines series of the Mid-Continent region. It is

[62] Dane, C. H., Rothrock, H. E., and Williams, J. S., 1938. *U. S. Geol. Survey, Bull.* 874-C, p. 169.

[63] Moore, R. C., et al., 1944. *Geol. Soc. Amer., Bull.*, vol. 55, pp. 675-706.

correlated with part of the Cherokee shale of southeastern Kansas and with the middle of the Deese formation of the Ardmore basin in southern Oklahoma; and with the middle part of the Millsap Lake group of the Strawn series of north-central Texas.

Thickness and Character: In Hughes County the Thurman sandstone averages 230 feet in thickness and is composed of a series of thick, irregular conglomeratic sandstone units interbedded with silty gray shales.

The sandy lithology of the formation produces a rugged outcrop which is covered with a thick oak-history forest.

In the southeast and east-central parts of T. 4 N., R. 11 E. the formation consists of four massive sandstone units and three intervening sandy shales. In a section measured south to north in the east half of T. 4 N., R. 11 E., the formation is 241 feet thick. (See measured stratigraphic section number 35.) Typically the lower sandstone unit (IPth-1 of map) contains the coarsest chert fragments, though they occur in irregular zones in all four of the mapped units. Because the conglomerates in the lower sandstone unit are typical and well-exposed, they are described in the following paragraph.

The conglomerates are composed largely of sub-rounded chert gravel and sand. Average size of the fragments is one-fourth inch in a well-developed conglomerate zone such as that occurring in the center of the south line of sec. 35, T. 4 N., R. 11 E. Here the fragments include fine quartzite and quartz gravels as well as chert. The conglomerate grades abruptly laterally into fine-grained sandstone or siltstone though in some other localities the conglomerates appear to be associated with minor channeling. Fine, white to gray chert flakes about two millimeters or less in their longest diameter occur in the conglomerate in this and other localities. The matrix is largely medium-grained to silty, light brown sandstone. The coarsest gravels are of pebbles about 1 inch in diameter.

The divisions of the formation made by the writer in Hughes County could not be traced to the south across northern Coal County owing to rapid facies change. A section measured along U. S. Highway 75 about 2 miles southwest of Non indicates only three major units—massive upper and lower sandstones and a thick intervening zone of silty, gray shale containing numerous siltstone and sandstone lenses. Both sandstone units contain fine chert conglomerates and dull gray-white chert flakes.

Minor channeling, especially at the top of the upper sandstone unit, is common, as is cross-bedding and lensing. Most of this channeling occurred prior to final consolidation of the sandstones. (See Figure 3). This is implied in a few exposures by the contortion in both the channeled sandstones and the material filling the channels. The term "scour hole" might be more applicable than channel. The average width of these channels is about 12 feet and the scoured depressions average 3 feet in depth. (See measured stratigraphic section number 36.)

It should be emphasized that the units mapped as "shales" (IPth of map) are so silty at many places that the term "argillaceous siltstone" might be applied. Also numerous sandstone and siltstone lenses are present in these zones. However, as the top and base of the four more resistant sandstone units could be mapped over much of the outcrop of the formation in the county, the divisions were extended, though with difficulty, to the borders of the county.

Fine white chert flakes in the sandstones and siltstones are very common. These flakes and the chert conglomerates described above are not limited to the Thurman sandstone, although so far as the writer knows, they have not been reported from any of the underlying Boggy sandstones in any abundance. All the younger Pennsylvanian formations in the county which contain thick sandstone beds contain chert conglomerates or fine white chert flakes. In fact, the conglomerates in the Wewoka and Seminole formations are coarser and are thicker than those in the Thurman.

The occurrence of coarse chert conglomerates in the Thurman and succeeding formations is confined mostly to the south and central parts of the county. It appears that the source of the conglomerates was to the southeast and that they were deposited by streams flowing northwestward across the present strike of the beds. Oakes[64] has discussed the causes of deposition and the

[64] Oakes, Malcolm C., 1948. *The Oklahoma Academy of Science, Proc.*, vol. 28, pp. 70-71.

sources of these conglomerates in a paper entitled "Chert River". The occurrence of the conglomerates is limited laterally by minor channeling, which probably occurred just subsequent to the deposition of the associated sandstones and shales, or as lateral gradation to sandstones along the strike of the beds. This gradational aspect, both north and south along the strike of the several formations containing chert conglomerates, would imply a source in a direction at approximately a right angle to the strike of the beds.

According to Tanner,[65] the band in which chert conglomerates occur seems to extend northwest into upper Pennsylvanian and lower Permian beds of south and central Seminole County. However, the chert conglomerates in the Vamoosa formation extend farther north and south than do chert conglomerates in other formations; they extend northward beyond Seminole County.

(For diagramatic presentation of the thickness and character of the Thurman sandstone, see Plate III.)

Stuart Shale

First Reference: J. A. Taff, 1901.

Nomenclator: J. A. Taff, 1901.

Type Locality: It is presumed that this formation was named for the town of Stuart in east-central Hughes County.

Original Description: The following is the original description given by Taff[66] of the Stuart shale in the Coalgate quadrangle:

> There is a gradual transition upward from the Thurman sandstone through thin beds of shaly sandstone and shale interstratified into the Stuart shale. This formation has a thickness of about 275 feet in the northeastern and central parts of its exposure and about 100 feet in its western part. It is composed of three members, an upper and a lower one of shale separated by a variable sandstone 10 to 50 feet thick. In the central part of the quadrangle a thin sandstone and chert conglomerate lentil occurs in the lower shale member. This lower member of the formation has a nearly constant thickness of about 120 feet. This shale, unlike the lower member, crops in the steep slopes of the escarpments and hills which are surmounted by the succeeding Senora sandstone, and is, for the most part, wooded and concealed by talus.

[65] Tanner, William F., February, 1952. Personal communication.
[66] Taff, J. A., 1901. *U. S. Geol. Survey, Geol. Atlas*, Folio No. 74, p. 4.

Other Descriptions: After Taff's original mapping of the Stuart shale across the Coalgate quadrangle, Morgan[67] traced the formation westward into the east-central part of Pontotoc County. He reported that the formation terminates there against two faults. Concerning the Stuart shale Morgan wrote:

> The thickness of the Stuart shale is approximately 80 feet. It consists of dark shales ranging through shades of green, blue, and black, and near its top and bottom also carries a few thin beds of sandstone. About 15 feet below the top of the formation is generally a zone of brown concretions, which were of assistance in mapping.

History of Usage: Present usage of the term Stuart shale is the same as that of Taff.

Distribution: Regionally the Stuart shale extends northeastward from east-central Pontotoc County across northern Coal, southern Hughes, and northwestern Pittsburg Counties. The formation was traced by Oakes[69] north of the North Canadian River across western McIntosh into western Muskogee County, where he reported it to be overlapped by the Senora formation.

The Stuart shale borders Hughes County along the south side of T. 4 N., R. 9 and 10 E. It is mostly blanketed by the Gerty sand in the southeast part of T. 4 N., R. 10 E. The formation then trends northeast across the northwest part of T. 4 N., R. 11 E., and the east half of T. 5 N., R. 11 E. The outcrop is three miles wide at the county line in the area east of Stuart. The width of outcrop averages about 2 miles across the county.

In the southeast corner of T. 4 N., R. 9 E. the formation dips about 1° NW and strikes N. 50° E. To the northeast, in the vicinity of Stuart, the formation dips about 1° NW and strikes N. 40° E.

Stratigraphic Position: In Hughes County the Stuart shale lies conformably on the Thurman sandstone and is overlain conformably by the Senora formation.

To the northeast, in northwest Pittsburg County, the Stuart overlaps the Thurman and is in turn overlapped by the overlying Senora formation in the area south of Boynton in southwestern Muskogee County.[70]

[67] Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 86.
[69] Oakes, Malcolm C., January, 1952. Personal communication.
[70] Oakes, Malcolm C., January, 1952. Personal communication.

Paleontology: Thirty-seven species were identified from the Stuart shale in Hughes County. Most of the collections are from the silty upper and lower shale zones in the southeastern part of the county.

Fossils identified from the Stuart formation in Hughes County:

Anthozoa
- Lophophyllidium sp.
- Pleurodictyum eugeneae White

Conularida
- Calloconularia holdenvillae (Girty)

Bryozoa
- Polypora whitei Ulrich
- Rhombopora lepidodendroides Meek
- Septopora elliptica Warthin

Brachiopoda
- Lindstroemella patula (Girty)
- Chonetes granulifer armatus Girty
- Cleiothyridina orbicularis (McChesney)
- Composita subtilita (Hall)
- Crurithyris planoconvexa (Shumard)
- Juresania nebrascensis (Owen)
- Mesolobus mesolobus (Norwood and Pratten)
- Mesolobus mesolobus euampygus (Girty)
- Nudirostra rockymontanum (Marcou)
- Rhipidomella carbonaria (Swallow)

Pelecypoda
- Anthraconeilo taffiana Girty
- Astartella concentrica Conrad
- Edmondia gibbosa McCoy
- Edmondia ovata Meek and Worthen
- Nucula anodontoides Meek
- Nuculana bellistriata (Stevens)

Gastropoda
- Meekospira bella Walcott
- Meekospira peracuta (Meek and Worthen)
- Meekospira peracuta choctawensis Girty
- Pharkidonotus percarinatus (Conrad)
- Trepospira depressa (Cox)
- Worthenia tabulata (Conrad)

Nautiloidea
- Metacoceras cornutum Girty
- Pseudorthoceras knoxense (McChesney)

Ammonoidea
- Gastrioceras venatum Girty

Plantae
- Stigmaria sp.

Age and Correlation: According to Moore and others[71] the Stuart shale is of lower Allegheny age. It is correlated with the middle part of the Deese formation in the Ardmore basin in southern Oklahoma; and with the middle part of the Millsap Lake group of the Strawn series in north central Texas.

[71] Moore, R. C., et al., 1944. *Geol. Soc. Amer., Bull.*, vol. 55, pp. 657-706.

Thickness and Character: The Stuart shale as exposed in southeastern Hughes County consists of a sandy gray shale containing a northward-wedging sandstone unit (IPst-1 of map) and a southward wedging sandstone unit (IPst-2 of map). The average thickness of the formation is 250 feet. (See Plate III, Measured Outcrop Sections).

These "middle" sandstone units lie in the same horizon and average 60 feet in thickness across most of their outcrop. However, in the southeast corner of T. 5 N., R. 11 E., the southward-wedging unit (IPst-2 of map) splits into two thin tongues, both of which rise rapidly in the section and change facies to shale. The lower tongue was traced southward into the west half of sec. 26, T. 5 N., R. 11 E., where it is no longer mappable as a unit. The upper tongue was traced into the center of the west half of section 33, T. 5 N., R. 11 E., where its identity is lost.

In like manner the northward-wedging unit (IPst-1 of map) thins rapidly and wedges out in the southeast part of T. 5 N., R. 11 E. and drops in the section slightly. Most of these and other scattered sandstone units throughout the formation are medium to fine-grained, and grade into siltstones and finer grained sandstones at and near the tips of the wedges.

The thickness of the Stuart shale is estimated at 374 feet in the zone where both of the sandstone wedges are present, but a small structure present in the area may have caused some error in the calculation of the shale thicknesses. (See measured stratigraphic sections numbers 32 and 33.) A section measured just south of the town of Stuart is more typical of the formation to the north. Here the Stuart is 300 feet thick. It consists of an upper zone of sandy gray shale 134 feet thick, a middle zone of fine-grained, gray-brown sandstone 48 feet thick, and a lower, silty, gray shale zone 124 feet thick. (See Figure 4).

The three-fold division of the Stuart shale cannot be mapped south and west of the extreme south-central part of the county. There the Gerty sand blankets the outcrop of the Stuart for 4 miles. The Gerty also covers the upper part of the underlying Thurman sandstone and the lower part of the overlying Senora formation. This, plus a rapid change of lithology and a change in strike in

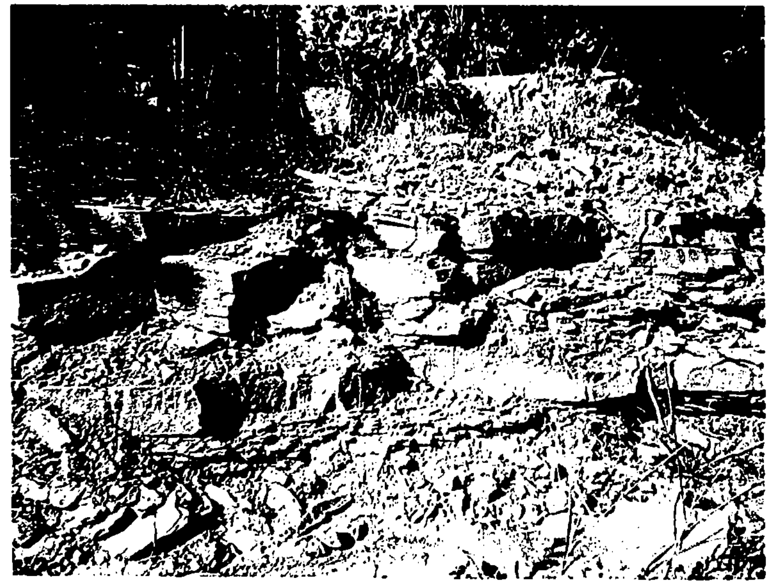

Figure 4. Thin-bedded sandstone of the Stuart formation in roadcut in the center of E. line, sec. 12, T. 5 N., R. 11 E.

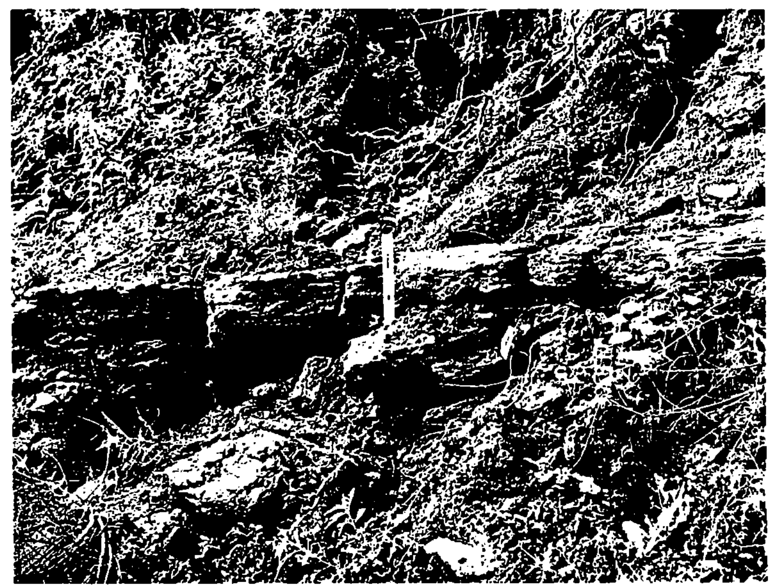

Figure 5. Unnamed limestone in lower sandstone member of Senora formation, roadcut 500 feet east of the SW cor. sec. 36, T. 9 N., R. 12 E.

this area, makes exact correlations to the southwest difficult. Sandstone beds included in the top of the Stuart shale west of Non may be in the lower part of the Senora formation.

The Stuart as measured in the southeast part of T. 4 N., R. 9 E. and the northeast part of T. 3 N., R. 9 E. is 217 feet thick. It consists of a lower sandy shale zone 85 feet thick, a conglomeratic sandstone 32 feet thick and an upper shale zone 100 feet thick which contains several thin and irregular sandstones. (See measured stratigraphic section number 37.)

A dense, light blue-gray, finely-crystalline limestone is exposed in the center of the south line of section 33, T. 4 N., R. 9 E. This limestone can be mapped for a short distance into northern Coal County. It averages 3 feet in thickness and occurs about 100 feet below the top of the formation.

Brief mention should be made here of the method used in Plate III in illustrating the outcrop sections measured in T. 4 N. The measured outcrop sections are placed in the cross section in relation to their relative north-south position over most of the county. Owing to a change in strike, the Thurman, Stuart, and Senora formations crop out in an almost east-west trend across the south part of T. 4 N. Therefore, sections were taken in Rs. 9, 10, and 11 E. across T. 4 N. and are so labeled in Plate III.

(For detailed sections describing the Stuart formation see measured stratigraphic sections 31, 32, 33, 34, 35, 36, 37, 38, and 39.)

Senora Formation.

First Reference: J. A. Taff, 1901.

Nomenclator: J. A. Taff, 1901.

Type Locality: Taff did not mention a specific type locality, but the formation was named from the old post office of Senora, in southern Okmulgee County.

Original Description: Concerning the Senora formation in the Coalgate quadrangle, Taff[72] wrote:

> This formation is composed of interstratified sandstones and shaly beds having a thickness of nearly 500 feet in the northeastern corner of the quadrangle. The thickness of the formation decreases toward the southwest chiefly by the

[72] Taff, J. A., 1901. *U. S. Geol. Survey, Geol. Atlas*, Folio No. 74, p. 4.

thinning of the sandstone beds, until at the western border of the quadrangle, it does not exceed 150 feet. The lower 320 feet of the formation there is composed almost entirely of sandstone which forms a very rugged and stony highland with sandstone bluffs, in places nearly 100 feet high, along the eastern side. This sandstone grades upward through thin sandy beds into shale strata which are approximately 160 feet in thickness.

This original description largely concerned the outcrop of the Senora formation across southern Hughes County.

Other Descriptions: After mapping the Senora formation westward into east-central Pontotoc County, George D. Morgan[73] described the formation as consisting of a thick basal sandstone and of a shale sequence with interbedded brown and yellow-brown sandstones.

History of Usage: Subsequent usage has followed Taff's original description.

Distribution: Regionally the Senora formation extends from central Pontotoc County northeastward across Hughes, Pittsburg, Okfuskee, and Okmulgee Counties and has been traced into northeastern Oklahoma. (This includes beds formerly assigned to the lower-middle Cherokee shale.)

The formation enters Hughes County near Citra, in the southwest part of the county, and crops out in a wide belt across the south-central, east-central, and northeast part of the county. The average width of the outcrop band is 7 miles.

In the Citra area the formation dips about 1° NW and strikes N. 50° E. Across the north half of its outcrop in the county the formation dips 88 feet per mile N. 60° W. and strikes N. 30° E.

Stratigraphic Position: In Hughes County the Senora formation is conformable on the underlying Stuart formation. Though the base of the formation is not present in the northern part of the county, Dane, Rothrock, and Williams[75] mapped the contact with the underlying Stuart formation in western Pittsburg County and did not mention any unconformable relationship.

73 Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 87.

75 Dane, C. H., Rothrock, H. E., and Williams, J. S., 1938. *U. S. Geol. Survey, Bull.* 874-C, p. 168.

Oakes[76] reports that the Senora formation overlaps the Stuart northward in the area immediately south of Boynton in western Muskogee County and rests on the Boggy formation from there northward.

Silty shales of the upper Senora shale member intertongue with siltstone tongues of the overlying Calvin sandstone.

Paleontology: Fifty species were identified from the Senora formation.

Fossils identified from the Senora formation in Hughes County:

Anthozoa
- Lophophyllidium sp.
- Stereostylus ? radicosus (Girty)

Conularida
- Calloconularia holdenvillae (Girty)

Crinoidea
- Aatocrinus patulus (Girty)

Bryozoa
- Rhombopora lepidodendroides Meek
- Septopora elliptica Warthin
- Tabulipora carbonaria (Worthen)

Brachiopoda
- Lindstroemella patula (Girty)
- Lingula carbonaria Shumard
- Chonetes granulifer (Owen)
- Composita subtilita (Hall)
- Composita trilobata Dunbar and Condra
- Condrathyris perplexa (McChesney)
- Crurithyris planoconvexa (Shumard)
- Derbyia crassa (Meek and Hayden)
- Juresania nebrascensis (Owen)
- Marginifera lasallensis (Worthen)
- Marginifera splendens (Norwood and Pratten)
- Mesolobus mesolobus (Norwood and Pratten)
- Mesolobus mesolobus decipiens (Girty)
- Neospirifer cameratus (Morton)
- Nudirostra rockymontanum (Marcou)

Pelecypoda
- Allorisma terminale Hall
- Anthraconeilo taffiana Girty
- Astartella concentrica Conrad
- Aviculopecten occidentalis (Shumard)
- Limipecten texanus (Girty)
- Nuculana bellistriata (Stevens)
- Promytilus swallovi (McChesney)
- Schizodus affinis Herrick

Gastropoda
- Cymatospira montfortiana (Norwood and Pratten)
- Euphemites vittatus (McChesney)
- Glabrocingulum grayvillense (Norwood and Pratten)
- Meekospira peracuta (Meek and Worthen)
- Soleniscus typicus Meek and Worthen

76 Oakes, Malcolm C., January, 1952. Personal communication.

Strobeus brevis White
Trepospira depressa (Cox)
Worthenia tabulata (Conrad)
Nautiloidea
Liroceras liratum (Girty)
Ammonoidea
Gastrioceras venatum Girty
Trilobita
Griffithides parvulus Girty
Plantae
Stigmaria sp.

Age and Correlation: According to Moore and others,[77] the Senora formation is of Middle Allegheny age. It is in the middle of the Des Moines series of the Mid-Continent region. It is correlated with the upper part of the Cherokee shale of southeastern Kansas; and with the middle part of the Deese formation of the Ardmore basin, in southern Oklahoma.

Oakes has mapped the Senora formation north to the Arkansas River, and Branson has studied it from there to the Kansas-Oklahoma line. The Tiawah limestone, the "Pink lime" of subsurface terminology, is the lowest named bed of the Senora in that area and is very near the base. The Chelsea sandstone is continuous with the upper part of the sandstone member (IPsn-1a of map). The strata from the top of the Chelsea sandstone up to the base of the Fort Scott limestone are equivalent to the shale member (IPsn-2 of map) and include the following named units in ascending order: the Broken Arrow coal, the Verdigris limestone, the Prue sand of subsurface terminology, the Iron Post coal, the Kinnison shale, and the Breezy Hill limestone. The Verdigris limestone is equivalent to the Ardmore limestone of southeastern Kansas and Missouri.

Thickness and Character: In Hughes County the Senora formation consists of a lower sandstone member (IPsn-1 of map) about 350 feet thick and an upper shale member (IPsn-2 of map) which averages 150 feet in thickness.

The formation has a rather uniform thickness of about 500 feet in the northeast and central parts of the county, but thins rapidly south and west of Gerty. In a section measured south of Citra in the southwest part of the county, the upper shale member is 114 feet thick and the lower sandstone is 116 feet thick, giving

[77] Moore, R. C., 1949. *Geol. Soc. Amer., Bull.*, vol. 55, pp. 657-706.

a total thickness of 230 feet for the locality. A shale zone 65 feet thick is present in the lower sandstone at this locality. (See measured stratigraphic section number 39.) The sandstones of the lower member are generally discontinuous in the southwest part of the county and contain many silty gray shale lenses; the upper shale member contains numerous thin, irregular sandstone and siltstone lenses in its lower part and appears to grade downward into the lower sandstone member.

The contact with the underlying Stuart formation is masked by the Gerty sand in secs. 27, 28, and 29, T. 4 N., R. 10 E., a distance of over 2 miles. One of the important factors in determining the course of the river which deposited the Gerty sand across this area probably was the local gradation to shale of many of the sandstone units which offered less resistance to erosion in this area. Some 3 miles northeast of this masked area the lower, generally massive, sandstone member begins to change facies. Sandy shale zones thicken at the expense of the sandstone to the south and west. Whatever the reason, the stream sands and gravels now make correlation of the base of the Senora formation to the southwest into Coal and Pontotoc Counties subject to some uncertainty.

Throughout the central and northern part of its outcrop, the lower sandstone member (IPsn-1 of map) consists of a series of medium-grained to silty, gray and light brown sandstones interbedded with very silty, gray and maroon shales. These shale zones are irregular in thickness and contain numerous lenses of sandstone and siltstone as well as two thin limestones.

North of the Canadian River the lower member is divided into three units (IPsn-1a, 1b, and 1c of map). The lower unit (IPsn-1a of map) contains a series of rather continuous, medium to fine-grained sandstones and siltstones with interbedded silty, gray shales and averages 300 feet thick. The sandstone beds in this "complex" were mapped wherever possible, although rapid lensing out of the thinner units made an exact numbering system impossible. No specific numbers or symbols are put on specific beds, but all are colored alike on the geologic map. In the central and northeast part of T. 8 N., R. 12 E. a blue-gray, medium-crystalline, fossiliferous limestone 10 inches thick (IPsn-1a1 of map) is 84 feet below the top of this unit. (See Figure 5.) This is a good marker bed and can be traced northward into western McIntosh County. Good exposures of this limestone occur in a road cut 400 feet east of the southwest corner of sec. 36, T. 9 N., R. 12 E. and in McIntosh County at a point 0.3 mile east of the southwest corner of section 7, T. 9 N., R. 13 E.

In the upper part of this lower sandstone member is a gray, silty shale (IPsn-1b) which averages 55 feet thick and contains a thin, dense, blue-gray limestone (IPsn-1b1 of map) near its base. This limestone, the "Senora limestone" of subsurface usage, has been traced by the writer westward across the county by the use of electric logs. (See Plate II.) The limestone is fossiliferous, weathers reddish-brown, and has fossils exposed in bold relief on its weathered surfaces. It averages only 3 feet thick and at many places is associated with calcareous, fine-grained sandstone lenses giving the impression of greater thickness. A good exposure is in a quarry located at the center of the east line of sec. 27, T. 9 N., R. 12 E. The limestone could not be traced with certainty south of the Canadian River, but a thin, conglomeratic, finely-crystalline blue-gray limestone that occurs 300 feet west of the northeast corner of sec. 26, T. 4 N., R. 9 E. resembles the "Senora limestone" to the north in some respects. In this southern area the limestone is about 100 feet below the top of the formation and has two thick sandstone units between it and the overlying upper shale member (IPsn-2 of map).

Several wells drilled in the western part of the county have flakes of coal in the cuttings at the approximate zone of the "Senora limestone". A thin coal bed in the approximate stratigraphic position of the limestone is reported in a pit in the southwest corner of sec. 31, T. 9 N., R. 12 E. However, the pit is filled with water and the exact stratigraphic relationship of this coal could not be determined.

The upper unit of the lower sandstone member is a thin-bedded, fine-grained to silty, brown sandstone (IPsn-1c of map) which averages 10 feet in thickness. This unit can be identified in the O. Grimes Number 1 Steel well located in the NE SW SW of

sec. 17, T. 8 N., R. 11 E. (See well No. 3, Plate II.) This is approximately 3½ miles down dip to the west of the outcrop. West of this point the sand body can no longer be followed as a definite zone, and the sand grades to shale down dip under the central part of the county.

The upper shale member of the formation (IPsn-2 of map) crops out across the county and is well-exposed in high southeast-facing scarps capped by the overlying Calvin sandstone. The shale is gray, silty to sandy, and contains numerous sandstone lenses. This member is 156 feet thick in sec. 27, T. 6 N., R. 10 E., 1 mile southeast of Calvin (see measured stratigraphic Section No. 30) but slightly thicker to the north. It is approximately 160 feet thick west of Dustin in the northeast part of the county (See measured stratigraphic section No. 1). Exact measurements of thick shale intervals in this and adjoining counties are difficult if not impossible to obtain by surface methods. Use of barometer elevations and dip projections are only approximate in this low dip country, and many of the contacts with underlying sandstone units are graditional. For these reasons, the writer used electrical logs of wells immediately down dip from the outcrop of various beds to measure the true thickness of some of the sections. The beds are sufficiently uniform in thickness down dip to make this method of determining thickness more accurate than surface methods. (See Subsurface Geology).

Of special interest is the intertonguing of the shales of the upper Senora with the overlying sandstones and siltstones of the Calvin sandstone. The discussion of this relationship is included with the section concerning the Calvin sandstone.

(See measured stratigraphic sec. Nos. 1, 2, 7, 8, 9, 26, 28, 29, 31, 32, 33, 34, 37, 38, and 39 for detail on part of the Senora formation.)

(See Plate III, Measured Outcrop Sections, and Plate II, Electric Log Cross Section, for graphic representation of stratigraphic details concerning the formation).

Calvin Sandstone.

First Reference: J. A. Taff, 1901.

Nomenclator: J. A. Taff, 1901.

Type Locality: The town of Calvin, Hughes County, Oklahoma.

Original Description: J. A. Taff,[79] in 1901, gave the following description of the Calvin sandstone:

> Above the Senora formation there is a deposit of massive and thin-bedded sandstone with some shaly beds in the upper part having a thickness of 140 to 240 feet. For nearly 140 feet upward from the base, the rock is a massive but not a very hard sandstone. In the northern part of its occurrence this lower and more massive member of the formation crops in the steep hillsides and bluffs overlooking the more level Senora formation toward the east. In the southern part of its outcrop the lower sandy member becomes shaly, and even the massive beds which occur are more friable than the same deposits in the northern part of the quadrangle. Near the middle of this lower sandstone member, west of Sand Creek, there is a shaly and slightly calcareous bed which contains iron in the form of hematite. On account of the bright-red color of the iron upon weathering this bed is a marked feature of the formation.
>
> The upper part of the Calvin sandstone is least shaly in the northern part of the area, and many of the beds are hard and weather into slabs and hard plates. The upper 90 to 100 feet of the formation here contains two, and in places more, shaly beds 10 to 20 feet in thickness. The sandstone beds of the upper portion decrease southwestward from 40 feet in thickness to thin layers interstratified with shales.

Other Descriptions: Following Taff's mapping in the northern half of the Coalgate quadrangle, Morgan[80] traced the formation into northeastern Pontotoc County, where it is probably cut out by a fault in the north half of T. 3 N., R. 7 E. Morgan reported that the formation thins to 40 feet just north of its southernmost exposure and consists of coarse-grained, brown and grayish-brown sandstones, with interbedded thin shale layers.

In 1951 Ries completed the mapping of the Calvin from the north boundary of Hughes County across Okfuskee County. He reported a rather uniform thickness of 245 feet for the formation across the county. Ries[81] further stated:

79 Taff, J. A., 1901. *U. S. Geol. Survey, Geol. Atlas,* Folio No. 74, p. 4.
80 Morgan, C. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 86.
81 Ries, E. R., In press. *Okla. Geol. Survey, Bull.* 71.

> The Calvin formation in Okfuskee County is divided into three unnamed members: a basal sandstone "complex" member . . . a thick middle shale member . . . and an upper sandstone member.
>
> The basal sandstone member consists of a series of two to eight sandstones with thin, intervening shales. This "complex" seems to maintain a rather uniform thickness regardless of the number of sandstones . . . This member is 70 feet thick.

History of Usage: Subsequent usage has followed Taff's original description.

Distribution: Regionally the Calvin sandstone extends northeastward from northeastern Pontotoc County through Hughes, Okfuskee, and Okmulgee Counties, reaching almost to the Arkansas River.

This formation crops out in a wide northeast trending belt across Hughes County, roughly dividing it into two equal parts. The width of outcrop in the northwest part of T. 4 N., R. 9 E. is 2.5 miles, but is progressively wider to the northeast where the formation is thicker, and has a width of 7 miles in the central portion of T. 7 N., Rs. 10 and 11 E. The strike of the formation across the county is N. 25° E. and the regional dip about 88 feet per mile NW.

Stratigraphic Position: In Hughes County the Calvin sandstone intertongues with silty shales of the underlying Senora formation and is overlain conformably by the Wetumka shale.

Paleontology: Though neither Morgan[82] nor Taff[83] reported any fossils from outcrops of the Calvin sandstone to the south, Ries[84] listed 34 species collected in Okfuskee County. His collection included articulate brachiopods (15 species) and pelecypods (16 species). Twenty-seven species were collected and identified in Hughes County by the writer.

Fossils identified from the Calvin formation in Hughes County:

Anthozoa
- Pleurodictyum eugeneae White

Crinoidea
- Delocrinus granulosus Moore and Plummer

82 Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 20.
83 Taff, J. A., 1901. *U. S. Geol. Survey, Geol. Atlas,* Folio No. 74, p. 4.
84 Ries, E. R., In Press. *Okla. Geol. Survey, Bull.* 71.

Bryozoa
- Polypora whitei Ulrich

Brachiopoda
- Chonetes granulifer Owen
- Composita ovata Mather
- Crurithyris planoconvexa (Shumard)
- Linoproductus insinuatus (Girty)
- Linoproductus prattenianus (Norwood and Pratten)
- "Marginifera" muricatina Dunbar and Condra
- Mesolobus mesolobus (Norwood and Pratten)
- Mesolobus mesolobus decipiens Girty
- Punctospirifer kentuckiensis (Shumard)

Pelecypoda
- Allorisma terminale Hall
- Edmondia gibbosa McCoy
- Edmondia ovata Meek and Worthen
- Lima retifera Shumard
- Nucula girtyi Schenck
- Promytilus swallovi (McChesney)
- Schizodus wheeleri Swallow

Gastropoda
- Bucanopsis meekiana Swallow
- Meekospira bella Walcott
- Strobeus brevis White
- Trepospira depressa (Cox)

Nautiloidea
- Metacoceras cornutum Girty

Ammonoidea
- Gastrioceras hyattianum Girty

Plantae
- Calamites sp.
- Stigmaria sp.

Age and Correlation: According to Moore and others,[85] the Calvin sandstone is of middle Allegheny age. It is in the middle part of the Des Moines series of the Mid-Continent region. It is correlated with the lower part of the Marmaton group of Kansas; and with the upper part of the Deese formation of the Ardmore basin in southern Oklahoma.

The Calvin sandstone has been traced by Oakes[86] northward to within a few miles of the Arkansas River, where the Fort Scott limestone, the basal formation of the Marmaton group of Kansas, is about 10 feet below the base of the Calvin. However, from the latitude of Calvin northward several tongues of the Calvin sandstone grade into the underlying Senora shale and the lowest of these tongues may be as old as the Fort Scott limestone, or even older.

85 Moore, R. C., et al., 1944. *Geol. Soc. Amer., Bull.*, vol. 55, pp. 657-706.

86 Oakes, Malcolm C., January, 1952. Personal communication.

Thickness and Character: Throughout most of its outcrop across Hughes County, the Calvin sandstone (ℙcv-1 of map) consists of medium-grained to silty, gray and brown, massive to thin-bedded sandstones and has an average thickness of 270 feet. The formation is consistently 320 to 350 feet thick north of the Canadian River but is thinner to the southwest and in the area west of Gerty (the northwest part of T. 4 N., R. 9 E.) is only 230 feet thick.

In the north part of the county the formation is divided into three units:—a lower sandstone unit (ℙcv-1 of map), a middle silty shale unit (ℙcv-2 of map), and an upper sandstone unit (ℙcv-3 of map). The lower unit consists of a series of discontinuous, medium-grained to silty, gray and brown sandstone beds with sandy to silty, gray shale lenses. (See Figure 6.) It is about 150 feet thick in the east and central parts of T. 9 N., R. 11 E. Sandstone and siltstone tongues split off from the basal part of this lower unit, thin rapidly, and intertongue with shale of the underlying Senora formation.

The occurrence of these tongues is limited to the area north of the Canadian River and was not reported by Ries to the north in Okfuskee County. However, only a small area of outcrop of the formation was available to him in that county. Oakes[87] reported the presence of similar tongues at the base of the Calvin farther north in Okmulgee County. Most of the tongues continue in the same stratigraphic position or drop slightly in the section as they split away from the massive sandstone zone. However, in the northern part of the county several tongues (see ℙcv-1a to ℙcv-1m) split off from the basal Calvin, drop in the section, and approach the upper sandstone unit of the Senora sandstone member, finally grading to shale and losing their identity.

Although many thin sandstone and siltstone tongues diverge from the basal part of the Calvin, all could not be mapped accurately. Thirteen of these tongues were mapped in some detail and are numbered ℙcv-1a through ℙcv-1m in Plate I. The stratigraphic relations of several of these tongues are shown in Plate III.

87 *Ibid.*

It should be pointed out that the tracing of the "shale tongues" of the Senora formation up into the Calvin was done mostly on a zonal basis. Exact boundaries could not be followed and are not, in fact, present. The nature of these shale tongues changes rapidly as they leave the main body of the shale member of the Senora. Thus beds are mapped as "shale" tongues that are technically argillaceous siltstones with irregular, sandy to silty shale lenses. However, these "shale" zones can be traced for varying distances into the overlying Calvin, where they thin rapidly and lose their identity. Worthy of mention are the tongues IPcv-1a and IPcv-1b which split off from the main sand body of the Calvin in NE¼ sec. 14, T. 6 N., R. 10 E. and are not traceable across Spring Branch 1 mile to the north. In a section measured in the center of sec. 22, T. 6 N., R. 10 E., the basal sand unit of the Calvin is massive, light brown, largely fine-grained in texture, and about 24 feet thick. Northeast along the strike this sandstone thins and grades to siltstone with numerous silty shale lenses scattered throughout the unit. A section measured in the east half of sec. 11, T. 6 N., R. 10 E. shows that the lower massive sandstone unit mentioned above has split into two thin sandstone tongues. The lower tongue consists of cream-gray silty clay and siltstone and is only 3.5 feet thick. Twenty-eight feet above it lies the upper tongue which is 8.5 thick and is also a light gray siltstone. Between these two tongues is a zone of lensing, argillaceous, gray siltstones and silty gray shales.

The tongue (labeled IPcv-1j on the geologic map) which leaves the main lower Calvin scarp abruptly in the northeast corner of sec. 1, T. 8 N., R. 11 E., thins rapidly as it drops in the section. In the SE¼ of NE¼ of this section, where the sandstone is still a part of the main scarp, it is 38 feet thick, massive, and of medium to fine-grained texture. Here it is about 160 feet above the top of the lower Senora sandstone member. One mile north in the southeast corner of sec. 36, T. 9 N., R. 11 E., the tongue has thinned to 17 feet and is very thin-bedded and silty. At this point it is only 105 feet above the top of the lower sandstone member of the Senora formation, and it is about 60 feet below the "new" basal Calvin sandstone zone. The tongue was traced northeast 1 mile across the west side of sec. 30, T. 9 N., R. 12 E., where it could

Figure 6. Thin-bedded, lensing sandstones in lower part of Calvin formation in roadcut on south side of Oklahoma Highway 9, SW¼ sec. 24, T. 9 N., R. 11 E.

Figure 7. Conglomerate in lower member of Wewoka formation in roadcut 0.4 mile west of the SE cor. sec. 16, T. 5 N., R. 9 E.

not be mapped farther north without some question. At its last good exposure in the SE cor. NW¼ sec. 30, the tongue is only about 3 feet thick and consists of thin-bedded to lensing, fine-grained sandstones and siltstones. Here it is approximately 50 feet above the top of the lower sandstone member of the Senora, though exact measurements are impossible at this point.

It should be emphasized that ideally the tongues should all be located in the section with respect to the top of the Calvin sandstone. However, the great width of outcrop of the formation and the obscure nature of the contact with the overlying Wetumka shale made this very difficult. In an attempt to explain further the nature of the occurrence of these tongues, an electric log cross-section was prepared down the dip of the beds beginning in the vicinity of Calvin and trending northwestward to the area just south of Holdenville. This section shows that one and possibly several tongues are present down the dip to the northwest and thin rapidly and disappear near the western boundary of Hughes County. The base of the main sand body appears to stay at a constant interval above the "Senora limestone". Five miles northwest of the town of Calvin, the Calvin sandstone is 300 feet thick in the subsurface. Where the large tongue which occurs there at the base of the Calvin thins and disappears, however, the formation thins to 190 feet.

The presence of these sandstone tongues which wedge out in subsurface to the northwest and also to the northeast along the strike of the beds indicates that the source of these sediments was southeast or possibly south. These tongues were apparently deposited in a deltaic type of environment. The streams carrying the sediments changed direction often as they flowed across a broad delta, deposited fine sands and silts first down one slope and then changed direction and concentrated their deposits in another area—thus the variance in the position of the tongues in the section as seen along the strike of the beds on the surface. The sandstone tongues become finer-grained and grade to siltstones as they leave the main sand body, another bit of evidence pointing to a deltaic origin.

In the north part of the county an attempt was made to carry southward a sandy shale zone (IPcv-2 of map) which is mapped to the north of the county as the middle Calvin shale unit. This was difficult owing to the rapid gradation of the shales of this unit to siltstones and fine-grained sandstones and also because of the lack of good exposures. A section measured along State Highway 9 in the cen. E½ sec. 21, T. 9 N., R. 11 E. showed this "shale" unit to be about 118 feet thick and to contain silty, gray to buff shales and numerous irregular siltstone lenses. Strictly speaking, in northern Hughes County, the term "middle shale unit" is hardly applicable.

An argillaceous siltstone zone considered to represent the rapidly thinning "shale" zone could be followed with difficulty across the extreme western part of T. 8 N., R. 11 E. In the SW¼ sec. 6, T. 8 N., R. 11 E., the zone is 44 feet thick and contains numerous clay and siltstone lenses. In the N½ of sec. 26, T. 8 N., R. 10 E., the "shale" zone is barely discernable but is approximately 14 feet thick. Shales mapped in the SE cor. sec. 25, T. 8 N., R. 10 E. may be the last exposure of this zone.

The upper sandstone unit (IPcv-3 of map) is not mappable south of secs. 25 and 26, T. 8 N., R. 10 E., and the Calvin was mapped as one unit (IPcv-1 of map) from there south. This upper sandstone unit is about 75 feet thick in secs. 4 and 5, T. 9 N., R. 11 E. near the north county line. It thins rapidly to the south from this point, but exact thicknesses were difficult to determine to the south owing to the blanket of alluvium and terrace deposits.

An illustration of the relation of the lower, middle and upper units of the Calvin in the north part of the county is presented in Plate III.

A subsurface electric log cross-section across the north part of the county shows that the Calvin has a thickness of 330 feet immediately west of its outcrop in the east half of T. 8 N., R. 11 E., and thins to 260 feet in the northwest corner of the county. (See wells Nos. 5 and 12 of cross section, Plate II.)

(For further details of the Calvin sandstone as it occurs in Hughes County, see measured stratigraphic sections Nos. 1, 2, 10, 11, 12, 19, 26. 28, 29, 30, 37, and 39.)

Wetumka Shale.

First Reference: J. A. Taff, 1901.

Nomenclator: J. A. Taff, 1901.

Type Locality: The old townsite of Wetumka, about 1 mile east of the present townsite.

Original Description: Taff[88] described the Wetumka shale in his "Coalgate Folio". His references to locations largely concern southern Hughes County and extreme northeastern Pontotoc County. He described the Wetumka as follows:

> The shaly beds of the Calvin sandstone grade into the succeeding Wetumka shale, so that the division line between the formations cannot be easily determined stratigraphically nor very accurately mapped.
>
> With the exception of thin shaly sandstone layers near the center, the Wetumka shale is composed of friable, laminated clay shales. It is estimated to be about 120 feet thick throughout its occurrence in the Coalgate quadrangle.
>
> From the head of Big Creek to the Canadian River Valley this shale crops in gently rolling prairie land and produces a soil more fertile than is usually found upon other formations in this region. Beds near the top are exposed in many places in the escarpment beneath the sandstone beds of the succeeding Wewoka formation. In the western part of its occurrence the Wetumka shale lies in the nearly level plain of Muddy Boggy Creek Valley.

Other Descriptions: In 1924 Morgan,[89] working in the Stonewall quadrangle to the southwest of Hughes County, wrote that the Wetumka is 150 to 250 feet thick.

In his recent work in Okfuskee County to the north, Ries[90] reported the thickness of the Wetumka to range from 120 feet to 146 feet.

History of Usage: Present usage has followed Taff's original description.

Distribution: Regionally, the Wetumka shale is mapped as a unit northeastward from the northeast part of Pontotoc County across Hughes, Okfuskee, Okmulgee, and Tulsa Counties to the Arkansas River.

[88] Taff, J. A., 1901. *U. S. Geol. Survey, Geol. Atlas,* Folio No. 74, p. 4.
[89] Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 86.
[90] Ries, E. R., In press. *Okla. Geol. Survey, Bull.* 71. pp. 41-42.

In Hughes County, the Wetumka shale (IPwt of map) is exposed only beneath the scarps capped by the succeeding lower sandstone of the Wewoka formation. There are few exposures of the shale on the gentle dip slopes on the top of the Calvin sandstone, for subsequent streams seeking less-resistant beds have cut back through these shales, eroding them and leaving an alluvial cover on the uppermost sandstones of the Calvin. Thus the contact between the Wetumka and Calvin formations is effectively blanketed over most of its outcrop across Hughes County.

The formation is best exposed in the central part of T. 5 N., R. 9 E. and the outcrop belt trends N. 20° E. across the county, never exceeding 1.5 miles in width.

The formation dips about 92 feet per mile NW and strikes N. 25° E.

Stratigraphic Position: In Hughes County the Wetumka shale overlies the Calvin sandstone conformably and is overlain conformably by the Wewoka formation.

Paleontology: Morgan[91] made several collections and recorded 35 species from the Wetumka shale in the Stonewall quadrangle to the southwest of Hughes County. Ries,[92] working in Okfuskee County to the north, reported no fossils in the shales.

Forty-nine species were collected and identified by the writer.

Fossils identified from the Wetumka formation in Hughes County:

Porifera
- Wewokella solida Girty

Anthozoa
- Lophophyllidium sp.
- Pleurodictyum eugeneae White

Conularida
- Calloconularia holdenvillae (Girty)

Crinoidea
- Delocrinus granulosus Moore and Plummer

Bryozoa
- Polypora crassa Ulrich
- Rhombopora lepidodendroides Meek
- Tabulipora carbonaria (Worthen)

Brachiopoda
- Lindstroemella patula (Girty)
- Petrocrania modesta (White & St. John)
- Chonetes granulifer Owen
- Chonetes granulifer armatus Girty
- Composita ovata Mather
- Composita subtilita (Hall)
- Crurithyris planoconvexa (Shumard)
- Hustedia mormoni (Marcou)
- Juresania nebrascensis (Owen)
- Linoproductus prattenianus (Norwood and Pratten)
- Marginifera lasallensis (Worthen)
- Marginifera muricatina Dunbar and Condra
- Marginifera splendens (Norwood and Pratten)
- Nudirostra rockymontanum (Marcou)

Pelecypoda
- Allorisma terminale Hall
- Anthraconeilo taffiana Girty
- Astartella concentrica Conrad
- Edmondia ovata Meek and Worthen
- Nucula wewokana Girty
- Nuculana bellistriata (Stevens)
- Nuculopsis girtyi Schenck
- Promytilus swallovi (McChesney)
- Schizodus affinis Herrick
- Schizodus alpinus (Hall)
- Yoldia glabra Beede and Rogers

Gastropoda
- Euphemites vittatus (McChesney)
- Glabrocingulum grayvillense (Norwood and Pratten)
- Meekospira choctawensis Girty
- Strobeus brevis White
- Trepospira depressa (Cox)
- Worthenia tabulata (Conrad)

Nautiloidea
- Liroceras liratum (Girty)
- Pseudorthoceras knoxense (McChesney)

Ammonoidea
- Gastrioceras hyattianum Girty

Plantae
- Calamites sp.
- Stigmaria sp.

Age and correlation: According to Moore and others,[93] the Wetumka shale is of middle-upper Allegheny age. It is approximately in the upper-middle of the Des Moines series of the Mid-Continent region. It is correlated with the lower part of the Labette shale of northeastern Oklahoma and southeastern Kansas; and with that part of the Deese formation immediately below the Rocky Point conglomerate of the Ardmore basin, in southern Oklahoma.

Thickness and Character: The Wetumka shale (IPwt of map) has a constant thickness of about 120 feet in its outcrop across Hughes County. It consists of blue-gray to cement-gray, sandy to silty shales which are fossiliferous at many places. Near the

91 Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 92.
92 Ries, E. R., In press. *Okla. Geol. Survey, Bull.* 71.
93 Moore, R. C., et al., 1944. *Geol. Soc. Amer., Bull.* vol. 55, pp. 657-706.

base and top of the formation are numerous thin-bedded discontinuous sandstone and siltstone beds. Thus, the contacts with the underlying Calvin sandstone and the overlying lower sandstone unit of the Wewoka formation are not sharp in most exposures.

Good exposures of the Wetumka are rare owing to the blanket of stream alluvium and terrace deposits which covers the lower part of the dip slope of the underlying Calvin sandstone. The thickness reported above was taken from electric logs of wells across the county which were drilled west of the outcrop.

Although the thickness along the strike of the formation is rather constant, the formation thins rapidly in the subsurface to the west. In the P. McIntyre No. 1 Allen well in the NW¼NE¼SW¼ sec. 11, T. 9 N., R. 8 E., in the northwest part of the county, the Wetumka is only about 56 feet thick. (See well No. 11, Plate II.)

Wewoka Formation.

First Reference: J. A. Taff, 1901.

Nomenclator: J. A. Taff, 1901.

Type Locality: Taff mentioned no specific type locality, but he named the formation after the town of Wewoka in east-central Seminole County.

Original Description: J. A. Taff[94] gave the following original description of the Wewoka formation:

> Above the Wetumka shale there is a succession of massive and, for the most part, friable sandstones and shales, seven in number in alternating beds 40 to 130 feet thick. These beds together are about 700 feet thick and are named the Wewoka formation, from the town of the same name in the Wewoka Quadrangle to the north. The separate massive beds composing the formation are of sufficient thickness to be mapped, but on account of the obscurity of the contact lines, due to the friable nature of the beds, it is not possible to accurately distinguish them.
>
> The lowest of the four sandstone divisions of the Wewoka formation is thinner, though generally harder, than the succeeding ones. At its base there are local indurated beds of sandy chert conglomerate. These conglomerates are most prominent near the western border of the quadrangle where they form bluffs facing Boggy Creek Valley. This group of sandstones and conglomerates becomes thinner eastward and northward, so that its outcrop is hardy perceptible on the border of the Canadian River Valley.
>
> Above this sandstone and conglomerate there is fossiliferous friable blue clay shales for 120 feet, ending locally in thin white fossiliferous limestone. This shale is exposed in many deep gulches bordering the Canadian River on the south, and outcrops in the rolling prairie land between Allen and Leader. Especially good exposures may be seen in the deep ravines in the NE¼ of Sec. 23, T. 5 N., R. 8 E., where abundant fossil shells weather out free and occur in calcareous clay concretions.
>
> The succeeding sandstone member is about 110 feet thick. It caps the high land near the western border of the quadrangle, south of the Canadian River and forms high bluffs surmounting the escarpments, facing eastward upon the north side of the river. Its beds are massive and friable, breaking down readily into loose sand and weathering into rounded ledges.
>
> Above this sandstone, and near the middle of the formation, there is a soft fossiliferous blue clay shale nearly 130 feet thick. This shale is remarkable for the abundant and perfectly preserved fossil shells which it contains. Its full section is exposed on the Memphis and Choctaw Railroad, 2 miles north of mouth of Little River. Above this thick shale there is a sandstone 60 feet thick, which is succeeded by 45 feet of shale. Next above comes the highest sandstone member of the formation, which is estimated to be about 100 feet in thickness. The uppermost beds of this sandstone are shaly and culminate in a shelly sandy limestone.

Taff's original description in his "Coalgate Folio" concerns largely the outcrop of the formation in the west-central part of Hughes County and in the extreme northeastern part of Pontotoc County to the southwest.

Other Descriptions: Morgan[95] mapped the Wewoka to the southeast in Pontotoc and Seminole Counties. He described the Wewoka as 400 feet of shale beds with several sandstone members. One is at the base and it grades locally into chert conglomerate.

94 Taff, J. A., 1901. *U. S. Geol. Survey, Geol. Atlas*, Folio No. 74, p. 4.

95 Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 94.

A thin fusulinid limestone occurs in the upper part of the formation. Locally there is limestone conglomerate in the upper part of the Wewoka, and in one small area a conglomerate contains pebbles of igneous rock.

History of Usage: The term Wewoka appears to have been used consistently in the original sense of Taff.

Distribution: Regionally the Wewoka formation extends in a wide belt northeastward from northeastern Pontotoc County across Hughes, Okfuskee, and Okmulgee Counties. In Pontotoc County the formation is cut out by the Ahloso fault about 3 miles southeast of Ada.

The Wewoka formation crops out in Hughes County in a broad belt that trends northeastward across the west-central and north-central part of the county. The width of outcrop across the county is about 7 miles and fairly consistent. The strike of the formation is approximately N. 25° E., and the regional dip as computed from the electric logs over the area is about 92 feet per mile NW.

Stratigraphic Position: In Hughes County the Wewoka formation lies conformably on the Wetumka shale and is overlain conformably by the Holdenville shale.

Paleontology: In 1915 George H. Girty[97] described the prolific fauna of the Wewoka formation. Since that time the fossiliferous shales of the formation have become well-known as an ideal collecting zone. Morgan,[98] Ries,[99] and others have also reported large faunal collections from the formation. In the course of the present work 93 species were identified.

Fossils identified from the Wewoka formation in Hughes County:

Fusulinid
- Fusulina inconspicua Girty

Porifera
- Wewokella solida Girty

Anthozoa
- Lophophyllidium sp.
- Pleurodictyum eugeneae White
- Stereostylus ? radicosus (Girty)

[97] Girty, G. H., 1915. *U. S. Geol. Survey Bull.* 544 .
[98] Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, pp. 97-101.
[99] Ries, E. R., In press. *Okla. Geol. Survey, Bull.* 71.

Conularida
- Calloconularia holdenvillae (Girty)

Crinoidea
- Delocrinus granulosus Moore and Plummer

Bryozoa
- Fenestrellina mimica (Ulrich)
- Fistulipora carbonaria Ulrich
- Polypora nodocarinata Ulrich
- Polypora whitei Ulrich
- Prismopora lobata Warthin
- Rhombopora lepidodendroides Meek
- Septopora blonda Moore
- Septopora elliptica Warthin

Brachiopoda
- Lindstroemella patula (Girty)
- Lingula carbonaria Shumard
- Orbiculoidea missouriensis (Shumard)
- Chonetes granulifer Owen
- Chonetes granulifer armatus Girty
- Cleiothyridina orbicularis (McChesney)
- Composita ovata Mather
- Composita subtilita (Hall)
- Condrathyris perplexa (McChesney)
- Crurithyris planoconvexa (Shumard)
- Derbyia crassa (Meek and Hayden)
- "Dictyoclostus" americanus Dunbar and Condra
- "Dictyoclostus" portlockianus (Norwood and Pratten)
- Dielasma bovidens (Morton)
- Hustedia miseri Mather
- Hustedia mormoni (Marcou)
- Juresania nebrascensis (Owen)
- Linoproductus insinuatus (Girty)
- Linoproductus prattenianus (Norwood and Pratten)
- Marginifera lasallensis (Worthen)
- "Marginifera" muricatina Dunbar and Condra
- Marginifera splendens (Norwood and Pratten)
- Mesolobus mesolobus (Norwood and Pratten)
- Mesolobus mesolobus decipiens Girty
- Mesolobus mesolobus euampygus (Girty)
- Neospirifer cameratus (Morton)
- Neospirifer dunbari King
- Nudirostra rockymontanum (Marcou)
- Punctospirifer kentuckiensis (Shumard)
- Rhipidomella carbonaria (Swallow)
- Wellerella osagensis (Swallow)

Pelecypoda
- Acanthopecten carboniferus (Stevens)
- Allorisma terminale Hall
- Anthraconeilo taffiana Girty
- Astartella concentrica Conrad
- Astartella vera Hall
- Aviculopecten occidentalis (Shumard)
- Aviculopinna americana Meek
- Aviculopinna peracuta (Shumard)
- Conocardium obliquum Meek
- Edmondia gibbosa McCoy
- Edmondia ovata Meek and Worthen
- Nucula anodontoides Meek
- Nucula parva (McChesney)
- Nucula wewokana Girty
- Nuculana bellistriata (Stevens)

Nuculopsis girtyi Schenck
Promytilus swallovi (McChesney)
Schizodus affinis Herrick
Schizodus alpinus (Hall)
Schizodus wheeleri Swallow
Yoldia glabra Beede and Rogers

Gastropoda
Amphiscapha catilloide (Conrad)
Bellerophon crassus wewokanus Girty
Bucanopsis meekiana Swallow
Euphemites vittatus (McChesney)
Glabrocingulum grayvillense (Norwood and Pratten)
Meekospira choctawensis Girty
Meekospira peracuta (Shumard)
Pharkidonotus percarinatus (Conrad)
Strobeus brevis White
Strobeus intercalaris (Meek and Worthen)
Strobeus primogenius (Conrad)
Trepospira depressa (Cox)
Worthenia tabulata (Conrad)

Nautiloidea
Liroceras liratum (Girty)
Metacoceras cornutum Girty
Metacoceras sangamonense (Meek and Worthen)
Pseudometacoceras sculptile (Girty)
Pseudorthoceras knoxense (McChesney)

Ammonoidea
Gastrioceras excelsum (Meek)
Gastrioceras goniolobus (Meek)
Peritrochia ganti (Smith)

Trilobita
Ameura sangamonensis (Meek and Worthen)
Griffithides parvulus Girty

Chondrichthyes
Petalodus destructor (Newberry and Worthen)

Plantae
Calamites sp.
Stigmaria sp.

Age and Correlation: The Wewoka formation is in the upper part of the Des Moines series of the Mid-Continent region. It is correlated with the upper part of the Labette formation, the Oologah formation, the Nowata shale, and the Lenapah limestone in Oklahoma, north of the Arkansas River, and thus with the greater part of the Marmaton group of Kansas and Nebraska; with beds between the top of the Rocky Point conglomerate and the base of the Confederate limestone in the Deese formation of the Ardmore basin, in southern Oklahoma; and with part of the upper Strawn series, in north-central Texas.

Thickness and Character: In Hughes County the Wewoka formation consists of four massive to thin-bedded sandstone units (ℙwk-1 to ℙwk-4 of map) with thick, interbedded and intertonguing

shales (all lettered ℙwk on map). The average thickness of the formation is 680 feet. Though the sandstone units may be traced completely across the county, many of the individual sandstone beds in each unit are discontinuous, many of them intertonguing with the overlying or underlying shale zones. Typically the base of each sandstone unit appears to be continuous along its outcrop. However, closer examination shows that most of the lower sandstone units wedge out northward and that the overlying bed thickens and replaces it in the same approximate horizon.

The lower sandstone unit (ℙwk-1 and ℙwk-1a of map) consists of a series of massive to thin-bedded. lenticular, medium-grained to silty sandstones of erratic thickness across the county. It is exposed typically as the caprock of a well-defined scarp that crosses the county in a northeast direction. Also included in this unit is a thick overlying shale zone which is well-exposed in the steep scarp capped by the lower sandstone of the succeeding sandstone unit (ℙwk-2 of map). The sandstone body averages 60 feet in its outcrop across the county, but in secs. 8 and 17 in the northwest part of T. 7 N., R. 10 E. it is only about 6 feet thick (see measured stratigraphic sections Nos. 23 and 24). About 1 mile north of this area, in section 5, and directly north in secs. 32 and 33, T. 8 N., R. 10 E., this sandstone is slightly thicker and consists of two units separated by a shale zone. These sandstone beds may be seen directly superimposed in the SE cor. sec. 32. There the lower tongue (ℙwk-1 of map) is only 0.6 feet thick and is separated from the upper unit (ℙwk-1a of map) by a 14-foot sandy shale zone. The top of the upper unit is eroded at this locality and is thicker than the 5.5 feet listed in measured stratigraphic section No. 18. The lower tongue is not mappable north and east of Grief Creek where this stream crosses and blankets the outcrop of the formation in secs. 28 and 29, T. 8 N., R. 10 E. The inferred stratigraphic relationship is shown in Plate III. Here again intricate and important stratigraphic details are masked by stream alluvium, and the course of the stream across this area was largely determined by the lack of resistance of the sandstone unit. This blanketing effect occurs in several critical areas and affects almost all the formations mapped. From here northward the upper part of this sandstone (ℙwk-1a of map) is mapped as the base of the Wewoka formation.

South of Atwood in the SE cor. sec. 34, T. 6 N., R. 9 E. a heavy chert conglomerate occurs in the lower sandstone unit. The chert gravels average one-fourth inch in diameter and are sub-rounded. The largest chert fragments found were slightly more than one-half inch in their longest dimension. The matrix is coarse to fine-grained sandstone and silty, gray-brown clay. A similar conglomerate occurs in the lower Wewoka sandstone in the SE¼ sec. 16, T. 5 N., R. 9 E. (See Figure 7.)

The shale overlying the lower sandstone is silty, gray, and averages 120 feet thick. The thickness is erratic along its outcrop owing largely to the irregular development of the sand body (IPwk-2, 2a, 2b, and 2c of map) which overlies it. (See Plate III.) The shale is fossiliferous and contains, especially near its top and bottom, numerous lenticular sandstones or siltstones.

Unit number 2 (IPwk-2 of map) is a massive to medium-bedded, fine-grained, light brown sandstone 130 feet thick in the SW¼ sec. 31, T. 6 N., R. 9 E. To the north near the center of the south half of T. 7 N., R. 9 E., this unit consists of three sandstones (IPwk-2a, 2b, and 2c) which can be mapped northward several miles. (See Plate III.) The lower sandstone unit (IPwk-2a) is over 50 feet thick in the S½ sec. 6, T. 8 N., R. 10 E. and contains two siltstone tongues separated by a silty, gray shale zone. Neither of these tongues is definitely traceable north of a small alluvium-filled creek valley which crosses the central part of sec. 30, T. 8 N., R. 10 E. The second sandstone tongue (IPwk-2b of map) forms the "new" base of the major sandstone unit in the northern half of section 30 and the southwestern part of sec. 20, T. 8 N., R. 10 E., but north of there it too wedges out.

To the north of sec. 20, T. 8 N., R. 10 E. the upper sandstone unit (IPwk-2c) is the lowest sandstone body present in the number 2 unit. Across Tps. 8 and 9 N., R. 10 E. this sandstone has an average thickness of 85 feet, is medium to fine-grained, brown to gray-brown in color, and contains numerous silty gray shale lenses.

The overlying shale is blue-gray, sandy to silty at many places and is very fossiliferous. The average thickness is 120 feet.

The succeeding sandstone unit (IPwk-3 of map) is massive, conglomeratic, and light brown in its most southern occurrence in the county in the N½ SE¼ sec. 9, T. 5 N., R. 8 E. The unit is about 125 feet thick in this area, although the top is eroded locally. The conglomerate consists of fine chert gravels averaging one-fourth inch in diameter in a matrix of gray-brown, medium to fine-grained sandstone and silty shale.

Northward from Deep Creek to the north-central part of T. 7 N., R. 9 E., the massive unit is divided into three sandstone bodies (IPwk-3a, 3b, and 3c) with intervening shale zones. The lower and upper sandstones (IPwk-3a, and 3c) are tongues which thin northward and disappear. The middle sandstone (IPwk-3b) continues northward into Okfuskee County. The lower tongue could not be traced north of a small fault in the SE cor. of sec. 10, T. 7 N., R. 9 E., and from that point northward the middle sand body (IPwk-2b of map) is mapped as the base of this third unit. Likewise, the upper sandstone tongue thins and loses its character and is not mapped north of the S½ sec. 33, T. 8 N., R. 9 E. (For a graphic illustration of these relationships, see Plate III.) To the north of this area to the north line of the county, the middle sandstone (IPwk-3b of map) has a rather constant thickness of 110 feet, though there are numerous silty shale lenses associated with the sandstone at irregular intervals.

The overlying shale averages 75 feet thick but is erratic because of lensing sand bodies that limit it. The upper and lower parts of the shale are silty and the shales grade downward into the underlying sandstone. The contact with the overlying sandstone unit number 4 is generally sharp.

The uppermost sandstone unit of the Wewoka formation (IPwk-4 of map) supports a high scarp which trends northeastward across the county just east of Spaulding and Holdenville, and west of Yeager. The sandstone averages 60 feet thick and is fairly uniform in thickness across the county. It is generally massive but may be medium to thin-bedded near its lower and upper boundaries. It is medium to very fine-grained, light brown, and contains numerous argillaceous siltstone lenses at irregular intervals. A highly leached, red-brown, sandy limestone about two feet thick occurs near the top of the sandstone unit in sec. 15, T. 9 N., R. 9 E. and is exposed in a road cut 500 feet east of the southwest corner of that section. Other thin limestones occur irregularly at or just above the top of this upper sandstone, and there is some question as to whether some of these limestones should be included in the Wewoka formation or in the overlying Holdenville formation.

A dense, blue-gray, fossiliferous limestone occurs just above the uppermost sandstone of the Wewoka 100 feet east of the SW cor. sec. 29, T. 8 N., R. 9 E. This limestone may be equivalent to the limestone that is exposed immediately west of Holdenville in a road cut in the SE cor. of sec. 13, T. 7 N., R. 8 E. The limestone exposed in sec. 13 is traceable to the south and is definitely in the lower part of the Holdenville formation, and lower in the section than the Homer limestone.

A further discussion of the formation as it extends into the subsurface is presented under "Subsurface Stratigraphy."

(For more detailed descriptions of the specific units of the Wewoka, see measured stratigraphic Sections Nos. 3. 5, 11, 12, 13, 18, 21, 23, 24, 25, 27, and 30.)

Holdenville Shale

First Reference: J. A. Taff, 1901.

Nomenclator: J. A. Taff, 1901.

Type Locality: Town of Holdenville, Oklahoma, and westward.

Original Description: In his "Coalgate Folio" in 1901, Taff[102] described the Holdenville formation as follows:

> This shale, 250 feet in thickness, rests upon the Wewoka formation. The surface of the formation becomes broader northward in the more level country about Holdenville, 3 miles north of the border of the quadrangle.
>
> The formation is composed of friable blue clay shale, with local thin beds of shelly limestone and shaly calcareous sandstone in the upper part. The sandstone ledges outcrop in terraces around the slopes of hills bordering the north side of Little River. The thin limestone occurs about 35 feet below the top of the formation, and its out-

[102] Taff, J. A., 1901. *U. S. Geol. Survey, Geol. Atlas,* Folio No. 74, p. 4.

> crop is usually covered by the sandstone and conglomerate debris from the overlying formation. In its usual exposure 1 to 2 feet only of shaly limestone may be seen. At other places a bed of shell breccia loosely cemented is found, representing the thin hard plates of the shelly rock. The shales are rarely exposed. The smooth grass-covered prairie soil, however, even in the steep slopes, bears evidence of the friable shale beneath.

Other Descriptions: After tracing the Holdenville formation to the southwest of Hughes County into northern Pontotoc County, Morgan[103] wrote the following description:

> The Holdenville formation consists largely of shale, but also contains numerous sandstone beds and two mappable limestone members. Some of the sandstones locally develop into massive chert conglomerates that are lithologically identical with the conglomerate at the base of the Seminole in the type area of that formation.
>
> In the northeastern part of the quadrangle the Holdenville is approximately 235 feet thick. It thins southward, however, and at its southern extremity, where it is overlapped by the Seminole, does not exceed 100 feet.

Ries[104] gave the following description of the Holdenville in Okfuskee County to the north:

> The Holdenville formation consists of a succession of shales, sandstones, and a few local limestones. Generally speaking, the shales are very thick and the sandstones are thin. The limestones vary up to 2 feet in thickness.
>
> The shales are yellowish-brown to grayish-green in color. At many places they contain small concretions. These shales carry a prolific fauna in places.
>
> The sandstones have an erratic nature. They thicken and thin in short distances, and in many places, they are friable and poorly developed, making surface mapping difficult.
>
> The limestones are thin, fossiliferous, and on weathering surface becomes a yellow-brown in color due to the high iron content . . . . .
>
> Two Holdenville sandstones were mapped across the county. The lowermost of these . . . lies 15 to 60 feet above the top of the Wewoka formation. This variation is due to thickening of the underlying shale to the south

[103] Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 103.
[104] Ries, E. R., In press. *Okla. Geol. Survey, Bull.* 71.

> . . . This sandstone varies in thickness from 2 feet to 12 feet . . . .
>
> The upper Holdenville sandstone is more uniform in thickness and lateral extent. In the northern part of the county this sandstone is well developed and forms large escarpments. In the southern portion, the sandstone is more friable and therefore forms lower escarpments . . . . The sandstone varies from 3 to 12 feet in thickness. Generally speaking, this sandstone thickens southward.
>
> The thickness of the Holdenville formation varies from 280 feet in the southern part of the county to 200 feet in the extreme northern part.

History of Usage: The term Holdenville has always been used in the present sense.

Distribution: Morgan traced the Holdenville from the type locality southward across southeastern Seminole County to a point near Lawrence in central Pontotoc County. To the north of Hughes County the formation has been traced across Okfuskee, Okmulgee, and southern Tulsa Counties.

The Holdenville crops out in the west-central and northwest parts of Hughes County. It is best exposed in a belt about 2½ miles wide in the area between Spaulding and Holdenville in the west-central part of the county. The regional dip of the formation is 92 feet per mile N. 65° W.

Stratigraphic Position: In Hughes County, in the type area, the Holdenville shale lies conformably on the Wewoka formation and is overlain by the Seminole formation. Morgan,[105] after mapping the Seminole - Holdenville contact to the southwest of Hughes County, stated that the Seminole formation overlaps the Holdenville formation in central Pontotoc County. The Holdenville-Seminole contact across Hughes County offers little or no evidence for placing an unconformity at the base of the Seminole formation. The upper shale zone of the Holdenville is irregular in thickness, but this is true of almost every shale unit overlain by a sandstone unit in Hughes County. (See Plate III).

[105] Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 103.

Paleontology: The shales of the Holdenville formation carry a prolific fauna, and 62 species were identified. The fauna is typical of the Des Moines series, containing such representative forms as *Mesolobus mesolobus* and *"Marginifera" muricatina.*

Fossils collected from the Holdenville formation in Hughes County:

Fusulinid
- Fusulina inconspicua Girty

Porifera
- Wewokella solida Girty

Anthozoa
- Lophophyllidium sp.
- Stereostylus ? radicosus (Girty)

Conularida
- Calloconularia holdenvillae (Girty)

Crinoidea
- Delocrinus granulosus Moore and Plummer

Bryozoa
- Polypora elliptica Rogers
- Polypora whitei Ulrich
- Rhombopora lepidodendroides Meek
- Tabulipora carbonaria (Worthen)

Brachiopoda
- Lindstroemella patula (Girty)
- Lingula carbonaria Shumard
- Chonetes granulifer Owen
- Chonetes granulifer armatus Girty
- Cleothyridina orbicularis (McChesney)
- Composita ovata Mather
- Composita subtilita (Hall)
- Condrathyris perplexa (McChesney)
- Crurithyris planoconvexa (Shumard)
- Derbyia crassa (Meek and Hayden)
- "Dictyoclostus" americanus Dunbar and Condra
- Hustedia mormoni (Marcou)
- Juresania nebrascensis (Owen)
- Linoproductus insinuatus (Girty)
- Linoproductus prattenianus (Norwood and Pratten)
- Marginifera lasallensis (Worthen)
- "Marginifera" muricatina Dunbar and Condra
- Marginifera splendens (Norwood and Pratten)
- Mesolobus mesolobus (Norwood and Pratten)
- Mesolobus mesolobus decipiens Girty
- Mesolobus mesolobus euampygus Girty
- Neospirifer cameratus (Morton)
- Nudirostra rockymontanum (Marcou)
- Rhipidomella carbonaria (Swallow)

Pelecypoda
- Acanthopecten carboniferus (Stevens)
- Allorisma terminale Hall
- Astartella concentrica Conrad
- Aviculopecten occidentalis (Shumard)
- Conocardium obliquum Meek
- Edmondia ovata Meek and Worthen
- Nucula anodontoides Meek

Nuculana bellistriata (Stevens)
Nuculopsis girtyi Schenck
Promytilus swallovi (McChesney)
Schizodus affinus Herrick
Yoldia glabra Beede and Rogers

Gastropoda
Amphiscapha catilloide (Conrad)
Bucanopsis meekiana Swallow
Cymatospira montfortiana (Norwood and Pratten)
Euphemites vittatus (McChesney)
Meekospira choctawensis Girty
Strobeus brevis White
Trepospira depressa (Cox)

Nautiloidea
Liroceras liratum (Girty)
Metacoceras cornutum Girty
Pseudometacoceras sculptile (Girty)
Pseudorthoceras knoxense (McChesney)

Ammonoidea
Gonioloboceras goniolobus (Meek)

Trilobita
Ameura sangamonesis (Meek and Worthen)
Griffithides parvulus Girty

Plantae
Calamites sp.
Stigmaria sp.

Age and Correlation: The Holdenville shale is the uppermost part of the Des Moines series of the Mid-Continent region. It is continuous with the Memorial shale, of former usage, in Tulsa County, Oklahoma, and their upper and lower boundaries are continuous. Holdenville is the older and more used term and takes precedence. The term Memorial shale is no longer used by the Oklahoma Geological Survey. The Holdenville shale is correlated with shale of patchy occurrence in Kansas and Missouri, heretofore called the Memorial shale.

Thickness and Character: Across most of Hughes County the Holdenville shale consists of blue-gray, fossiliferous shale which is divided into upper and lower units (IPhd-1 and IPhd-3 of map) by one or more sandstone beds (IPhd-2a, 2b, and 2c of map). The Homer and Sasakwa limestones in the lower and upper parts of the formation respectively in Seminole County to the west are much thinner northward in Hughes County and are absent north of the vicinity of Spaulding. The Holdenville has an average thickness of 250 feet across the county. (See Plate III for an illustration of stratigraphic relationships of the various beds of the Holdenville shale.)

The lower shale unit averages 100 feet thick and contains two limestones, the Homer (IPhdh of map), and an unnamed limestone (IPhdl of map). The Homer occurs 26 feet below the base of the middle sandstone unit (IPhd-2a) in the NE cor. sec. 9, T. 6 N., R. 8 E. There it is 2.7 feet thick, massive, blue-gray, coarsely-crystalline and weathers into red-brown slabs. The Homer is less than 3 inches thick in the SE¼ NW¼ sec. 10, T. 6 N., R. 8 E. and could not be traced northward from this area. One mile north of Spaulding in the SW cor. sec. 35, T. 7 N., R. 8 E., a dense, medium-crystalline, fossiliferous limestone (IPhdl of map) occurs 100 feet below the base of the middle sandstone unit and just above the upper sandstone unit (IPwk-4) of the Wewoka formation. This limestone does not resemble the Homer limestone to the south. It is traceable northward and is the limestone that is exposed on the southwest outskirts of Holdenville in the SE cor. sec. 14, T. 7 N., R. 8 E. and discussed with the upper part of the Wewoka formation. The northernmost exposure of this lower limestone is in the southeast corner of sec. 8, T. 8 N., R. 9 E. where the limestone is associated with jet black to gray-black, waxy shale. The area is blanketed by terrace deposits and the interval between the limestone and the underlying Wewoka sandstone could not be determined.

A sandstone lens (IPhd-1a of map) occurs near the base of the lower Holdenville shale unit in the vicinity of Holdenville. Its relation to the underlying upper Wewoka sandstone is obscured by buildings and roads in the city of Holdenville. It is possible that this sandstone merges with the underlying sandstone of the Wewoka, but as this relationship could not be proved the sand body was mapped as part of the Holdenville. This sandstone rises rapidly in the section north of Holdenville and possibly merges with the lower sandstone (IPhd-2a) of the middle sandstone unit of the Holdenville. Here again the exact relationships could not be proved due to the thick blanket of terrace deposits along Wewoka Creek in the west half of T. 8 N., R. 9 E.

The middle sandstone unit of the Holdenville (IPd-2 of map) is massive to thin-bedded, calcareous at many places and forms a high scarp in the south part of its outcrop across the county. Irregularly occurring limestone lenses are common. (See Figure 8.)

It is about 59 feet thick in the area west of Spaulding and contains a shale bed about 12 feet thick 8 feet below its top. To the north of Deep Creek this middle sandstone unit consists of three sandstone bodies with two intervening sandy shale zones. The sandstone units are numbered, lower first, IPhd-2a, 2b, and 2c. The lower unit is 19 feet thick but thins rapidly northward in SW cor. sec. 26, T. 7 N., R. 8 E., and could not be located immediately west of Holdenville. However, a thin sandstone in the S½ sec. 12, T. 7 N., R. 8 E. is in the same approximate horizon and was mapped northward as the same unit.

About 18 feet above the lower sandstone (IPhd-2a of map) of the middle sandstone unit is a thin siltstone tongue (IPhd-2b of map) which is 3.5 feet thick and is well exposed in a road cut 300 feet north of the SE cor. sec. 27, T. 7 N., R. 8 E. This siltstone thins and disappears in the NW cor. sec. 26, T. 7 N., R. 8 E.

The upper sandstone body of the middle sandstone unit (IPhd-2c of map) averages 6 feet in thickness and was traced northward to Okfuskee County.

The upper shale unit (IPhd-3 of map) is composed of soft, gray, waxy, fossiliferous shales and averages 80 feet thick. It contains the Sasakwa limestone (IPhds of map) 35 feet below its top of secs. 8, 17, and 20, T. 6 N., R. 8 E. about 3 miles south and west of Spaulding.

The Sasakwa limestone is typically medium-crystalline, blue-gray, and highly fossiliferous. Its average thickness in its limited outcrop in Hughes County is 0.7 foot. It weathers into thin yellow-gray slabs. (See Figure 9.) Ries[109] has mapped the Sasakwa to the west and south and has studied the fauna in detail. He reported 38 species from the limestone. The Sasakwa is more than 29 feet thick in the quarry at Sasakwa but thins rapidly northward and disappears just east of the Hughes County line. The last definite exposure of the limestone to the north is in the N½ SE¼ sec. 8, T. 6 N., R. 8 E. where it is less than 1 inch thick.

(For details concerning various parts of the Holdenville shale, see measured stratigraphic sections Nos. 3, 5, 14, 15, 16, 17, 20, 21, 23, 24, 25, and 27.)

[109] Ries, E. R., In press. *Okla. Geol. Survey, Bull.* 71.

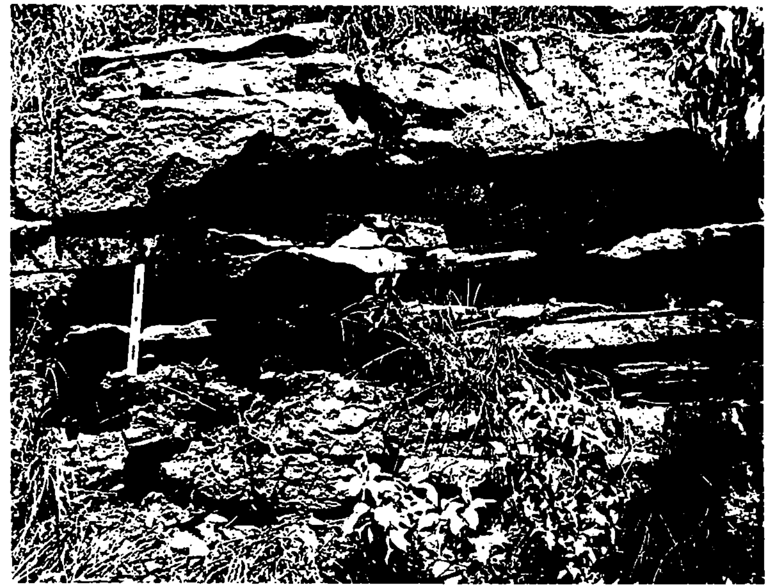

Figure 8. Middle sandstone unit of Holdenville formation (IPhd-2a) in roadcut 0.3 mile east of the SW cor. sec. 3, T. 6 N., R. 8 E.

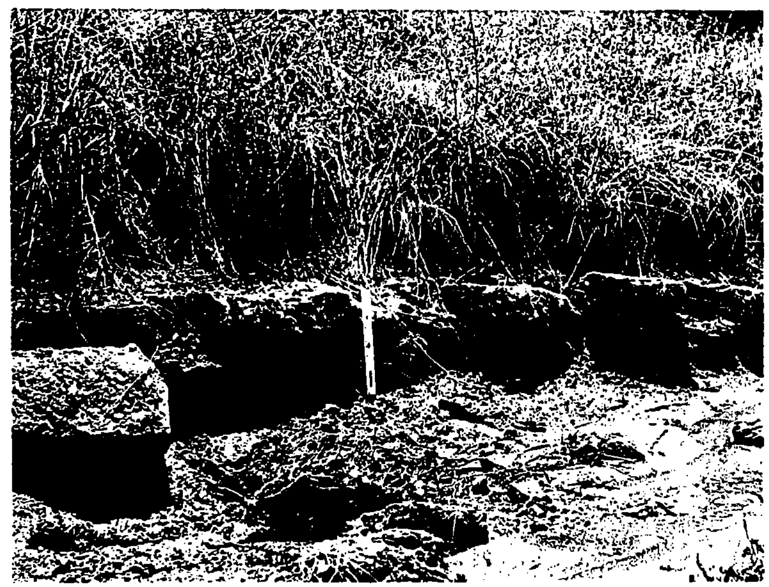

Figure 9. Sasakwa limestone member of the Holdenville shale just east of roadcut in the SW cor. sec. 8, T. 6 N., R. 8 E.

MISSOURI SERIES

Only the lower part of the Missouri series is present in Hughes County. The Seminole formation of lowermost Missouri age and the lower and middle parts of the overlying Coffeyville formation are exposed in the west-central and northwest part of the county. These formations have a total thickness of about 605 feet in and immediately west of northwestern Hughes County.

The contact with the underlying Des Moines series is apparently conformable across Hughes County, though an unconformity has been reported between these two units in other parts of the Mid-Continent region. West of Hughes County the Missouri series is overlain unconformably by the Vamoosa formation of Virgil age.

Seminole Formation.

First Reference: J. A. Taff, 1901.

Nomenclator: J. A. Taff, 1901.

Type Locality: The old Seminole Nation which is now Seminole County, Oklahoma.

Original Description: After mapping the lower part of the Seminole formation in the northwest part of the Coalgate quadrangle. Taff[110] wrote the following description:

> About 50 feet of the lower part of the Seminole conglomerate is exposed in a small area in the northwestern corner of the Coalgate Quadrangle. This part of the formation is composed of laminated or stratified sub-angular chert, with a sprinkling of quartz pebbles from 3 inches in diameter to small grains in a cement of fine brown and usually ferruginous sand. The coarse conglomerate in the beds at the base is loosely cemented and on weathered surfaces breaks down into rounded boulders and loose gravel. 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.

Although Taff approximately defined the upper limit of the Seminole formation, he did not map it. Morgan[111] working in the Stonewall quadrangle to the west, defined the top of the formation as extending up to the base of the DeNay limestone, and mapped it, using these limits, in southern Seminole and northeastern Pontotoc Counties.

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110 Taff, J. A., 1901. *U. S. Geol. Survey, Geol. Atlas,* Folio No. 74, p. 4.
111 Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 103.

Ries,[112] after mapping the Seminole formation across Okfuskee County to the north of Hughes County, reported that the formation averages 264 feet thick.

History of Usage: Use of the term Seminole formation in the type area has followed Morgan's definition.

Distribution: Regionally the Seminole formation extends northeastward from central Pontotoc County across Seminole, Hughes, Okfuskee, Okmulgee, Creek, Tulsa, and Nowata Counties.

The formation trends north-northeast across the west-central and northwest parts of Hughes County. The width of outcrop averages 2 miles. The formation dips about 90 feet per mile NW and strikes N. 15° E.

Stratigraphic Position: To the north of Hughes County the Seminole formation lies above the Holdenville shale and below the Checkerboard formation. To the south and west of the county the formation lies above the Holdenville formation and below the DeNay limestone, the lower member of the Francis formation. Across most of Hughes County neither the Checkerboard formation nor the DeNay limestone is present, and the top of the formation was mapped as the base of the lowest sandstone unit (IPcf-1 of map) of the Coffeyville formation (lower Francis to the south).

In the central part of the Stonewall quadrangle to the southwest of Hughes County, Morgan[113] reported that the Seminole formation lies unconformably on the Holdenville formation and is overlain conformably by the Francis formation. Farther to the south, west of Lawrence, the Seminole formation is overlain unconformably by the Ada formation.

In Hughes County the Seminole-Holdenville contact appears conformable, though many geologists have reported a regional unconformity at this horizon.

Paleontology: Conspicuously absent in the collections from the Seminole formation are such typical Desmoinesian forms as *"Marginifera" muricatina* and *Mesolobus mesolobus*. Forty-two species were identified from the Seminole formation in the course of the present work.

112 Ries, E. R., In press. *Okla. Geol. Survey, Bull.* 71.
113 Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 109.

Fossils identified from the Seminole formation in Hughes County:

Anthozoa
- Lophophyllidium sp.
- Pleurodictyum eugeneae White

Conularida
- Paraconularia crustula (White)

Crinoidea
- Delocrinus granulosus Moore and Plummer

Echinoidea
- Echinocrinus megastylus (Shumard)

Bryozoa
- Rhombopora lepidodendroides Meek

Brachiopoda
- Lindstroemella patula (Girty)
- Chonetes granulifer Owen
- Cleiothyridina orbicularis (McChesney)
- Composita ovata Mather
- Composita subtilita (Hall)
- "Dictyoclostus" americanus Dunbar and Condra
- "Dictyoclostus" portlockianus (Norwood and Pratten)
- Dielasma bovidens (Morton)
- Hustedia mormoni (Marcou)
- Linoproductus insinuatus (Girty)
- Marginifera lasallensis (Worthen)
- Marginifera splendens (Norwood and Pratten)
- Neospirifer cameratus (Morton)
- Nudirostra rockymontanum (Marcou)
- Punctospirifer kentuckiensis (Shumard)
- Wellerella osagensis (Swallow)

Pelecypoda
- Allorisma terminale Hall
- Astartella concentrica Conrad
- Aviculopecten occidentalis (Shumard)
- Aviculopinna americana Meek
- Nucula anodontoides Meek
- Nuculopsis girtyi Schenck
- Promytilus swallovi (McChesney)
- Schizodus affinis Herrick
- Schizodus wheeleri Swallow

Gastropoda
- Amphiscapha catilloide (Conrad)
- Bucanopsis meekiana Swallow
- Glabrocingulum grayvillense (Norwood and Pratten)
- Pharkidonotus percarinatus (Conrad)
- Strobeus primogenius (Conrad)
- Trepospira depressa (Cox)

Nautiloidea
- Metacoceras cornutum Girty
- Pseudorthoceras knoxense (McChesney)

Age and Correlation: The Seminole formation is of lower Conemaugh age. It is at the base of the Missouri series in the Mid-Continent region. It is correlated with the lower part of the

Pleasanton-Bourbon group of Iowa, Nebraska, Missouri, and Kansas; and with the lower part of the Hoxbar group of the Ardmore Basin, in southern Oklahoma. According to Oakes,[115] the lower sandstone unit of the Seminole is overlapped by the middle shale unit in southern Nowata County; also, the upper sandstone unit thins northward, overlaps the middle shale unit south of the Kansas-Oklahoma line, and is called the Hepler sandstone in Kansas.

Thickness and Character: The Seminole formation in Hughes County consists of three conglomeratic sandstone units (IPsl-1, 2, 3, of map), each with an overlying sandy to silty gray shale. Each of the sandstone units contains fine, gray-white chert flakes throughout its outcrops in the county, but chert conglomerates are present in the sandstones only south and west of the north part of T. 7 N., R. 8 E. This is the approximate northern limit in Hughes County of occurrence of coarse to fine chert conglomerates so common farther south.

The formation averages 300 feet thick in its outcrop across Hughes County.

In sec. 5, T. 6 N., R. 8 E. the lower sandstone unit (IPsl-1 of map) is about 49 feet thick and is mainly fine to coarse conglomerates. The coarse conglomerates are massive, conspicuous lenses erratically distributed. The chert fragments composing the conglomerate are sub-rounded, gray-white to brown, and average one-fourth inch in diameter. Fragments up to 2 inches were found, however. (See Figure 10.) To the north and south of this immediate area the conglomerates grade into medium to fine-grained sandstone and siltstone. These conglomerates are not continuous along the strike and are generally coarsest and thickest in the middle part of their exposure. North of Deep Fork Creek the lower sandstone unit is divided into two sandstone bodies (IPsl-1a of map). A silty gray shale averaging 30 feet in thickness separates these two sandstones across the central part of T. 7 N., R. 8 E. and the southeast part of T. 8 N., R. 8 E. The upper unit (IPsl-1a of map) is about 10 feet thick across this area, but the lower unit thins rapidly northward from 46 feet in the S½ sec. 11, T. 7 N., R. 8 E., where

[115] Oakes, M. C., February, 1952. Personal communication.

it is conglomeratic sandstone, to 6 feet of silty and thin-bedded sandstone in the eastern half of sec. 23, T. 8 N., R. 8 E. As interpreted by this writer, this sandstone wedges out immediately to the north and the sandstone occupying its position north of Wewoka Creek is the overlying sandstone unit, IPsl-1a. This sandstone averages 30 feet thick and is continuous northward to Okfuskee County.

A sandy shale zone (IPsl of map) which averages 80 feet in thickness overlies the lower sandstone unit.

The overlying sandstone unit (IPsl-2) is massive, highly conglomeratic, and averages 20 feet thick in its southernmost exposure in the county in the W½ sec. 5, T. 6 N., R. 8 E. It is slightly thicker to the north in the E½ sec. 16, T. 7 N., R. 8 E. and then thinner northward and appears to wedge out immediately under, or to be cut out by, the upper Seminole sandstone unit (IPsl-3 of map) in the W½ of sec. 14, T. 8 N., R. 8 E. Correlations are difficult in this area because of the wide belt of alluvial and terrace deposits of Wewoka Creek.

The upper sandstone unit (IPsl-3 of map) of the Seminole is only 7 feet thick in the northeast part of T. 6 N., R. 8 E.. in east-central Seminole County.[116] It is thicker to the north as it passes into Hughes County and is 13 feet thick in an exposure in the center of the north line of sec. 4, T. 7 N., R. 8 E. Here the unit is thin-bedded, fine-grained and contains thin sandy shale lenses. The sandstone reaches a maximum thickness of 60 feet in sec. 36, T. 9 N., R. 8 E., where a 23-foot silty shale zone occurs 7 feet above the base of the unit.

As defined by Morgan[117] from its exposures to the southwest in southern Seminole and northern Pontotoc Counties, the top of the Seminole formation is considered to be at the base of the DeNay limestone. This limestone occurs 11 feet above the upper sandstone unit (IPsl-3 of map) in the extreme northeast part of T. 6 N., R. 7 E. in east- central Seminole County.[118] There the upper zone of the Seminole formation consists of 11 feet of gray, sandy to silty shale. The DeNay was traced northeastward into the NW

[116] Tanner, William F., March, 1952. Personal communication.
[117] Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 110.
[118] Tanner, William F., March, 1952. Personal communication.

cor. of sec. 20, T. 7 N., R. 8 E., Hughes County. There it is approximately 22 feet above the upper sandstone unit of the Seminole formation. The DeNay could not be traced north of this area, though Sarles[119] earlier had mapped the limestone into the center of sec. 17, T. 7 N., R. 8 E. The limestone mapped by Sarles in this locality as "DeNay" is here interpreted to be a sandy limestone which is associated with the top of the upper Seminole sandstone unit (IPsl-3 of map). It is well below the horizon of the DeNay and does not resemble it lithologically.

North of the last occurrence of the DeNay limestone, the base of the lower sandstone (IPcf-1 of map) of the overlying Coffeyville formation was mapped as the base of the Coffeyville. Thus, all the shale zone lying between the top of the upper Seminole sandstone unit and the base of the lower Coffeyville sandstone unit is mapped northward with the Seminole formation. This shale zone averages 85 feet thick in its outcrop across the northwest part of T. 7 N., R. 8 E. but thins northward and is only about 24 feet thick on the north county line in sec. 6, T. 9 N., R. 9 E.

The stratigraphic relations and lithology of the various units of the Seminole formation are illustrated in Plate III.

(For more details concerning the thickness and lithology of the various parts of the formation, see measured stratigraphic Sections Nos. 3, 5, 10, 14, 15, 16, 17, 20, 21, 22, 23, 24, 25, and 27.)

*Coffeyville Formation.**

First Reference: Schrader and Haworth,[120] 1905.

Nomenclators: Schrader and Haworth,[121] 1906.

Type Locality: Apparently the type locality is in the vicinity of Coffeyville, Kansas.

* The rocks of the Coffeyville formation in Hughes County are also the lower part of the Francis formation, and the Francis will be shown on the new geologic map of Oklahoma, now in preparation, as far north as the North Canadian River.

[119] Sarles, J. E., 1943. Unpublished M.S. thesis, Univ. of Okla.

[120] Schrader, F. C., and Haworth, Erasmus, 1905. *U. S. Geol. Survey, Bull.* 260, p. 448.

[121] Schrader, F. C., and Haworth, Erasmus, 1906. *U. S. Geol. Survey, Bull.* 296, p. 14.

Figure 10. Chert conglomerate in basal member of Seminole formation. Roadcut at center of S. line sec. 5, T. 6 N., R. 8 E.

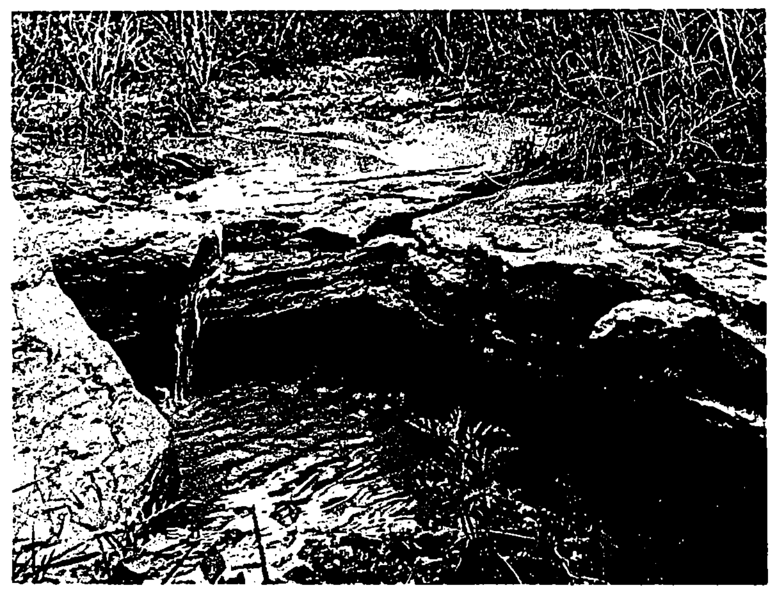

Figure 11. DeNay limestone in lower part of Coffeyville formation. Cen. W. line sec. 20, T. 7 N., R. 8 E. Scale indicated by 1-foot ruler at top of bed.

Original Description: In describing the Coffeyville formation from its occurrence in the Independence quadrangle, Kansas, Schrader and Haworth[122] wrote:

> 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 (Lenapah).

Other Descriptions: After tracing the Coffeyville formation south from Okfuskee County across northwestern Hughes County and into east-central Seminole County, the writer found that the formation is equivalent to the lower part of the Francis formation. The Francis was first described by Morgan[123] in the Stonewall quadrangle to the south. Concerning the lower part of the Francis, he stated that the Francis formation is 500 feet thick and that within it and at its base is the DeNay limestone. The major part of the formation is shale, with a persistent sandstone in the lower 250 feet. The shales contain abundant limestone concretions.

After mapping the Coffeyville formation in Okfuskee County to the north, Ries[124] described the beds in detail.

He found the formation to consist of three greenish shales and two escarpment-forming sandstones. The lower shale, measured from the top of the Checkerboard limestone to the base of the first sandstone, is from 5 to 20 feet thick. The lower sandstone is 2 to 20 feet thick, the middle shale 80 feet, the upper sandstone 10 to 30 feet, and the upper shale 135 feet. Ries reported the formation to be 245 feet thick.

The Checkerboard limestone which lies directly below the lower Coffeyville shale throughout most of Okfuskee County is absent in the south part of that county and is not present in Hughes County. Ries[125] wrote that the unit grades to shale southward in Okfuskee County.

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122 *Ibid.*
123 Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 114.
124 Ries, E. R., In press. *Okla. Geol. Survey, Bull.* 71.
125 *Ibid.*

History of Usage: Schrader and Haworth[126] included the Ladore-Dudley shale, the Mound Valley limestone, the Galesburg shale, the Dennis limestone and the Cherryville shale in the Coffeyville formation as originally defined. Use of the term varied widely until 1937, when the formation was restricted by Moore, Newell, Dott, and Borden[127] to include only the rocks between the Checkerboard limestone and the Dennis (Hogshooter) limestone.

Distribution: Regionally, rocks of the Coffeyville formation and its equivalents extend from near Fitzhugh in Pontotoc County northeastward across eastern Seminole County, northwestern Hughes County, and central Okfuskee County, where there is a change of strike slightly to the north, and extend on into southern Kansas.

In Hughes County the Coffeyville crops out only in the east part of T. 9 N., R. 8 E. and in the west part of T. 7 N., R. 8 E. The DeNay limestone, which marks the base of the formation to the south, is present in Hughes County only in sec. 20, T. 7 N.. R. 8 E.

Stratigraphic Position: As redefined by Moore, Newell, Dott, and Borden[128] the Coffeyville formation rests on the Checkerboard limestone and is overlain by the Dennis (Hogshooter) limestone. The relations are apparently conformable. As Ries traced the formation southward across Okfuskee County he found that the Checkerboard did not extend south of the south-central part of that county. He then mapped the formation southward using the base of the lower sandstone unit as the base of the formation.

In most of its outcrop across Hughes County the same sandstone unit used by Ries in Okfuskee County was mapped as the base of the formation, and the underlying shale unit was mapped with the Seminole formation.

The base of the Coffeyville formation in the southwestern part of Hughes County, sec. 20, T. 7 N., R. 8 E., is the DeNay limestone, which rests on the upper shale of the Seminole formation with apparent conformity. It disappears by gradation into shale northward.

126 Schrader, F. C., and Haworth, Erasmus, 1906. *U. S. Geol. Survey, Bull.* 296.
127 Moore, R. C., Newell, Norman D., Dott, R. H. and Borden, J. L., 1937. The Kansas Geol. Society, Eleventh Annual Field Conference, p. 41.
128 *Ibid.*

Only the middle and lower part of the Coffeyville are exposed in Hughes County, but in the type area the formation is overlain conformably by the Hogshooter formation.

Paleontology:

Fossils identified from the Coffeyville formation in Hughes County:

Anthozoa
- Lophophyllidium sp.
- Pleurodictyum eugeneae White

Conularida
- Paraconularia crustula (White)

Crinoidea
- Delocrinus granulosus Moore and Plummer

Echinoidea
- Echinocrinus megastylus (Shumard)

Bryozoa
- Fistulipora carbonaria Ulrich
- Polypora elliptica Rogers
- Rhombopora lepidodendroides Meek
- Tabulipora carbonaria (Worthen)

Brachiopoda
- Lindstroemella patula (Girty)
- Chonetes granulifer Owen
- Cleothyridina orbicularis (McChesney)
- Composita subtilita (Hall)
- Composita trilobita Dunbar and Condra
- Derbyia crassa (Meek and Hayden)
- Crurithyris planoconvexa (Shumard)
- Dictyoclostus americanus Dunbar and Condra
- Dictyoclostus portlockianus (Norwood and Pratten)
- Dielasma bovidens (Morton)
- Hustedia mormoni (Marcou)
- Juresania nebrascensis (Owen)
- Linoproductus insinuatus (Girty)
- Linoproductus prattenianus (Norwood and Pratten)
- Neospirifer cameratus (Morton)
- "Marginifera" muricatina Dunbar and Condra
- "Marginifera" splendens (Norwood and Pratten)
- Wellerella osagensis (Swallow)

Pelecypoda
- Allorisma terminale Hall
- Astartella concentrica Conrad
- Aviculopecten occidentalis (Shumard)
- Aviculopinna americana Meek
- Edmondia gibbosa McCoy
- Edmondia ovata Meek and Worthen
- Nucula anodontoides Meek
- Nuculana bellistriata (Stevens)
- Nuculopsis girtyi Schenck
- Promytilus swallovi (McChesney)
- Schizodus affinis Herrick
- Schizodus wheeleri Swallow
- Yoldia glabra Beede and Rogers

Gastropoda
- Amphiscapha catilloide (Conrad)
- Bellerophon crassus wewokanus Girty

Euphemites vittatus (McChesney)
Meekospira choctawensis Girty
Stroheus brevis White
Strobeus intercalaris (Meek and Worthen)
Trepospira depressa (Cox)

Nautiloidea
Metacoceras cornutum Girty
Pseudorthoceras knoxense (McChesney)
Pseudometacoceras sculptile (Girty)

Ammonoidea
Gastrioceras hyattianum Girty

Plantae
Calamites sp.

Age and Correlation: The Coffeyville formation is in the lower part of the Missouri series of the Mid-Continent region. It is equivalent to most of the Bourbon and Bronson groups of Kansas. It is correlated with the lower part of the Hoxbar formation of the Ardmore basin in southern Oklahoma.

In the course of the present work the writer traced two sandstone units and their overlying shales, in the lower part of the Coffeyville, southward from Okfuskee County into the lower part of the Francis formation, as mapped by Morgan in the Stonewall quadrangle. The DeNay limestone, as mapped by Morgan, Tanner, and others to the south, occupies the same stratigraphic position as the Checkerboard limestone to the north; however, the DeNay is here mapped with the Coffeyville formation to conform with usage in mapping the Francis formation farther south.

Thickness and Character: Only the lower 160 feet of the Coffeyville formation is exposed in Hughes County. As mapped across most of its outcrop, the formation consists of two sandstone units (IPcf-1 and 2 of map) with thick overlying shales. Total thickness of the formation is about 250 feet. In sec. 20, T. 7 N., R. 8 E., the southwestern exposures of the Coffeyville in Hughes county, the DeNay limestone is present and is mapped as the base of the formation. It is a medium-crystalline, fossiliferous limestone which averages 1 foot thick. Typically, it weathers into orange-brown slabs and presents an irregular surface where crinoid stems and other fossils stand out in bold relief. The limestone is well exposed in a road cut in the center of the west line of sec. 20, T. 7 N., R. 8 E., Seminole County. (See Figure 11.)

The lower sandstone unit of the Coffeyville (IPcf-1 of map) averages 35 feet thick in its outcrop across Hughes County. It is, however, irregular in thickness from one area to another. It is composed chiefly of fine-grained, thin-bedded, light brown friable sandstone beds, and forms an easily traceable scarp across the northwest part of T. 7 N., R. 8 E. and the eastern part of T. 9 N., R. 8 E. There is a good exposure in a road cut in the center of the north line of sec. 8, T. 7 N., R. 8 E., where the sandstone is about 31 feet thick.

Above this lower sandstone unit is a thick shale zone (IPcf of map) which is exposed in a small area in the east half of T. 9 N., R. 8 E. There the shale is about 90 feet thick, gray-brown, and contains numerous thin siltstone beds near its top and base.

Only the middle and lower parts of the upper Coffeyville sandstone (IPcf-2 of map) are exposed in Hughes County. The lower 41 feet of this sandstone is exposed in the northwest part of the county where it is fine-grained to silty and cream-gray to brown. A silty, gray shale zone 17 feet thick occurs about 12 feet above the base of the unit in the SE cor. sec. 11, T. 9 N., R. 8 E.

The uppermost unit of the Coffeyville is absent in Hughes County but Ries[130] reported the overlying shale zone of the Coffeyville to be about 135 feet thick in adjacent Okfuskee County.

(For more detailed description concerning parts of the Coffeyville formation, see measured stratigraphic sections Nos. 3, 6, 14, 15, 16, 20, 22, 23, 24, 25, 27.)

Quaternary Stratigraphy

On top of many of the highest hills and at scattered localities at lower elevations in Hughes County there are thin patches of gravel and pebbles. These gravels apparently are the remnants of a blanket of clay, sand, and gravel which probably covered the area in late Quaternary time and was stripped partly away by erosion. The gravels probably were deposited originally near the centers of the channels of large streams which had their headwaters in the area east of the Rocky Mountains. The courses of these streams shifted from time to time, however, for no concentration or trend of these gravels was noted, and they were found in every part of the county.

130 Ries, E. R., In press. *Okla. Geol. Survey, Bull.* 71.

The gravels range in size from fine to coarse and many cobbles as much as 5 inches in their longest dimension were found. They consist largely of quartz, quartzite, chert, and dense, blue-gray, finely-crystalline limestone, and all are sub-rounded to well-rounded. The outer surfaces are typically gray to yellow-brown and are pitted and otherwise weathered due to long exposure. These deposits are not suitable for a commercial source of gravel owing to their large size and to the scattered occurrence.

An occurrence of these gravels may be seen on the Calvin sandstone in the center of sec. 18, T. 5 N., R. 10 E.

There are numerous deposits of sand and clay in Hughes County that appear to drape the underlying consolidated formations. These deposits effectively blanket the tops and slopes of the highest hills in many places and do not show developed terrace levels. They are mapped as "Qt" on the geologic map.

Most of these deposits are near the present course of the Canadian River though they are well-represented along the North Canadian River, Wewoka Creek, and Little River.

It is true that erosion could have destroyed evidence as to the presence of terraces formerly associated with these deposits. However, many of the deposits are the results of the gradual downcutting of a stream to its present level without the pauses necessary to build distinct terraces.

The deposits typically are yellow-brown to orange-brown, silty clays and medium to fine-grained sands and silts. Good exposures of this type of deposit may be seen about 2 miles northwest of Calvin in secs. 16 and 17, and the northern halves of secs. 20 and 21, T. 6 N., R. 10 E. There the sand and clay deposits cap the top of the Calvin sandstone about 200 feet above the present level of the Canadian River.

Terrace Deposits

There are three distinct stream terraces (Qt on map) along the Canadian River in Hughes County. The lowest terrace is between 10 and 15 feet above the present flood plain and may be seen 1 mile northeast of Calvin where it borders the south side of the present stream channel. A higher and more extensive stream

terrace also occurs in this area and is well-exposed along both sides of the river. This terrace is 30 to 40 feet above the present river level. It is perhaps best exposed on State Highway 68, just south of the Canadian River near the bridge 3½ miles north of Atwood. These terraces are flat-lying and under cultivation. A higher terrace is present north of Atwood and south of the Canadian River. It is also exposed just east of Calvin in the center of sec. 27, T. 6 N., R. 10 E. This terrace lies from 65 to 80 feet above the present river level. It is highly dissected, having been subjected to more erosion than the more recent terraces below it. These terraces were formed during pauses in the downcutting of the Canadian River.

Tanner[131] has found equivalent terraces along the Canadian River in southern Seminole County to the west. He also reported higher terrace deposits and the unclassified surficial deposits discussed elsewhere in this paper.

Gerty Sand

A distinctive belt of sand, clay, and gravel averaging 2 miles in width trends southeast across the southwest part of the county, effectively blanketing the underlying Pennsylvanian sandstones and shales. This deposit represents a past course of the Canadian River south of the channel which it now occupies across the central part of the county. This deposit is mapped as "Qtg" on the geologic map.

J. A. Taff named this formation for the town of Gerty* in the south-central part of Hughes County. He described the Gerty as it occurs in the northern part of the Coalgate quadrangle as follows:[132]

> Generally the sand becomes coarse downward, ending in gravel at the base. In many places the finer sediments have been washed away, leaving beds of coarse gravel and thin mantles of pebbles. In places the deposit is of even texture; in other places it grades gradually from fine to coarse materials; and in still other places, especially noted in well sections, there are alternate strata of bluish, red and yellow clay, silt and sand, usually ending at the base in quicksand or gravel.

131 Tanner, William F., March, 1952. Personal Communication.
* Original spelling.
132 Taff, J. A., 1901. *U. S. Geol. Survey, Geol. Atlas*, Folio No. 74, p. 5.

The sand is composed of fine white quartz which is usually more or less mixed with yellow silt. The pebbles of the gravel are well rounded and smooth, varying in size from that of a hen's egg to a sand grain. They are composed of quartz, quartzite, jasper and chert, and vary in color from white, yellow, red, and black. Very little material from the country rock such as limestone, shale, and sandstone was found mixed with the gravel.

No fossils were found in the Gerty in Hughes County, but Morgan[133] reported that a tusk, possibly belonging to a species of mastodon, *Mammut americanum,* was found in the Gerty in the northern part of the Stonewall quadrangle. He further stated:

> . . . Taff's original description of the Gerty sand is in exact accord with extensive deposits which occur in the northern part of the Stonewall quadrangle, and which, because of their similarity with the Guertie sand, are correlated with that formation.

According to Hendricks,[134] known outcrops of the Gerty sand extend from the vicinity of Byars in northeastern Garvin County eastward across southern Pottawatomie, southern Seminole. northern Pontotoc, southern Hughes, northeastern Coal, Pittsburg and western Latimer Counties. Tanner,[135] working later in southern Seminole County, doubts whether any of the high terrace deposits in that county should be correlated with the Gerty as they do not lie at the same approximate level and are not similar to Gerty exposures in other adjoining counties.

The Gerty sand slopes gently eastward in an almost continuous belt. From northeastern Pontotoc County the old channel may be traced southeastward from Allen through Gerty, Non, and to the vicinity of Ashland in southwestern Pittsburg County. From Ashland, probably largely due to the presence of the Ashland anticline immediately to the south, the stream flowed east-northeast to a point just northwest of Haileyville in east-central Pittsburg County. From there the river swung northward, probably along the present course of Gaines Creek to the north boundary of Pittsburg County.[136] From that point eastward the river occupied the

133 Morgan, G. D., 1924. *Okla. Bureau of Geology, Bull.* 2, p. 103.
134 Hendricks, T. A., 1937. *U. S. Geol. Survey, Bull.* 874-A, pp. 26-33.
135 Tanner, William F., March, 1952. Personal communication.
136 Hendricks, T. A., 1937. *U. S. Geol. Survey, Bull.* 874-A, pp. 30-32.

same channel that it has today. For an excellent summary of the past history of the Canadian River in Pittsburg and surrounding counties refer to Hendricks' report on the McAlester District.[137]

In its exposure across Hughes County the Gerty typically contains gray to orange-brown, silty clay, coarse sand, and gravel near its base, and grades upward to medium to fine-grained sands and silty, multicolored clays near its top. (See Figure 12.) The gravels average one-fourth inch in diameter, are well-rounded, and are composed mostly of quartz, quartzite, silicified wood, chert, and jasper. Cobbles as much as 5 inches in their longest dimension are present. Much of the top of the deposit is covered with coarse to fine-grained white dune sand. This sand was derived from the Gerty, but has been transported some distance by wind action.

The probable source rocks of these coarse sands and gravels are Cretaceous and older rocks of the Rocky Mountain area or even, in part, the Tertiary deposits of the High Plains area. C. B. Reed studied the petrified wood collected by Hendricks and reported that part or all of it is probably of Cretaceous age.

The Gerty averages 35 feet thick across Hughes County. Typically, it reaches a maximum of about 40 feet in the central parts of its outcrop but thins rapidly toward its edges. The top of this deposit slopes southeastward at about 7 feet per mile across the county. Many exposures of the contact of the base of the Gerty and the truncated sandstones and shales of the Pennsylvanian formations are present. A good exposure of the Gerty resting on the eroded Stuart sandstone (IPst-1 of map) may be seen in the creek bed in the center of the north line of sec. 35, T. 4 N., R. 10 E.

Small springs are numerous around the outer edge of the Gerty and are discussed, along with the value and distribution of important gravel deposits, in the section on mineral resources.

The Canadian River occupied the old "Gerty" channel for some time, for several terrace deposits in Pittsburg County appear to be related to the level of the river when it followed its southern route.

137 Hendricks, T. A., 1937. *U. S. Geol. Survey, Bull.* 874-A, pp. 30-32.

According to Hendricks,[139] successive piracies in the Haileyville-McAlester district east of Hughes County diverted the channel north of that area into its present channel. During that time Little River flowed across the central part of Hughes County in the channel now occupied by the Canadian River. It was an important tributary to the Canadian River and joined it immediately south of Eufaula in south-central McIntosh County. It had a high gradient and was actively enlarging its drainage basin to the west. Too, it stood at a lower elevation north of Atwood (in T. 6 N., R. 9 E., Hughes County) than did the Canadian River which then flowed eastward some 10 miles to the south. An actively cutting tributary of Little River apparently branched off from that stream north of Atwood and worked its way southward, finally cutting into the channel of the Canadian River and diverting it northward into the channel of Little River which it now occupies in its course across Hughes County.

Flood Plain Deposits

Alluvial sands and clays occur in abundance along the larger streams in Hughes County. These deposits are mapped as "Qal" on the geologic map.

Though no specific rules may be applied in differentiating present alluvial deposits from low terrace deposits, certain generalizations may be made. Typically the alluvial deposits should: (1) be associated with present streams, (2) be subject to possible flooding during periods of high water, (3) present a rather flat upper surface, (4) not be highly dissected, (5) contain twigs, branches, or bits of organic matter, (6) be darker in color, and not typically red.

In dry periods the silts and sands of the larger alluvial deposits are piled into dunes along the flood plains by wind action.

It has been reported to the writer that the sands in the channel of the Canadian River just north of Calvin are more than 50 feet thick and grade into gravel near the base. The present channels of the large rivers of the county are so choked with sediments that the streams are forced to meander across their own deposits in times of low water.

139 Hendricks, T. A., 1937. *U. S. Geol. Survey, Bull.* 874-A, pp. 33-34.

SUBSURFACE STRATIGRAPHY

Introduction

Seldom does the surface geologist have the opportunity to project his study into the subsurface accurately. The conditions necessary for a combined surface and subsurface study of the various beds that crop out across Hughes County are ideal and are summarized below.

1. The beds dip gently to the northwest at about 70 feet per mile over most of the county.

2. Surface casing is seldom run to depths greater than 200 feet, therefore electric log records begin near the surface. In many wells surface casing extends to only 50 to 100 feet. Thus in all parts of the county it is not necessary to go more than 1 to 3 miles westward from the outcrop to obtain the thickness of a particular sandstone or shale unit in the subsurface.

3. The thicknesses of the beds are sufficiently uniform down dip for short distances to make these measurements more reliable than many of the surface measurements. This is due to the great uncertainties in using an assumed dip for a formation and projecting measurements over a wide belt of outcrop on the surface. A correction of about 1.7 feet per 100 feet of thickness must be subtracted from the thickness as determined by well logs to obtain the true thickness of a particular bed or zone, because the dip averages a little less than 1 degree over most of the area.

4. Many wells have been drilled in Hughes County and adjoining counties to the north and west, and electric logs are easily obtainable. Especially abundant are wells in the west-central, north-central, and northwest parts of the county.

In order to provide additional data to supplement that obtained by mapping the surface formations across Hughes County, a subsurface electric log cross-section was made across northern Hughes County in the direction of the regional dip of the surface beds. (See Plate II.) This cross section added another dimension to the surface study as each outcropping unit was traced into the subsurface to the northwest. It provided information as to the regional dip of the various beds, presence of certain unconformities, and thickness and character of the formations down dip, and enabled the writer to correlate surface beds with certain named subsurface units.

Preparation of Electric Log Cross Section

In preparing the cross section an arbitrary line parallel to the approximate regional dip of the surface beds was drawn through the northern part of the county so that it passed through or near areas where well logs were available. This line was continued on into northeastern Seminole County so that formations that crop out in extreme northwestern Hughes County could be checked against well logs to the northwest. The direction of regional dip is about N. 70° W. in northern Hughes County. (See index map showing location of wells included in the cross section, Plate II.)

Wells located nearest to this line were chosen for use in the cross section. When rapid facies changes were apparent, other logs were studied in the surrounding area to obtain the correct correlation.

Wells chosen for use in the section were numbered consecutively from southeast to northwest along the line of section. The wells were plotted in their true position on a large scale map of the area and then were projected parallel to the strike of the beds to their respective positions along the line of the cross section. Usually projections of less than 1 mile were necessary to obtain this alignment. The exact sandstone, shale, or limestone unit in which the well started was lettered for reference and was then carefully checked in the next and succeeding logs to the northwest to obtain a positive correlation. Probably the best example of this method is shown in wells No. 10 and 11 of the cross section. Well No. 10 starts in the top of the upper sandstone unit of the Seminole formation (IPsl-3 of map). A uniform projection of a sandstone unit in wells No. 14, 13, 12, and 11 to the northwest intersects exactly the elevation of the well on the surface. This correlation may be worked the opposite way by projecting the approximate regional dip of the top of the bed exposed at the surface to the northwest into the subsurface.

Discussion

The uppermost part of the Boggy formation and all overlying formations shown in the cross section are exposed in Hughes County or northeastern Seminole County. In many cases not only the formational boundaries, but also the individual units of each formation could be traced into the subsurface. Thus, most of the Des Moines series and the middle and lower parts of the Missouri series were first mapped on the surface and then traced into the subsurface in this study.

The Boggy formation contains the well known Red Fork sandstone, Inola limestone, and Bartlesville sandstone in the subsurface.

After mapping the Thurman, Stuart, and the lower part of the Senora formations on the surface, it was apparent that due to their irregular nature no exact correlation of these beds into the subsurface could be made. The Thurman and Stuart are not present in northeastern Oklahoma, as they are overlapped by the Senora formation in that direction.

The "Senora limestone", or "Henryetta coal", is perhaps the best subsurface marker that is present on the surface in Hughes County. This limestone is marked IPsn-1bl on the geologic map. For a description of this limestone see the section concerning the thickness and character of the Senora formation. This limestone occurs in both the surface and subsurface 146 to 177 feet below the Calvin sandstone. (See Table III for thicknesses of all Pennsylvanian units exposed in or under Hughes County.) The Senora formation has been traced carefully to the north on the surface and there correlated with the following well known subsurface units: Verdigris lime, Henryetta coal, Skinner sand, and the Pink lime. It is the lower Senora sandstone member that produces in the large Olympic pool in northwestern Hughes and southwestern Okfuskee counties.

TABLE III

THICKNESSES OF PENNSYLVANIAN UNITS IN SURFACE AND SUBSURFACE IN HUGHES COUNTY

Formations or units	Subsurface Thickness of Units in Northwestern Hughes County (Well No. 11)	Thickness From Wells Near Outcrop or From Measured Sections		Subsurface Thickness in Eastern Part of Co.	
			Well No.		Well No.
Coffeyville formation		298	13		
Seminole formation	307	307	11		
Missouri series		605			
Holdenville formation	185	200	10		
Wewoka formation	675	708	9		
Wetumka formation	56	115	8		
Calvin formation	279	350	5		
Upper Senora shale	146	177	4		
Lower Senora sandstone		350	*		
Stuart formation		290	*		
Thurman formation	982	245	*		
Boggy formation		180	**		
Savanna formation McAlester formation Hartshorne formation	368			840	1
Des Moines series	2,691	3,220	***		
Atoka formation	174			660(?)	1
Wapanucka shale	188			580(?)	1
Cromwell sandstone	82			190	1
Morrow series	270			770	1
Pennsylvanian system	3,442				

* Thickness from measured section in southeastern Hughes County.
** Only uppermost part exposed in southeastern Hughes County.
*** Total thickness of the Des Moines and Missouri series exposed in Hughes County.

The Calvin sandstone thins from about 350 feet on its outcrop in the northern part of the county to 279 feet in the northwest part of the county in the subsurface. Many petroleum geologists working the area have limited the "Calvin" of the subsurface to the lower part of the Calvin as mapped on the surface. This zone is a rather massive sandstone unit 146 feet thick in well No. 14, and its top and base are easily traceable in wells across the county. The top of this subsurface unit is marked "Top Lower Calvin" on

the cross section. A silty shale zone overlying this unit in the subsurface has been called "Wetumka" previously, but is here shown to lie in the Calvin sandstone. Another subsurface cross section was made across the Calvin-Holdenville area, and it shows that sandstone tongues at the base of the lower Calvin wedge out to the northwest. The Calvin formation has been carefully mapped to the north, and subsurface correlations there indicate that the Calvin is the approximate equivalent of the Oswego zone. In east-central Oklahoma many petroleum geologists correlate the Prue sand which occurs just below the Oswego lime with the Calvin sandstone. The Calvin produces in several fields in the western part of the county.

The Wetumka shale thins rapidly across Hughes County in the subsurface, though it retains its general character. It thins from 115 feet in well No. 8 near its outcrop to 56 feet in well No. 11 in the northwest part of the county. Correlations indicate that the Wetumka is the approximate equivalent of the upper part of the Oswego lime zone of the subsurface in northeastern Oklahoma.

Each of the four main sandstone units of the Wewoka formation was traced across the county in the subsurface. The formation thins from 708 feet in well No. 9 near its outcrop to 675 feet in well No. 11 in the northwest part of the county. Sandstone tongues split off from the base of the second and third sandstone units and thin and disappear down dip. The Wewoka formation has been traced on the surface into northeastern Oklahoma, and there it has been correlated with the subsurface Lenapah lime—Big Lime section.

The thin limestone and sandstone units of the Holdenville formation could not be traced into the subsurface. The formation thins from 200 feet in well No. 10 near its outcrop to 185 feet in well No. 11 to the northwest.

The Seminole formation also is thinner to the west, being 307 feet thick in well No. 11 near its outcrop and only 270 feet thick in well No. 14 to the northwest in Seminole County.

The Coffeyville formation is 298 feet thick in well No. 13 near its outcrop in the northwest part of the county. The two sandstone units mapped on the surface are easily traceable into the subsurface. According to Ries,[140] the "Checkerboard" limestone of the subsurface is in the upper part of the Seminole formation. The Checkerboard was not identified at the surface in Hughes County.

Paleogeographic Setting

In early Pennsylvanian (Springer) time the Ouachita trough, lying south of the more recent McAlester basin of east-central Oklahoma, received a thick sequence of clastic sediments. Rocks of Springer age are not present under Hughes County, owing to the thinning and convergence of these rocks out of the Ouachita trough. Sedimentation continued at a rapid rate in the Ouachita trough on into Morrow time, and rocks of this age overlapped the underlying Springer to the north and west. During Morrow time the Cromwell sandstone, Union Valley limestone, Wapanucka shale, Wapanucka lime, and "post Wapanucka" shale were deposited over the Hughes County area on the eroded Caney (Mississippian) shale.

Following the deposition of the Morrow sequence, there was a period of uplift in this and other parts of the Mid-Continent region. According to Dott,[142] this orogeny was responsible for the Hunton-Tishomingo uplift immediately to the south and west of Hughes County and several other important structural features of the southern part of the Mid-Continent region. The rock strata were tilted gently eastward and erosion reduced the relief of the area to that of an almost flat-lying plain. It was over this eroded surface that the sands and shales of the Atoka formation were deposited.

It was in early Atoka time that the McAlester basin which borders Hughes County on the southeast began its rapid subsidence and the Ouachita trough stopped its rapid downwarping.

The unconformity at the base of the Atoka across Hughes County is well shown on the electric log cross section (Plate II), though the unconformity is not definitely recognizable in the extreme eastern and southeastern parts of the county. Especially

140 Ries, E. R., 1951, In press. *Okla. Geol. Survey, Bull.* 71.
142 Dott, R. H., 1941. *Amer. Assoc. of Petroleum Geologists, Bull.*, vol. 25, pp. 1669-1670.

noteworthy is the truncation of the upturned Wapanucka lime in the eastern part of the county. The Wapanucka lime is not present northwest of well No. 6 of the cross section in the north-central part of the county.

In the east and southeast parts of the county the Atoka thickens rapidly and change facies to argillaceous sandstones and silty shales. The thickness of the Atoka in Well No. 1 in the east-central part of the county is about 660 feet, but to the southeast in southwest Pittsburg County Hendricks[143] reported the formation to be over 5,400 feet thick. This thickening is where the formation passes from the more stable shelf area of west-central and south-eastern Hughes County into the McAlester basin.

The unconformity at the base of the Atoka cuts out 119 feet of section between well No. 6 in the north-central part of the county and well No. 13 in northeastern Seminole County. This is a distance of about 14 miles and a truncation of about 8 feet per mile.

As the Atoka formation onlapped older beds to the west across this area, irregular sand bodies were deposited along and above the zone of unconformity. These sandstones are referred to by subsurface geologists as the "Gilcrease zone." The sands are lenticular and differ in age from place to place.

Following this onlap of Atokan beds to the northwest, another uplift tilted the beds eastward and exposed the upper beds of the Atoka to erosion over this area. The succeeding Hartshorne sandstone truncates the upper part of the Atoka beds across the north-central and northwestern parts of Hughes County. According to Ries,[144] this unconformity cuts out the entire Atoka section and the Hartshorne sandstone rests on Mississippian rocks in north-western Okfuskee County to the north. In Hughes County this unconformity cuts out 350 feet of section between well No. 4 and well No. 13 of the cross section. This is a distance of about 17.5 miles and a rate of truncation of 20 feet per mile.

143 Hendricks, T. A., 1939. *U. S. Geol. Survey, Bull.* 874-D, p. 265.
144 Ries, E. R., 1951. In press. *Okla. Geol. Survey, Bull.* 71.

Deposition apparently continued almost uninterruptedly through lower and middle Des Moines time in this area, though the southern shoreline of the sea covering this area migrated north and west toward Hughes County.

The older beds of the Des Moines series, which are present only in the subsurface in Hughes County, thin toward the west. Several beds or zones may be traced across the county without difficulty. The Booch sandstone and the "Brown lime" zone of Savanna-McAlester age are easily traceable across the area. The Inola limestone of lower Boggy age is a good subsurface marker across the county. The irregular lensing of the sandstones across Hughes County, their contained floras and faunas, and the intertonguing of the sandstones with shales in many places are but a few of the characteristics which indicate that the beds were deposited near the shoreline as it gradually shifted to the north and west. Minor downward pulsations, indicated by thick, intervening shales, interrupted migration of the shoreline. The sandstone tongues described in the section on the Calvin sandstone and other formations indicate a deltaic type of environment.

STRUCTURE

Structurally the beds cropping out in Hughes County are a part of the Prairie Plains homocline, a broad structure that dips about 1 degree to the west.

The strike of the older beds in the south and southeast parts of the county is east to northeast, but the strike of the younger beds is toward the north in the central and northern parts of the county. Dips average 90 feet per mile and range from north-northwest in the southern part of the county to west-northwest in the central and northern parts. The rather abrupt change in the strike of the beds which occurs across southern Hughes County reflects the repeated uplifts in the Arbuckle Mountain area that occurred during and subsequent to the deposition of the beds exposed in this area.

There are several anticlines in Hughes County that have small amounts of closure, although plane table mapping is necessary to outline these structures accurately. Much detailed structural mapping has been done by oil companies in the area, but none of this work is available to the general public.

There are numerous faults in the county. These are normal faults and have an average throw of about 30 feet. The faults average less than 2 miles in length, and most of them could not be traced confidently more than a mile. Most of the faults trend northwest almost at right angles to the strike of the formations. Several of the faults form an en-echelon pattern in the central part of the county. This belt roughly parallels the strike of the Wewoka formation in that area. A second trend of faults, not as important as the first, is to the northeast. These faults roughly parallel the strike of the beds which they cut and are approximately perpendicular to the main trend of faults in the county.

The downthrown side of most of the northwest-trending faults is to the southwest. With the regional dip to the northwest, normal erosion after faulting offsets the upthrown or northeast side to the northwest.

Many of the faults occur in parallel or converging pairs. The small blocks limited by these faults are either tilted irregularly with one side upthrown and the other downthrown or occur as small grabens. A small tilted block is well-illustrated in the southeast corner of T. 9 N., R. 8 E., and there is a small graben 1 mile east of Holdenville in secs. 16 and 17, T. 7 N., R. 9 E.

MINERAL RESOURCES OF HUGHES COUNTY

OIL AND GAS

Some 700 wells produce annually over two and a half million barrels of oil from Hughes County.[145] Forty-six oil and gas fields, many producing from several pay zones, are scattered across the central and northern parts of the county. Table IV contains a list of the oil and gas fields in the county.

Oil exploration in the county is continuing at a rather even rate. An average of 11 wildcats have been drilled annually for the past 3 years. One hundred thirty-four wells were drilled in 1952. Of this total 55 were oil wells, 15 were gas wells, and 64 were dry holes. Over 26,000 acres of undeveloped but potential oil land were under lease by major oil companies in 1952, and several thousand acres were held by small operators.[146]

TABLE IV

OIL AND GAS FIELDS OF HUGHES COUNTY, OKLAHOMA

1. Adams District	17. Gilcrease	33. Olympic
2. Alabama	18. Gilcrease, S. W.	34. Papoose
3. Alabama, N. W.	19. Greasy Creek	35. Pecan Grove
4. Alabama, S. E.	20. Grief Creek	36. Sasakwa, S. E.
5. Allen	21. Hawkins, N. W.	37. Spaulding S. W.
6. Atwood, North	22. Hilltop	38. Spaulding Townsite
7. Benjamin	23. Holdenville, East	39. Spaulding W.
8. Calvin	24. Holdenville, West	40. Wetumka
9. Diamond	25. Holdenville, North	41. Wetumka, East
10. Dustin	26. Horn's Corner	42. Wetumka, South
11. Dustin, S. E.	27. Horn's Corner, North	43. Wetumka, S. E.
12. Fish	28. Jefferson	44. Wewoka
13. Fish, East	29. Lamar	45. Yeager
14. Fream	30. Lamar, East	46. Yeager, North
15. Fuhrman	31. Long	
16. Fuhrman, North	32. Long, North	

Zones of production range in age from Ordovician (Wilcox) to middle Pennsylvanian (Calvin) in age. The most important formations, together with the average depth to the top of the pay zone in the northwestern part of the county, are listed in Table V.

145 "'Oil and Gas Field Development in the United States and Canada". 1953. Review of 1952, *National Oil Scouts and Landmen's Association*, Yearbook, vol. 23, pp. 504-525.

146 "Oil and Gas Field Development in the United States and Canada, 1953," Review of 1952. *National Oil Scouts and Landmen's Association*, Yearbook, vol. 23, p. 573.

TABLE V

IMPORTANT OIL AND GAS PRODUCING ZONES IN HUGHES COUNTY, OKLAHOMA

Formation	Age	Average Depth to Pay Zone
Calvin sand	upper-middle Pennsylvanian	1100 feet
Senora sand	upper-middle Pennsylvanian	1700 feet
Booch sand	upper-middle Pennsylvanian (McAlester)	2900 feet
Gilcrease sand	lower middle-Pennsylvanian (Atoka)	3175 feet
Cromwell sand	lower Pennsylvanian (Morrow)	3350 feet
Hunton lime	Silurian-Devonian	3875 feet
"Wilcox" sand	Ordovician (Simpson Group)	4180 feet

The conditions responsible for the accumulation of oil and gas in Hughes County are many. Production is obtained from simple anticlinal structures, faulted anticlines, and a variety of stratigraphic traps. A few examples will serve to illustrate the various types. The Fuhrman field produces from a simple anticlinal structure. The Yeager field produces from a faulted anticline. The Grief Creek field is a good example of one variety of stratigraphic trap. In this field a trap is formed by the abrupt wedging out of one of the Booch sands. Several fields produce from sands along truncated surfaces. The accumulation of oil in almost every field producing from the Gilcrease sands is controlled by the lensing nature of these sands.

The largest field located entirely within the county is Holdenville, West. This field produced in 1952 over 236,000 barrels of oil from four major zones (Calvin, Booch, Gilcrease and Wilcox). There are 143 wells in the field producing from 4,130 proven acres. Total cumulative production is 7,699,962 barrels of oil.[147]

147 *Ibid.*

The Hawkins, N. W. field is a large field located southwest of Spaulding in western Hughes County. In 1951, 74 wells produced 58,600 barrels of oil, mostly from the Booch sand. By 1952, production had declined to 55,600 barrels from 74 wells.

Other important fields located entirely within the county are Grief Creek, Adams District, Alabama, Benjamin, Horn's Corner, and fields in the Spaulding area. These fields average about 90,000 barrels of oil per year.

Two important fields, the Olympic and the Papoose, are partly in northern Hughes County and extend into Okfuskee County. The Papoose field is one of the oldest in the area, having been discovered in 1924. It has produced more than 23 million barrels of oil and is now producing about 74,000 barrels annually. The production is mostly from the Cromwell sand. The Olympic field was discovered in 1934 and has produced 18,284,466 barrels of oil since its discovery. Production is largely from shallow Senora sands (1700 feet) and averages about 300,000 barrels annually.

Two important fields extend from Seminole County eastward into Hughes County. The Wewoka field, discovered in 1923, produces from the Wilcox, Hunton, Cromwell, and Booch zones. However, the small part of the field extending into Hughes County produces largely from the Wilcox. The field has produced over 37 million barrels of oil since its discovery and produced 205,800 barrels in 1952. West of the large Holdenville, West field and mostly in Seminole County is the important Fish field. It produces from the Booch, Gilcrease, Cromwell, and Wilcox zones.

The most recent oil discovery of major importance in the county is the new Booch and Hartshorne sand development being carried out to the west of the Grief Creek field. New production has spread rapidly westward across sections 15, 16, 17, and 8, T. 7 N., R. 9 E. Several wells are now being drilled in the city limits. The lower Booch is the main producing sand, and it occurs at an average depth of 3,050 feet. The Hartshorne sand is usually topped about 50 feet below the base of the lower Booch sand in the area. The oil is high gravity (38°) and the sands yield readily to fracturing. Flow rates for potentials of over 20 barrels per hour are common.

Oil production is essentially limited to west-central, north-central and northwest parts of the county. This is along the eastern edge of the platform or "shelf" area of east-central Oklahoma. There was, in effect, a hinge line between the rapidly subsiding McAlester basin to the southeast and the more stable platform area to the northwest during lower and lower-middle Pennsylvanian time. The few fields in the southeastern and eastern parts of the county are largely gas producers. The Hilltop, Calvin, Lamar, Dustin, and Alabama, S. E. fields all fall in this category.

Volcanic Ash

There is a large deposit of volcanic ash at Dustin in northeastern Hughes County. (See Plate IV.) At the present time one mine is being worked in the southeast part of sec. 4, T. 9 N., R. 12 E. (See Figure 13.) There is a small strip mine in the center of the east line of the same section, and it is worked occasionally. Production from both mines averages less than one ton per week.

The ash is used in sweeping compounds, as a filler in paints, and as an abrasive in the manufacture of cleansing and scouring compounds and hand soaps. Recently the ash has been used in some concrete mixes to improve the uniformity and workability and to make the final products water proof. Burwell[148] reported experiments indicating that cellular products may be made from this volcanic ash.

The thickness of the deposit ranges from a few inches in a road cut in the NW cor. sec. 1, T. 9 N., R. 12 E. to about 20 feet in the SE cor. of sec. 4, T. 9 N., R. 12 E. Average thickness of the overburden is negligible.

The deposit is massive and was probably carried to the present site by wind and deposited by slope wash. In Hughes County, as in Okfuskee County immediately to the north, the ash deposits are associated with high terrace clay and sand deposits on a broad flat plain. This plain possibly represents the site of an abandoned southward meander of the North Canadian River. Ham[149] analyzed

148 Burwell, A. L., and Ham, W. E., 1949. *Okla. Geol. Survey, Circular No. 27*, pp. 50-51.

149 Burwell, A. L., and Ham, W. E., 1949. *Okla. Geol. Survey, Circular* No. 27, pp. 65-66.

two samples of volcanic ash from the Dustin area for mineral content. He reported the samples to be relatively pure, averaging over 90 percent volcanic glass shards. Accessory minerals reported are quartz, orthoclase feldspar, clay aggregates, and mica in small amounts.

Water Resources

Surface Water

The larger cities in the county, Holdenville, Wetumka, and Dustin, obtain their water supply from surface impoundment reservoirs, but ground water supplies that are ample for less populated areas are available at shallow depths. Lake Holdenville, 4 miles southeast of Holdenville, is the largest reservoir in the county, having a capacity of 3.2 billion gallons. Lake Wetumka, 4 miles north of that city, has a capacity of 600 million gallons. Lake Dustin is fed partly by springs and has a capacity of 3.2 million gallons.

The shales of many of the formations that crop out across the county are sufficiently impermeable to allow construction of small reservoirs for farm use.

Subsurface Water

Almost all the sandstones that crop out across Hughes County serve as shallow aquifers down dip to the west of their outcrop. Generally, supplies of ground water sufficient for farms are easily obtainable at shallow depths. Abundant supplies are obtained from wells drilled into the thick alluvial or high terrace sands and gravels at many places in the county.

There are many small springs in the county, especially in the southern part around the edges of the thick Gerty sand. These last are contact springs resulting from seepage of meteoric water down through the permeable sand and gravel until this zone is saturated. The old stream which crossed this area truncated slightly tilted beds of shale and sandstone, all less permeable than the overlying sand blanket, thus limiting ground water in its

Figure 12. Typical weathering of silty clay near base of Gerty sand, small creek bank in the NE¼ sec. 26, T. 4 N., R. 10 E.

Figure 13. Volcanic ash mine near Dustin, N½ SE¼ sec. 4, T. 9 N., R. 12 E.

downward migration. Surplus water then migrates laterally to the edges of the sand blanket and emerges at the surface as small seeps or springs. Around the fringes of the Gerty sand vegetation is more luxuriant than in adjacent areas. Heavy grasses and shrubs thrive and there are many watering holes for livestock.

Sand and Gravel

There is an abundant supply of sand and gravel in Hughes County. Pits have operated near Yeager, Wetumka, and Dustin in the northern part of the county and near Gerty and Non in the southern part. (See Plate IV.)

For general construction purposes sand is considered to range in size from one-fourth inch down to material coarser than 200 mesh, and gravel to range from one-fourth inch to 3½ inches in diameter.

The sands in Hughes county are relatively impure, containing clay and other minerals. They are nevertheless valuable for use chiefly in concrete work in the county. Abundant quantities of sand, generally associated with clay and gravel, are found along the flood plains of the larger streams and along an abandoned stream channel which crosses the south part of the county. (See Plate I. Qal and Qt deposits.)

Production of sand is scattered over the county, but gravel production is concentrated in three general areas:

Gerty-Non Area.—This belt of gravel, clay, and sand is a part of the Gerty sand. It is characterized by low relief, the presence of sand dunes, and the small amount of vegetation over much of the area. Sand supplies are readily available over the area under little or no soil overburden. In many places sandy red and yellow clays are interstratified with the sand deposits.

The gravel deposits are easily located by following the edge of the outcrop of the Gerty. The presence of contact springs bordering the deposit and the presence of heavy grasses just off of the deposit make this easy to do. Generally speaking, the gravel is typically at or near the base of the Gerty and rests directly upon the truncated Pennsylvanian formations which underlie the area. The gravel is not exposed in the central part of the area except where streams have removed the thick sand cover. In cross section the deposits of the Gerty are flat across the top and convex downward across the bottom; they are thickest in the central portions and thin rapidly toward the edges.

More than 70 percent of the gravel worked in the county comes from this area.

Yeager-Wewoka Creek Area:—Much sand and gravel has been removed from high terrace deposits associated with Wewoka Creek northwest of Yeager. In general the gravel of this area is of smaller diameter than that of other areas in the county. The main deposits are in the SW¼ sec. 9, T. 8 N., R. 9 E., but there are other deposits in a broad belt bordering the north side of Wewoka Creek in the area. Average thickness of the workable gravel is about 10 feet.

Wetumka-North Canadian River Area:—Terrace deposits of clay, sand and gravel cover a wide area in the immediate vicinity of Wetumka. The most favorable sources of gravel appear to be south of Wetumka in the W½ of sec. 34, T. 9 N., R. 10 E. Gravel deposits have been reported on the lower flood plain of the North Canadian River in secs. 2 and 3, T. 9 N., R. 10 E., but these sites were not visited.

The following table gives the results of mechanical analyses of 5 samples of sand and gravel taken from selected areas discussed above.[150]

[150] "The Natural Resources of Hughes County", 1948. *Engineering Experiment Station, Okla. A. and M. College,* Research Project No. 1, Stillwater, p. 24.

TABLE VI

SIEVE ANALYSES OF SAND AND GRAVEL IN HUGHES COUNTY, OKLAHOMA

Location	Thickness	Material	Analysis	Amount and Usage
W¼ Sec. 9 T8N R9E	More than 6 feet	Sand	Screen Analysis 14— 0.32% 48—18.24% 100—72.66%	Quantity-large; Concrete and Surfacing
E½ Sec. 33 T4N R10E	10 feet	Sand	Screen Analysis 14— 0.14% 48—53.86% 100—93.18%	Quantity-large; Surfacing
Sec. 8, 9 T8N R9E	10 to 20 feet	Gravel	Passing 2"—100.00% 1"— 95.38% ½"— 80.62% ¼"— 52.26%	Quantity-large; Surfacing
E½ Sec. 35 T4N R10E	10 feet	Gravel	Passing 2"—100.00% 1"— 91.76% ½"— 62.79% ¼"— 46.17%	Quantity-large; Surfacing
NW cor. Sec. 31 T4N R10E	3 to 7 feet	Gravel	Passing 2"—100.00% 1"— 79.87% ½"— 48.26% ¼"— 34.72%	Quantity-large; Concrete and Surfacing

COAL

Only one exposure of a coal bed that has been worked is known in Hughes County. This exposure is in the N½ SW¼ sec. 31, T. 9 N., R. 12 E. and is covered by 10 to 15 feet of overburden. The writer did not see this coal because of flooding of the shallow mine shaft, but it is reported to be about 12 inches thick. This coal lies near the top of the lower sandstone member of the Senora formation (IPsn-1c of map). A thin coal has been reported at this approximate horizon in wells drilled to the west of this area. Electric logs indicate that there is probably a thin coal bed at about the same position as the "Senora limestone." This limestone crops out across northeastern Hughes County, but no coal was seen associated with it.

Clay and Shale

Several of the formations which crop across Hughes County contain shale which is suitable for use in the manufacture of various clay products. According to tests conducted by Sheerar and Redfield,[151] many of the shales of the Wewoka and Holdenville formations are suitable for the manufacture of common brick. Certain shales of these formations are suitable for face brick, hollow tile, and sewer pipe.

Limestone

The only limestone of possible economic value in the county is the "Senora limestone" which is exposed at widely separated places in the northeast part of the county. (See Plate I, bed marked IPsn-1bl) This limestone is locally called "Blue granite" because of its hardness and dull blue-gray color. It is about 45 feet below the top of the lower sandstone member of the Senora formation and extends in the subsurface to the west across the county. Petroleum geologists use this lime as a marker in the subsurface.

The limestone is massive, dense, blue-gray, medium-crystalline, fossiliferous and contains many sandy lenses. Its average thickness is 3 feet. A quarry has been worked in the southeast corner of the northeast corner of sec. 27, T. 9 N., R. 12 E., and another possible quarry site is 1.2 miles south in a road cut.

Building Stone

Few of the sandstones exposed in the county are suitable for first quality building stone. In general the sandstones are friable and soft. Even and thin-bedding is not common in these sandstones. There are zones near the base of the Wewoka sandstone in the northeast corner of sec. 6, T. 9 N., R. 11 E. where sandstones have been quarried for building stone.

151 Sheerar, L. F., and Redfield, J. S., 1932. *Okla. A. and M. College, Div. Engineering Publication*, Vol. 3, No. 5, pp. 143-145.

SUMMARY

1. Sixty-five zones of sandstone, conglomerate, shale, and limestone, as well as all formational contacts, were mapped in Hughes County and their distribution shown on the geologic map.

2. The course of the streams across many of the sandstone units is determined by areas of facies changes. In these areas the beds are less resistant to erosion and the streams tended to cut across at these places. This explains why correlations are difficult across some areas that are covered by stream alluvium or terrace deposits.

3. Wewoka Creek and Little River show evidence of having played a much more important role in the drainage of the county in the past. Broad flood plains and extensive terrace deposits indicate a larger size and extent for these streams in the past.

4. Muddy Boggy, Sand, Panther, and Caney Boggy Creeks drain the south part of the county and flow southward into the Red River. They have high gradients and are actively enlarging their drainage basins to the north toward the Canadian River.

5. The Canadian River once flowed southeastward from the vicinity of Allen across southern Hughes, northeastern Coal, and central Pittsburg Counties. The Gerty sand of Hughes and adjoining counties roughly outlines the past course of this stream. An abrupt change of course from southeast to northeast just southeast of Hughes County was apparently caused by the presence of the Ashland anticline in northeastern Coal County. Little River was an important tributary to the Canadian River at that time and flowed across Hughes and northern Pittsburg Counties in the channel now occupied by the Canadian River. A tributary of Little River worked its way southward from the vicinity of Atwood and cut into the channel of the Canadian River, diverting it northward into its present channel.

6. Most of the soils in Hughes County are not fully matured, and a direct correlation of the geologic formations which furnish the parent material and the resulting soil types may be made. The better soils (Cherokee Prairie) are derived largely from the

shales and sandstones that crop out northwest of the contact between the Wetumka shale and the Calvin sandstone. These soils provide excellent croplands and pasturage, and most of the population of the county is concentrated in this area. The poorer soils of the county (Cross Timbers) are derived largely from sandy outcrops of the Calvin, Senora, Stuart, and Thurman formations which occur mainly in the east-central and southern parts of the county. Density of population and farm size in this area are appreciably lower than the average for the county.

7. Coarse chert conglomerates are common in the Thurman and younger formations, and the shale units separating the successive sandstones are thinner than in the Boggy and older formations.

8. Coarse chert conglomerates do not occur in Hughes County north of a northwest-trending line through the central part of the county. These conglomerates typically do not thicken toward the south but grade laterally to finer-grained sediments both to the northeast and the southwest. This indicates a southeast or possibly a southern source of these gravels.

9. There are numerous sandstone and siltstone tongues branching off at the base of the Calvin sandstone. These tongues wedge out to the northeast along the strike of the beds and to the northwest in the subsurface. The presence of these tongues and certain other physical properties of this unit indicate that deposition was deltaic and that the streams that deposited the tongues shifted irregularly across its surface.

10. The Homer and the Sasakwa limestones of the Holdenville formation are not present north of the vicinity of Spaulding in the west-central part of the county. The limestone on the fair grounds at Holdenville is not the Homer limestone but is a thin limestone near the base of the Holdenville formation.

11. Surface mapping indicates that the contact between the Des Moines and Missouri series is conformable in Hughes County.

12. The Coffeyville formation of northeastern Oklahoma and southeastern Kansas was traced southwest across Hughes County and found to be equivalent of the lower part of the Francis formation as mapped in the Stonewall quadrangle.

13. The Checkerboard limestone which lies immediately below the Coffeyville formation in Okfuskee County to the north is not present in Hughes County.

14. The DeNay limestone, basal unit of the Francis formation as mapped to the southwest of Hughes County, is absent north of the west-central part of the county. This limestone occupies the same stratigraphic position as does the Checkerboard limestone to the north and is considered to be its equivalent.

15. Though most of the fossils in the Pennsylvanian rocks in Hughes County are long ranging, the forms *Mesolobus mesolobus*, *"Marginifera" muricatina*, and *Delocrinus granulosus* appear to be limited to rocks of the Des Moines series.

16. The southeast edge of the central Oklahoma uplift or platform, a subsurface feature, trends northeastward across the central and northeastern parts of Hughes County. The McAlester basin lies to the south and includes the southeastern part of the county.

17. The oldest Pennsylvanian rocks present beneath the county are of Morrowan age. The Morrowan and the overlying Atoka rocks are very thick to the southeast of Hughes County but are much thinner across central Hughes County as they pass northwest out of the McAlester basin.

18. An important unconformity is present at the base of the Atoka series in the subsurface of this area. The upper part of the Wapanucka shale is truncated, and the Wapanucka lime is not present northwest of the north-central part of the county.

19. The Des Moines series overlies the Atoka unconformably in the subsurface in this area. This unconformity cuts out the entire Atoka section to the northwest of Hughes County.

20. Formational contacts and many of the individual units of the formations that crop out in Hughes County can be traced accurately into the subsurface to the northwest. Changes in thickness and character of the units may be interpreted. The exposed formations thin to the northwest in the subsurface and many of them grade to shale.

21. The "Senora limestone" of the subsurface crops out across northeastern and east-central Hughes County. This limestone is near the top of the lower Senora sandstone unit of the surface.

22. The oil produced at about 1,700 feet in the Olympic field of northwestern Hughes and southern Okfuskee Counties is from sandstones which occur in the top of the lower Senora sandstone member of the surface.

23. The "Calvin sandstone" which produces oil in the subsurface of northwestern Hughes, northern Seminole, and Okfuskee Counties is equivalent to only the lower part of the Calvin sandstone of the surface. The "Wetumka shale" of the subsurface is a silty shale zone within the Calvin formation of the surface.

24. Oil fields in Hughes County are limited to the area north and west of the outcrop of the lower part of the Calvin sandstone. This belt trends northeast across the county and roughly coincides with the southeastern edge of the central Oklahoma uplift. Gas production is obtained to the east of this zone, however. The change from basin to shelf environment occurs in this "hinge zone," and the occurrence of oil and gas is directly affected by the change.

25. Deposits of volcanic ash in the Dustin area are associated with high terrace deposits of the North Canadian River and are probably of Quaternary age.

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APPENDIX A

REGISTER OF FOSSIL LOCALITIES

Station 1. Boggy formation (IPbg of map) in W½ SE¼ sec. 26, T. 4 N., R. 11 E.

Station 2. Boggy formation (IPbg of map) about 50 feet below base of lower Thurman sandstone. About 500 feet SW of NE cor. sec. 35, T. 4 N., R. 11 E.

Station 3. Thurman formation (IPth of map) in road cut 0.45 miles south of NE cor. sec. 15, T. 4 N., R. 11 E. Just below IPth-1 sandstone.

Station 4. Senora formation (IPsn-1a of map) in and just north of road cut 0.45 mile east of SW cor. sec. 35, T. 9 N., R. 12 E.

Station 5. Stuart formation (IPst of map) in and just west of road cut 0.2 mile north of center of south line of sec. 33. T. 4 N., R. 10 E. Just below IPst-1.

Station 6. Boggy formation (IPbg of map) along small creek just south of center of sec. 26, T. 4 N., R. 11 E.

Station 7. Stuart formation (IPst of map) around base of small outlier of IPst-2 sandstone 0.3 mile north of SE cor. sec. 23, T. 5 N., R. 11 E.

Station 8. Boggy formation (IPbg of map) below massive Thurman sandstone (IPth-1 of map) in NW cor. sec. 25, T. 4 N., R. 11 E.

Station 9. Senora formation (IPsn-2 of map) near base of Calvin sandstone just west of the center of the south line of sec. 15, T. 7 N., R. 11 E.

Station 10. Thurman formation (IPth of map) in and just north of road cut 0.5 mile west of SE cor. sec. 13, T. 4 N., R. 11 E.

Station 11. Thurman formation (IPth-4 of map) in road cut 0.25 mile south of NW cor. sec. 6, T. 3 N., R. 11 E., Coal County.

Station 12. Stuart formation (IPst of map) along small creek in SE cor. sec. 35, T. 5 N., R. 11 E. Below IPst-1 sandstone.

Station 13. Boggy formation (IPbg of map) along north line of sec. 2, T. 3 N., R. 11 E., Coal County. About 60 feet below base of lower Thurman sandstone (IPth-1 of map).

Station 14. Senora formation (IPsn of map) in road cut 0.3 mile south of NE cor. sec. 34, T. 9 N., R. 12 E.

Station 16. Senora formation (IPsn-1a of map) about 500 feet south of a point in road 0.3 mile east of NW cor. sec. 31, T. 8 N., R. 12 E.

Station 17. Senora formation (IPsn-1a of map) in road cut 0.2 mile north of SE cor. sec. 14, T. 9 N., R. 12 E.

Station 18. Stuart formation (IPst of map) in road cut at bend in center of east line of sec. 26, T. 4 N., R. 9 E.

Station 19. Stuart formation (IPst of map) along small creek in SW cor. sec. 12, T. 5 N., R. 11 E. Below IPsn-1 sandstone.

Station 20. Boggy formation (IPbg of map) in small creek 300 feet west of road in center of east line of sec. 26, T. 4 N., R. 11 E.

Station 22. Calvin formation (IPcv-1 of map) in road cut just south of the center of sec. 28., T. 6 N., R. 10 E.

Station 23. Calvin formation (IPcv-1 of map) in road cut 0.35 mile east of SW cor. sec. 13, T. 7 N., R. 10 E.

Station 25. Stuart formation (IPst of map) along small creek just south of center of sec. 33, T. 4 N., R. 9 E.

Station 28. Thurman formation (IPth of map) just below IPth-3 sandstone in road cut 0.25 mile east of SW cor. sec. 28, T. 4 N., R. 11 E.

Station 29. Stuart formation (IPst of map) around base of outlier of IPst-1 sandstone just north of center of SE¼ sec. 14, T. 5 N., R. 11 E.

Station 30. Senora formation (IPsn-2 of map) just below Calvin sandstone in NE cor. sec. 11, T. 4 N., R. 9 E.

Station 31. Wetumka formation (IPwt of map) beneath scarp of lower Wewoka sandstone west of road about 0.5 mile south of NE cor. sec. 3, T. 5 N., R. 9 E.

Station 32. Thurman formation (IPth of map) in and just west of road cut 0.4 mile south of NE cor. sec. 12, T. 4 N., R. 11 E.

Station 33. Senora formation (IPsn-2 of map) in small creek bed in NW cor. sec. 23, T. 6 N., R. 10 E.

Station 34. Wewoka formation (IPwk of map) just north of road cut 0.4 mile west of SE cor. sec. 30, T. 7 N., R. 9 E.

Station 35. Wewoka formation (IPwk of map) just below sandstone unit (IPwk-3 of map) in NW cor. sec. 21, T. 7 N., R. 9 E.

Station 36. Wewoka formation (IPwk of map) in road cut 0.35 mile north of SE cor. sec. 15, T. 7 N., R. 9 E.

Station 37. Senora formation (IPsn-2 of map) around base of outlier of Calvin sandstone just south of center of north line of sec. 15, T. 4 N., R. 9 E.

Station 38. Wewoka formation (IPwk of map) in road cut 0.4 mile west of SE cor. sec. 18, T. 8 N., R. 10 E.

Station 39. Senora formation (IPsn-2 of map) just west of center of west line of sec. 12, T. 6 N., R. 10 E.

Station 41. Stuart formation (IPst of map) in SE¼ sec. 34, T. 5 N., R. 11 E., just north of bend in road at NE cor. sec. 3, T. 4 N., R. 11 E. Below base IPst-1 sandstone.

Station 42. Wetumka formation (IPwk of map) just south of bend in road in NW cor. sec. 12, T. 6 N., R. 9 E.

Station 44. Senora formation (IPsn-2 of map) about 60 to 80 feet below base of Calvin sandstone in NE cor. sec. 3, T. 7 N., R. 11 E.

Station 45. Calvin formation (IPcv-3 of map) just east of road cut in center of west line of sec. 12, T. 8 N., R. 10 E.

Station 47. Thurman formation (IPth of map) just below IPth-4 sandstone 500 feet SE of road corner 0.25 mile north of SE cor. sec. 16, T. 4 N., R. 11 E.

Station 50. Wewoka formation (IPwk of map) in road cut 0.45 mile east of SW cor. sec. 13, T. 7 N., R. 9 E.

Station 51. Holdenville formation (IPhd-3 of map) about 50 feet below base of lower Seminole sandstone (IPsl-1 of map) in SW cor. sec. 4, T. 6 N., R. 8 E.

Station 54. Wewoka formation (IPwk of map) in road cut and in small creek north of road in center of north line of sec. 17, T. 7 N., R. 9 E.

Station 55. Wetumka formation (IPwt of map) in scarp below Lower Wewoka sandstone in SE corner of sec. 5, T. 7 N., R. 10 E.

Station 56. Wewoka formation (IPwk of map) in road cut 0.15 mile south of NW corner of sec. 32, T. 8 N., R. 10 E.

Station 57. Wewoka formation (IPwk-4 of map) in road cut in SW corner of sec. 5, T. 9 N., R. 10 E.

Station 60. Wetumka formation (IPwt of map) just west of road cut 0.4 mile north of center of south line of sec. 26, T. 9 N., R. 10 E.

Station 61. Holdenville formation (IPhd-1 of map) near base of small outlier of IPhd-2a sandstone in NE corner of sec. 3, T. 6 N., R. 8 E.

Station 62. Seminole formation (IPsl of map) exposed 0.2 mile west of SE corner of sec. 13, T. 9 N., R. 8 E. in road cut.

Station 63. Holdenville formation (IPhd-1 of map) along small creek in NE corner of sec. 10, T. 6 N., R. 8 E.

Station 64. Holdenville formation (IPhd-3 of map) in road cut 0.2 mile east of SW corner of sec. 14, T. 7 N., R. 8 E.

Station 66. Wewoka formation (IPwk of map) north and south of road about 0.4 mile east of SW corner of sec. 34, T. 6 N., R. 8 E.

Station 67. Seminole formation (IPsl of map) about 500 feet north of State Highway 9 in SE corner of sec. 24, T. 9 N., R. 8 E.

Station 69. Wetumka formation (IPwt of map) in road cut in NW corner of sec. 6, T. 9 N., R. 11 E.

Station 70. Calvin formation (IPcv-2 of map) in and north of road cut 0.3 mile SW of NE corner of sec. 21, T. 9 N., R. 11 E.

Station 71. Calvin formation (IPcv-1 of map) in small creek in SW corner of sec. 23, T. 9 N., R. 11 E.

Station 72. Wewoka formation (IPwk of map) in road cut 0.3 mile north of SW corner of sec. 18, T. 5 N., R. 9 E.

Station 73. Wewoka formation (IPwk of map) just east of road 0.65 mile north of SW corner of sec. 5, T. 5 N., R. 9 E.

Station 75. Wewoka formation (IPwk of map) exposed around outlier of IPwk-3 sandstone unit in SW corner of sec. 19, T. 6 N., R. 9 E.

Station 77. Wewoka formation (IPwk of map) north of road cut in center of south line of sec. 1, T. 6 N., R. 8 E.

Station 78. Coffeyville formation (IPcf-1 of map) exposed in creek bed in south half of SE corner of sec. 1, T. 9 N., R. 8 E.

Station 79. Coffeyville formation (IPcf of map) exposed in NE corner of sec. 2, T. 9 N., R. 8 E.

Station 80. Holdenville formation (IPhd-3 of map) in and north of road cut 0.3 mile west of SE corner of sec. 11, T. 7 N., R. 8 E.

Station 81. Holdenville formation (IPhd of map) along small creek just below sandstone (IPhd-2c of map) in north-central part of sec. 4, T. 9 N., R. 9 E.

Station 82. Wewoka formation (IPwk of map) under sandstone (IPwk-4 of map) in SW corner of sec. 22, T. 6 N., R. 8 E.

Station 83. Wetumka formation (IPwt of map) exposed along small creek in SW part of sec. 8, T. 7 N., R. 10 E.

Station 84. Holdenville formation (IPhd-3 of map) in road cut in center of south line of sec. 17, T. 9 N., R. 9 E.

Station 86. Calvin formation (IPcv-1 of map) just north of private road in NE corner of sec. 15, T. 8 N., R. 11 E.

Station 87. Wewoka formation (IPwk of map) in and east of road cut 0.45 mile north of SW corner of sec. 15, T. 8 N., R. 9 E.

Station 88. Holdenville formation (IPhd of map) in roadcut 0.2 mile west of SE corner of sec. 17, T. 9 N., R. 9 E.

Station 90. Seminole formation (IPsl of map) exposed along small creek in center of north half of sec. 10, T. 7 N., R. 8 E.

Station 91. Holdenville formation (IPhd of map) in road cut about 0.35 mile west of center of east line of sec. 27, T. 7 N., R. 8 E.

Station 92. Seminole formation (IPsl of map) exposed in road cut 0.45 mile north of SE corner of sec. 6. T. 9 N., R. 9 E.

Station 97. Coffeyville formation (IPcf of map) exposed in road cut 0.4 to 0.6 mile west of SE corner of sec. 23, T. 9 N., R. 8 E.

Station 98. Coffeyville formation (IPcf of map) exposed just north of outlier of sandstone (IPcf-2 of map) on east line of sec. 11, T. 9 N., R. 8 E.

Station 100. Holdenville formation (IPhd-1 of map) near base of formation 300 feet west of NE corner of sec. 25, T. 7 N., R. 8 E.

Station 104. Holdenville formation (IPhd-1 of map) in center of sec. 32, T. 9 N., R. 9 E. Just below sandstone unit (IPhd-2c).

Station 106. Seminole formation (IPsl of map) about 900 feet west of a point in road 0.35 mile north of SE corner of sec. 36, T. 9 N., R. 8 E.

Station 107. Seminole formation (IPsl-1 of map) in and near road cut about 0.2 mile north of center of south line of sec. 31, T. 9 N., R. 9 E.

Station 109. Coffeyville formation (IPcf-1 of map) along small creek in SE corner of sec. 14, T. 9 N., R. 8 E.

Station 111. Wewoka formation (IPwk of map) west of railroad in NE corner of sec. 30, T. 7 N., R. 9 E.

Station 114. Seminole formation (IPsl of map) along small creek in the NE corner of sec. 29, T. 7 N., R. 8 E.

Station 115. Seminole formation (IPsl of map) exposed in road cut about 0.2 mile west of SE corner of sec. 4, T. 7 N., R. 8 E.

Station 118. Holdenville formation (IPhd-1 of map) in road cut 0.35 mile west of SE corner of sec. 6, T. 7 N., R. 9 E.

Station 119. Holdenville formation (IPhd-1 of map) in road cut 0.2 mile west of NW corner of sec. 30, T. 8 N., R. 9 E.

Station 121. Coffeyville formation (IPcf of map) exposed along small creek in SE corner of sec. 26, T. 9 N., R. 8 E.

Station 133. Coffeyville formation (IPcf of map) exposed in and north of road cut 0.2 mile east of SW corner of sec. 12, T. 9 N., R. 8 E.

Station 134. Seminole formation (IPsl of map) exposed around base of small hill just east of road 0.35 mile south of NW corner of sec. 18, T. 9 N., R. 9 E.

Station 136. Coffeyville formation (IPcf-1 of map) exposed in road cut 0.45 mile west of SE corner of sec. 12, T. 9 N., R. 8 E.

Station 142. Wetumka formation (IPwt of map) exposed just below base of Wewoka sandstone in and north of road cut 0.2 mile west of SE corner of sec. 13, T. 9 N., R. 10 E.

APPENDIX B

MEASURED STRATIGRAPHIC SECTIONS

TOWNSHIP 9 NORTH

1. Sec. 7, T. 9 N., R. 13 E., McIntosh County; secs. 12, 11, 10, 9, 8 and 7, T. 9 N., R. 12 E., Hughes County. East-west section along State Highway 9 beginning at a point 1.1 miles east of the McIntosh-Hughes county line where the upper portion of the lower Senora sandstone member (IPsn-1a) is exposed and proceeding westward along the south lines of secs. 12, 11, 10, 9 and then northwest across the upper Senora shale member in sec. 8 to the NE cor. sec. 7, T. 9 N., R. 12 E., where several thin basal sandstone wedges of the lower Calvin sandstone (IPcv-1l, 1m, and IPcv-1) are exposed. Compiled from barometer elevations, hand level measurements; dips measured by Brunton or checked regionally by the use of subsurface data; horizontal angles and distances taken from aerial photographs; field notes used for detail.

	Feet
Calvin sandstone, lower part	
Sandstone: weathers light brown; soft, thin to medium-bedded, fine-grained, locally silty; top eroded (IPcv-1)	12.0
Shale, silty: gray-brown, alternating thin-bedded siltstone and very silty shale	49.0
Siltstone: light brown, thin-bedded, wedges out northward (IPcv-1m)	2.1
Shale silty: alternating thin-bedded siltstone beds and silty shale: mostly covered	30.0
Siltstone: light gray-brown (very thin-bedded:) wedges out northward (IPcv-1l)	0.8
Senora formation	
Shale: gray silty to very sandy; local lenses of siltstone, mostly in lower part. (IPsn-2)	170.0
Covered: uppermost sandstone unit (IPsn-1c) about	50.0
Sandstone: light gray-brown massive, locally cross-bedded; top eroded and covered east of Dustin, by terrace deposits.	
Shale, silty: light gray siltstone beds intercalated with buff to gray, sandy and silty shales, numerous thin, mostly covered.	14.0
Sandstone: light brown, massive, bedded and cross bedded, coarse to fine-grained sandstone and siltstone.	9.5
Shale, silty: light gray; many thin siltstone beds and irregular zones of limonite concretions.	49.0
Limestone: very sandy light gray, highly fossiliferous; coarsely crystalline; weathers orange-brown.	0.9
Shale, silty: mostly covered; light gray; numerous thin siltstone beds.	85.0
Sandstone: light orange-brown; massive appearance, irregular bedding, ripple marks on some surfaces, fine grained.	8.5
Silty shale: light gray; argillaceous siltstone; poorly exposed.	10.0

2. Sec. 19, T. 9 N., R. 12 E., secs. 24, 23, 22, 21, T. 9 N., R. 11 E. East-west section beginning near the base of the upper Senora shale member (IPsn-2) in the SE cor. sec. 19; west 1.3 miles to base of Calvin sandstone; north to Highway 9 and west to center sec. 21, where the upper Calvin sandstone unit (IPcv-3) is exposed. Compiled from barometer elevations, hand-level measurements, and field notes; horizontal angles and distances taken from aerial photographs.

Calvin sandstone.	
Sandstone: brown; massive, highly-contorted, coarse to fine-grained sandstone to siltstone, weathers red-brown, top eroded. (IPcv-3)	15.0

	Feet
Shale-silty: mostly covered; gray; numerous thin siltstone beds (Top IPcv-2)	9.0
Siltstone: light cream gray; thin bedded; contains many *Linoproductus insinuatus*	4.0
Shale: covered	11.0
Siltstone: cream-gray; massive; weathers brown	3.5
Shale: covered, numerous thin siltstone beds	4.5
Siltstone: light gray; hard; has ripple marks in northeast-southwest trend	0.5
Shale silty: mostly covered; numerous thin-bedded siltstone beds and abundant limonite concretions	62.0
Siltstone: medium to thin-bedded, some fine-grained sand; few thin silty shale lenses up to 0.5 foot	5.0
Shale: covered	4.0
Siltstone: light gray-brown; cross-bedding on a broad scale	5.0
Shale: silty, khaki gray	2.5
Sandstone: light brown massive, fine-grained to silty.	4.5
Shale: covered (Base IPcv-2)	3.5
Sandstone: light gray-brown; cross bedded, very fine-grained, (Top IPcv-1)	6.5
Sandstone: mostly covered: consists of a series of intercalated silty gray-brown shales and fine-grained lensing sandstones and siltstones	25.0
Sandstone: appears massive, is locally channelled, cross-bedded, and contorted; medium to fine-grained sandstone and siltstone	15.0
Shale, silty: mostly covered; numerous thin siltstone beds	31.0
Siltstone: light gray; thin-bedded.	1.5
Sandstone silty; light brown medium bedded, very fine-grained, few brachiopods near base	3.5
Shale, silty: numerous thin siltstone beds	3.0
Sandstone: light gray, hard, very fine-grained; ripple marks trend east-west	0.4
Siltstone: thin-bedded with intercalated silty gray shale layers (Base IPcv-1)	3.5
Senora formation	
Shale: Mostly covered near base; upper 120 feet contains many thin siltstone beds; shale is silty, light gray, and contains several irregular zones of limonite concretions; about	180.0

3. Sec. 6, T. 9 N., R. 11 E.; secs. 1, 2, 3, 4, 5, 6, T. 9 N., R. 10 E.; secs. 1, 2, 3, 4, 5, 6, T. 9 N., R. 9 E.; Sec. 1, T. 9 N., R. 8 E. East-west section beginning .4 mile east of the SW cor. sec. 6, T. 9 N., R. 11 E. in the middle portion of the Wetumka shale and extending west to the SW cor. sec. 3, T. 9 N., R. 10 E., where the sands of the second Wewoka zone are detailed. Section then trends northwest to the center of sec. 5, T. 9 N., R. 10 E. where detail of the sands of the third Wewoka zone (IPwk-3) was obtained; section continues northwest through secs. 1, 2, 3, 4, 5, 6, T. 9 N., R. 9 E., and sec. 1, T. 9 N., R. 8 E., where the section ends in the lower portion of the Coffeyville formation. Compiled from barometer elevations, hand level measurements, well logs for large shale intervals, and field notes. Horizontal angles and distances taken from aerial photographs.

	Feet
Coffeyville formation	
Sandstone: light gray-brown, thin bedded, very fine-grained; many thin, silty gray shale lenses; top eroded (IPcf-1); about	19.0
Seminole formation	
Shale: mostly covered, light gray-brown; very silty with numerous silty lenses.	24.0
Sandstone: light gray thin-bedded, fine-grained, numerous silty shale lenses (IPsl-3)	20.0
Shale silty: light gray; covered except upper 8 feet: (IPsl-2) about	84.0

	Feet
Sandstone: thin bedded, very fine-grained with local lenses of coarse-grained sand; many silty gray lenses (IPsl-1)	21.0
Holdenville formation	
Shale: sandy; mostly covered; soft gray; locally very fossiliferous; about	60.0
Sandstone: light gray; thin bedded, very fine-grained sandstone and siltstone; poorly exposed (IPhd-2c).	3.5
Covered: shale	88.0
Siltstone: very thin-bedded, argillaceous siltstone, many intercalated silty shale lenses (IPhd-2a)	3.5
Shale silty: covered	11.0
Siltstone: gray	1.0
Shale: very silty, gray	5.0
Siltstone: light gray-brown, calcareous, hard	0.8
Siltstone: thin-bedded with intercalated silty gray shale beds	2.5
Covered: shales of lower part of Holdenville, about	60.0
Wewoka formation	
Sandstone: light brown; thin to medium-bedded, fine-grained to silty; top eroded (top IPwk-4)	6.5
Covered: alternating thin-bedded siltstones and silty gray shales	40.0
Sandstone: tan to brown; thin to medium-bedded, fine-grained; ripple marked (base IPwk-4)	11.0
Shale: silty, blue-gray; fossiliferous; lower 35 feet mostly covered, grades into thin-bedded sandstones above and below; about	98.0
Sandstone: Mostly covered; yellow-brown, thin-bedded, almost siltstone, (top IPwk-3b).	30.0
Sandstone: red-brown; medium to thin-bedded, fine-grained, contains many *Linoproductus prattenianus* and other brachiopods	2.5
Covered: alternating thin siltstones and sandy shales	44.0
Sandstone: numerous silty, gray shale lenses; irregularly bedded, fine-grained, fossiliferous	24.0
Siltstone and Sandstone: medium-bedded; upper 0.5 foot very fossiliferous, numerous brachiopods	5.0
Sandstone: light gray, thin bedded, fine-grained; fossiliferous, (base IPwk-3b)	2.5
Shale: gray, very silty	3.5
Siltstone: gray; fossiliferous	0.3
Shale: gray; silty, many limonite concretions	21.0
Siltstone: cream-gray; fossiliferous, many *Linoproductus insinuatus* in upper 0.7 foot; lower 1 foot is gray siltstone and silty shale	1.7
Shale: mostly covered, gray, numerous thin siltstone beds, base grades into underlying IPwk-2c	90.0
Sandstone: light brown thin-bedded, fine-grained; (IPwk-2c)	9.0
Covered: mostly shale	26.0
Sandstone: largely covered: fine-grained, lower 2.5 feet thin-bedded, upper 12.0 feet massive, all light brown	14.5
Covered: probably shale	10.5
Sandstone: gray, massive to medium-bedded near base; fine-grained, few thin silty lenses (base IPwk-2c)	17.0
Covered: probably shale, about	158.0
Sandstone: gray, very thin-bedded, fine-grained; grades downward into Wetumka shale (IPwk-1a)	68.0
Wetumka shale	
Shale: top 28 feet contains numerous thin siltstone beds; base covered by terrace deposits (IPwt)	66.0

4. Secs. 35, 36, T. 9 N., R. 12 E. East-west section measured along south lines of sections from bend in road ¼ mile east of SW cor. sec. 36.

	Feet
Senora formation, middle part	
Sandstone: light brown; medium-bedded, very fine grained, top eroded (top of IPsn-1a) about	17.0
Shale: gray-brown; very silty, many siltstone lenses	13.5

	Feet
Sandstone: lower 3.0 feet thin-bedded; upper portion medium-bedded, fossiliferous, very fine-grained light gray	7.5
Shale silty: light gray; many siltstone lenses	2.5
Sandstone: tan to buff, thin-bedded, very fine grained	11.5
Shale: gray silty to sandy	12.0
Sandstone: light brown; hard, fine-grained	0.9
Shale: light gray mostly covered.	30.0
Limestone: hard, very sandy; very fossiliferous in upper 7 inches, crinoid stems mat surface; weathers orange	1.7
Shale: covered, very sandy	11.0
Sandstone: light gray-brown; hard, medium-bedded to massive, ripple marks on top trend northeast	2.5
Siltstone: light brown, medium to thin-bedded, ripple marks trend northeast	5.0
Sandstone: light gray; massive, irregular, fine-grained; weathers orange	4.5
Sandstone: light orange-brown, soft, fine-grained, thin-bedded, micaceous	2.5
Shale: mostly covered; numerous siltstone beds	21.0

5. Secs. 24, 23, 22, 21, 20, T. 9 N., R. 9 E. East-west section along the north lines of sections beginning in the NW cor. section 24, and ending in the NW cor. sec. 20. Compiled from barometer elevations, hand level measurements, and field notes. Distances taken from aerial photographs.

	Feet
Seminole formation, lower part	
Sandstone: medium to thin-bedded, many silty shale lenses, fine-grained to silty; top 10 feet covered (IPsl-1)	36.0
Holdenville formation	
Shale: silty, gray	84.0
Sandstone: light brown; irregular, fine to medium-grained; (IPhd-2c) about	6.0
Shale: mostly covered, gray; fossiliferous	99.0
Sandstone: covered locally, (IPhd-2a), about	1.0
Shale: gray; many *Mesolobus mesolobus* and *Chonetes granulifer*	68.0
Wewoka formation	
Sandstone: light brown thin to medium-bedded, fine-grained, (top IPwk-4)	12.0
Siltstone: gray; thin-bedded, shaley	13.0
Sandstone: light brown; thin to medium bedded, many silty shale beds, (base IPwk-4)	40.0
Shale: gray, silty	41.0
Covered: probably shale	41.0
Sandstone: light brown; irregular lensing, coarse to fine-grained; top covered, (top IPwk-3)	50.0
Shale: silty, gray, many *Derbyia crassa*	6.5
Siltstone: gray; thin-bedded, shaly	13.0
Sandstone: gray; thin-bedded silty (base IPwk-3)	10.0
Shale: light gray-brown; sandy to silty; base covered, about	72.0

6. Secs. 13, 14, T. 9 N., R. 8 E., Southeast-northwest section measured from the SE cor. sec. 13 to the central part of sec. 14.

	Feet
Coffeyville formation, middle and lower parts	
Sandstone: medium to thin-bedded, very fine-grained; top eroded, (Near top IPcf-2), about	12.0
Shale: gray, silty; many thin-bedded siltstone beds near top	17.0
Covered: sandstone and siltstone	12.0
Sandstone: gray; thin-bedded, shaly to silty, (base IPcf-2)	26.0
Shale: gray, silty; mostly covered	101.0
Covered:	10.0
Sandstone: thin-bedded, has numerous siltstone and silty shale lenses (IPcf-1)	9.0
Seminole formation	
Shale: gray, silty	38.0
Sandstone: light gray-brown; mostly covered; thin bedded, (top IPsl-3)	11.0

	Feet
Shale silty: gray	19.0
Sandstone: thin-bedded, locally cross-bedded, fine-grained to silty (base IPsl-3)	8.5
Shale: mostly covered, gray, silty	35.0

7. Secs. 14, 11, T. 8 N., R. 12 E. Measured south to north along east lines of sections from ¼ mile south of NE corner of sec. 14.

	Feet
Senora formation, middle part	
Limestone: very sandy; very fossiliferous, coarse crystalline, weathers in 4 to 8 inch slabs with crinoid stems and other fossils standing out in relief on weathered surfaces	0.8
Shale: covered	11.0
Sandstone: light brown; lower 2 feet massive, top ripple marked; upper 5.5 feet thin-bedded; all fine-grained	7.5
Shale: mostly covered, many thin siltstone layers	51.0
Sandstone: light brown; very thin-bedded, silty	2.5
Siltstone: gray; many silty shale lenses	3.0
Sandstone: gray-brown; massive, very fine-grained	4.5
Shale: numerous thin-bedded siltstone beds near top	14.0
Sandstone: light cream gray, hard, very fine-grained	0.7
Shale: largely covered, few thin siltstone beds; base covered by terrace deposits	95.0

TOWNSHIP 8 NORTH

8. Secs. 8, 17, T. 8 N., R. 12 E. Section measured south to north along east lines of sections from valley 300 feet south of NE cor. sec. 17. Includes top of IPsn-1a, IPsn-1b, and IPsn-1c.

	Feet
Senora formation	
Sandstone: light brown; medium to thin-bedded, fine-grained to silty; top eroded (IPsn-1c)	4.5
Shale: light gray; sandy, mostly covered	45.0
Limestone: hard, silty; fossiliferous; weathers yellow-brown (IPsn-1b)	2.5
Shale: covered	9.1
Sandstone: light brown; massive, fine-grained (top IPsn-1a)	11.0
Siltstone: interbedded with silty shale beds	1.5
Sandstone: light brown; massive to medium-bedded, fine-grained	6.3
Siltstone: light gray; thin-bedded	3.5
Sandstone: massive, contorted, fine-grained	15.0
Covered: alternating sandstone and silty shale	8.5
Sandstone: light gray; thin-bedded	1.5
Shale: light gray; sandy	17.0
Sandstone: light brown; hard, fine-grained, ripple marked	0.8
Shale: largely covered in creek bed	13.0

9. Secs. 33, 29, T. 8 N., R. 12 E. Southeast-northwest section measured from center of section 33 along road to NW cor. sec. 29.

	Feet
Senora formation, middle and lower parts	
Sandstone: light tan: medium-bedded, fine-grained; upper 4.5 feet massive, top eroded (top IPsn-1a)	23.0
Silty shale: intercalated thin sandstone beds	5.0
Shale: mostly covered	6.2
Sandstone: light gray; massive, fine-grained to silty	5.5
Shale: light gray; silty, largely covered	49.0
Sandstone: red-brown; massive, medium to fine-grained	5.5
Shale: light gray-brown; mostly covered,	76.0
Sandstone: light brown; medium-bedded, fine-grained; top 2.5 feet has several thin, sandy, fossiliferous limestone beds	20.0
Shale: gray, sandy	4.2
Sandstone: gray-brown; medium-bedded, fine-grained	4.5
Covered: largely shale	26.0
Sandstone: light brown: massive, coarse to fine-grained; fine clay-ball conglomerates locally	21.0

	Feet
Shale: gray, silty	4.7
Sandstone: thin-bedded, sandy to silty shales at irregular intervals; sandstones have abundant *Derbyia crassa* and *Composita subtilita*	2.3
Shale: covered	7.3
Sandstone: light brown; massive, largely fine-grained,	7.5
Shale: few thin silt beds near top, base covered	55.0

10. Secs. 35, 34, T. 8 N., R. 11 E. East-west section measured from center of north line of section 2 west to the northeast corner of section 3 where the base of the Calvin sandstone is exposed.

	Feet
Calvin sandstone	
Sandstone: lower 28 feet mostly covered, thin-bedded; upper 7 feet massive, irregular, fine-grained; all light brown; top eroded (IPcv-1)	35.0
Senora formation,	
Shale: top contains numerous thin siltstone lenses up to 1.5 feet; gray, sandy; lower part mostly covered (IPsn-2)	170.0
Sandstone: upper 7.5 feet massive, light brown fine-grained to argillaceous, weathers orange-brown; lower 8.5 feet medium to thin-bedded siltstone, light brown (IPsn-1c)	16.0
Shale: lower 24 feet covered; gray, sandy	45.0
Sandstone: light brown; hard, fine-grained	0.8
Limestone: blue-gray; sandy, fossiliferous; weathers red-brown, (IPsn-1b)	1.8
Shale: covered	9.0
Sandstone: light brown; fine-grained (top IPsn-1a)	15.0

11. Sec. 7, T. 8 N., R. 11 E., and secs. 12, 11, 10, T. 8 N., R. 10 E. East-west section beginning near creek in center of north line of section 7 near top of lower Calvin sandstone and extended west along north lines of secs. 12, 11 and 10, to include the basal sands of the Wewoka formation.

	Feet
Wewoka formation, lower part	
Sandstone: light brown; thin-bedded near base; medium-bedded near top; fine-grained, top eroded. (IPwk-1)	29.0
Wetumka shale	
Shale: gray-brown; all but upper 60 feet covered; fossiliferous, (IPwt) about	128.0
Calvin sandstone	
Sandstone: thin-bedded, silty; top eroded (IPcv-3)	11.0
Shale: very sandy, gray	19.0
Covered: Mostly soft, fine-grained sandstones	33.0
Sandstone: light brown; mostly covered; thin bedded, fine-grained, top eroded	17.5
Covered: probably silty shale (IPcv-2)	29.0
Siltstone: blocky, light gray-brown	1.0
Shale silty: about	14.0
Siltstone: thin-bedded, numerous silty shale lenses	27.0
Shale silty: numerous thin siltstone beds near base (Top IPcv-1)	7.0
Sandstone: light brown; massive to medium-bedded, fine-grained	25.0

12. Sec. 24, 25, 26, T. 8 N., R. 10 E. Compiled from measurements taken in the above sections.

	Feet
Calvin sandstone	
Sandstone: light brown; medium-bedded, top eroded (IPcv-3)	3.5
Shale: covered	9.0
Sandstone: thin to medium-bedded, fine grained	2.0
Shale: mostly covered	6.0
Covered:	7.0
Sandstone: light brown, medium to thin-bedded, fine-grained, top eroded (Base IPcv-3)	7.0
Shale: mostly covered; very silty (IPcv-2)	14.0
Sandstone: light gray; thin-bedded, very silty, (top IPcv-1)	4.0
Shale: covered, very sandy	3.0
Siltstone: gray	3.0

	Feet
Shale: gray, very sandy	7.0
Siltstone: thin-bedded, gray	5.0
Shale: very silty, gray	4.0
Siltstone: thin-bedded, very shaly	3.5
Shale: covered	9.0
Sandstone: light brown; massive to contorted, fine-grained to silty, base covered	18.0

13. Sec. 30, T. 8 N., R. 10 E.; secs. 25, 23, 22, 11, T. 8 N., R. 9 E. Compiled southeast-northwest section from the above sections. Computed from barometer elevations, hand level measurements and field notes, with horizontal distances taken from aerial photographs.

	Feet
Wewoka formation, upper part	
Sandstone: thin-bedded near base, medium-bedded near eroded top (base IPwk-4)	38.0
Shale: upper 30 feet very silty, mostly covered	55.0
Sandstone: massive, fine to medium-grained, weathers brown (top IPwk-3b)	6.0
Shale: gray, mostly covered	40.0
Sandstone: brown; medium-bedded	7.0
Shale: covered	12.0
Sandstone: top covered, thin-bedded, fine-grained, (base IPwk-3)	27.0
Shale: silty, gray, mostly covered,	100.0
Sandstone; top covered, thin-bedded, silty, (IPwk-2c)	54.0
Shale: numerous thin siltstone beds, gray	40.0
Sandstone: thin-bedded to lensing, fine-grained, this sandstone wedges out 1 mile to the north, whereas 1 mile to the south it is 70 feet thick (IPwk-2b)	40.0
Shale: gray; silty, base covered	48.0

14. Secs. 3, 4, 5, 6, T. 8 N., R. 9 E.; secs. 1, 2, T. 8 N., R. 8 E. Compiled east-west section beginning below the uppermost Wewoka sandstone (IPwk-4) in the northwest corner of section 3 and ending in the center of section 2 atop the lower sandstone (IPcf-1) of the Coffeyville formation. Computed from barometer elevations, hand level measurements, and field notes; horizontal angles and distances taken from aerial photographs.

	Feet
Coffeyville formation, lower part	
Sandstone: brown; thin-bedded, fine-grained; top eroded (IPcf-1), about	5.0
Seminole formation	
Shale: mostly covered; gray, silty	15.0
Covered: probably upper thin-bedded sandstone of IPsl-3, about	18.0
Sandstone: gray-brown; thin-bedded, fine-grained, (near top IPsl-3)	15.0
Shale: silty, gray	23.0
Siltstone: gray; thin-bedded, grades to shale near base (base IPsl-3)	7.0
Shale: silty near top, gray	67.0
Sandstone: mostly covered; thin-bedded, some silty shale lenses IPsl-1a)	38.0
Holdenville formation	
Shale: gray; contains many *Marginifera splendens* and numerous *Nuculopsis girtyi* about	101.0
Sandstone: mostly covered; gray; thin-bedded, (IPhd-2c) about	5.0
Shale: blue-gray	10.0
Covered: about	174.0
Wewoka formation	
Sandstone: brown, contorted, channelled, coarse to fine-grained; top covered, (IPwk-4), about	40.0
Shale: sandy in upper 20 feet; blue-gray; base covered, about	65.0

15. Sec. 7, T. 8 N., R. 9 E.; secs. 12, T. 8 N., R. 8 E. East-west section beginning in the center of the north line of section 7 and ending at the road cut 100 feet west of the NW cor. sec. 11.

	Feet
Coffeyville formation, lower part	
Sandstone: reddish brown, lensing, medium to fine-grained; top eroded (IPcf-1)	17.0
Seminole formation	
Shale: silty, gray	12.0
Sandstone: red-brown; calcareous, fine-grained, (top IPsl-3)	1.0
Shale: numerous siltstone lenses	5.5
Sandstone cream gray; thin-bedded, some beds silty,	3.0
Covered: about	6.0
Sandstone: light brown; medium-bedded to irregular, fine-grained	6.0
Shale silty: few silt beds up to 2 inches	4.0
Sandstone: thin-bedded, fine-grained	3.0
Siltstone: gray; fine-grained	0.8
Shale: silty, gray	1.5
Siltstone: lensing, light brown	1.0
Shale silty: tan	2.0
Siltstone: light brown, lensing, (base IPsl-3)	0.5
Shale: gray: upper 30 feet very silty, about	106.0
Sandstone: largely covered: lower 16 feet thin-bedded, fine-grained to silty, (IPsl-1a), about	52.0
Holdenville formation	
Shale: blue-gray; fossiliferous, base covered	55.0

16. Secs. 17, 18, T. 8 N., R. 9 E.: secs. 13, 14, T. 8 N., R. 8 E. East-west section beginning in the NE cor. sec. 17 and ending 500 feet west of the NW cor. sec. 14. Computed from barometer elevations, hand level measurements, and field notes. Distances taken from aerial photographs.

	Feet
Coffeyville formation, lower part	
Sandstone: light cream-gray; medium to thin-bedded, fine grained, top eroded (IPcf-1)	13.0
Seminole formation	
Shale: gray; very silty, many siltstone lenses	35.0
Sandstone: light brown, lensing, fine-grained (top IPsl-3)	2.0
Shale: silty, gray	7.5
Sandstone: massive-appearing but broadly cross-bedded, medium-grained to silty	13.0
Shale silty: thin gray siltstone layers near top	1.0
Sandstone: yellow-brown, massive, fine-grained	2.0
Shale: gray	3.0
Shale silty: numerous thin siltstone layers	5.0
Siltstone: gray, thin-bedded, (base IPsl-3)	6.0
Shale: gray, silty	8.0
Covered: probably shale about	120.0
Sandstone: medium to thin-bedded, fine-grained to silty (IPsl-1)	23.0
Holdenville formation	
Shale: upper 60 feet gray, silty: lower 40 feet covered	100.0
Sandstone: gray; thin-bedded (IPhd-2c) about	5.0
Shale: silty, gray; fossiliferous	40.0
Covered: shale containing sandstone (IPhd-2b), about	116.0
Shale: dark blue-black; fissile	3.0
Limestone: dark blue-gray: dense, fine crystalline: fossiliferous, on weathered surface shows *Crurithyris planoconvexa*; weathers orange; massive, (IPhd-1s)	3.0
Shale: silty, gray: contains *Cleiothyridina orbicularis*, base covered	6.0

17. Secs. 25, 26, T. 8 N., R. 8 E.: east-west section along the north lines of sections.

	Feet
Seminole formation, lower part	
Sandstone: medium-bedded, fine-grained, few chert specks, top eroded (IPsl-1a), about	8.0

	Feet
Shale: gray: silty, mostly covered	26.0
Sandstone: light brown; very fine-grained to silty, lensing (IPsl-1)	6.0
Holdenville formation	
Shale: blue-gray; largely covered	57.0
Sandstone: gray-brown; fine-grained, poorly exposed (IPhd-2c), base covered, about	6.0

18. Secs. 35, 34, 33, 32, 31, T. 8 N., R. 10 E: Sec. 36, T. 8 N., R. 9 E. Compiled east-west section through above sections. Barometer elevations, hand level measurements, and field notes used, as well as aerial photographs for horizontal angles and distances.

	Feet
Wewoka formation, lower part	
Sandstone: poorly exposed, thin-bedded, fine-grained, top covered, (IPwk-2b) about	6.0
Shale: covered	36.0
Sandstone: medium-bedded except near base where thin-bedded and lensing, fine-grained, (IPwk-2a) about	70.0
Shale: gray, silty, about	13.0
Sandstone: largely covered, alternating thin-bedded siltstone and silty gray shale (a lower tongue of IPwk-2a which wedges out half a mile to the north,	13.0
Covered: probably shale	73.0
Sandstone: brown; thin-bedded, fine-grained, (IPwk-1a)	5.5
Shale: gray; covered, silty, about	14.0
Sandstone: brown; thin-bedded, medium-grained to silty, (IPwk-1)	0.6
Wetumka shale	
Shale: blue-gray, base covered	120.0
Calvin sandstone	
Sandstone: top eroded, contorted: brown; coarse-grained to very silty, base covered	12.0

TOWNSHIP 7 NORTH

19. Secs. 4, 5, 6, T. 7 N., R. 12 E.: secs. 1, 2, 10, 9, 8, T. 7 N., R. 11 E. Compiled east-west section beginning 400 feet east of center of west line of section 4 near the base of the Senora formation and extending west to Lamar, then southwest along Highway 84 to the southwest corner of section 8 where a sandstone near the top of the Calvin sandstone is exposed in a road cut.

	Feet
Calvin sandstone	
Sandstone: light to dark brown: medium-bedded to massive, may be cross-bedded locally, top eroded	18.0
Siltstone and shale: light gray; thin bedded (IPcv-1 near top)	2.0
Shale silty: cream-gray	3.5
Siltstone: thin-bedded; sandy shale beds numerous	4.0
Sandstone: yellow-orange: blocky, hard, fine-grained, contains abundant *Myalina swallovi*	2.5
Siltstone: cream-gray, shaly	4.5
Shale: cream-gray, very silty,	6.5
Sandstone: massive to irregular, fine-grained	7.0
Shale: covered	9.7
Sandstone: light brown; massive to irregular, medium to fine-grained	6.5
Covered: probably alternating silty shales and thin-bedded sandstones	30.0
Sandstone: fine-grained	2.5
Shale silty: interbedded with thin siltstone beds	7.5
Siltstone: gray; soft, interbedded with silty shales	12.0
Sandstone: yellow-brown; massive appearing, cross-bedded, fine-grained	14.5
Shale: covered, very sandy	6.5
Siltstone: yellow-brown: blocky, lensing, fine-grained; lower 0.9 foot thin-bedded gray claystone	1.8
Shale: gray: numerous thin siltstone beds near top	59.0

	Feet
Sandstone: thin-bedded with many silty shale lenses. Two miles to south this bed is 8 feet thick	4.5
Senora formation	
Shale: gray; top 8 feet has many thin siltstone beds, (Top IPsn-2)	14.0
Sandstone: light gray; blocky, hard, very fine-grained	0.8
Shale: covered	2.5
Siltstone: gray: interbedded with silty shales	3.2
Shale silty: gray	3.5
Siltstone: gray; thin-bedded	1.0
Shale: mostly covered, (base IPsn-2)	155.0
Sandstone: light brown, poorly exposed; irregular to massive, channeled locally, fine to coarse-grained; top eroded (IPsn-1c)	13.0
Shale: mostly covered, many thin siltstone beds	42.0
Limestone: sandy, coarse crystalline, vuggy; fossiliferous; weathers red-brown	2.5
Shale: covered	9.8
Sandstone: brown: massive to medium-bedded, fine-grained	11.0
Shale: gray; silty	10.5
Sandstone: light gray, medium to thin-bedded, fine-grained	3.5
Shale: covered	24.0
Sandstone: orange-brown; medium-bedded, fine-grained	9.0
Shale and Siltstone: gray; interbedded	1.5
Siltstone: gray-brown, medium-bedded	4.5
Shale: gray, sandy	2.5
Sandstone: gray; medium to thin-bedded, fine-grained	6.0
Shale: very silty	32.0
Sandstone: massive, fine-grained, numerous *Allorisma terminale* and *Linoproductus prattenianus*	13.0
Shale: gray; many siltstone lenses	55.0
Sandstone: massive, medium to very fine-grained,	18.0
Shale: mostly covered, has many thin siltstone beds; base covered by terrace deposits	55.0

20. Secs. 5, 6, T. 7 N., R. 9 E., secs. 1, 2, 3, 4, 5, T. 7 N., R. 8 E. Compiled section starting at top of upper Wewoka sandstone in the NW cor. sec. 5, T. 7 N., R. 9 E., and continuing west to the center of the north lines of sec. 5, T. 7 N., R. 8 E., where the lower sandstone of the Coffeyville formation is exposed. Computed from barometer elevations, hand level measurements and field notes; horizontal distances taken from aerial photographs.

	Feet
Coffeyville formation	
Sandstone: light brown; thin to medium-bedded, fine-grained; top eroded	2.5
Shale: gray, sandy	9.0
Sandstone: light brown; blocky, hard, fine-grained,	1.0
Shale: covered	3.0
Sandstone: gray; medium bedded, fine-grained,	4.0
Shale and siltstone: top 7 feet has many thin siltstone beds; shales gray and silty	20.0
Sandstone: light brown; medium-bedded, fine grained to silty, (base IPcf-1)	3.5
Seminole formation	
Shale: gray silty; mostly covered	77.0
Sandstone: medium to thin-bedded, fine-grained except for occasional coarse grained lenses, few fine chert specks; top eroded, (IPsl-3) about	13.0
Shale: mostly covered	40.0
Sandstone: thin-bedded, grades to siltstones, base gradational with underlying shale (IPsl-2)	12.0
Shale: mostly covered, gray; sandy, upper 20 feet contains numerous siltstone beds	122.0
Sandstone: gray; thick-bedded, grades to siltstone; top eroded,	

	Feet
(IPsl-1a)	9.0
Shale: covered	38.0
Sandstone: thin-bedded, fine chert specks locally, grades from coarse sand to siltstone to silty gray shale along strike (IPsl-1)	6.0
Holdenville formation	
Shale: covered (IPhd-3)	75.0
Sandstone: mostly covered, fine-grained (IPhd-2c)	6.0
Shale: covered	43.0
Sandstone: mostly covered, (IPhd-2a)	2.5
Shale: covered	32.0
Covered:	5.0
Sandstone: mostly covered, top grades to shale (1a=IPhd1a)	7.0
Shale: covered	69.0
Wewoka formation, upper part	
Sandstone: fine to medium-grained, irregular and lensing, top eroded on dip slope, (top IPwk-4)	20.0

21. Secs. 8, 7, T. 7 N., R. 10 E., secs. 12, 11, 10, 9, 8, 7, T. 7 N., R. 9 E., secs. 12, 11, T. 7 N., R. 8 E. Compiled east-west section beginning 750 feet west of the NE cor. sec. 8, T. 7 N., R. 10 E., in the upper part of the Wewoka shale and continuing west along the north lines of the sections to the center of the north line of section 11, T. 7 N., R. 8 E., where the eroded top of the lowest Seminole sandstone is exposed. Computed from barometer elevations, hand level measurements and field notes; horizontal distances taken from aerial photographs.

	Feet
Seminole formation	
Sandstone: light brown; thick to thin-bedded, medium to fine-grained, contains white chert specks, top eroded (IPsl-1)	16.0
Holdenville formation	
Shale: covered (IPhd-3)	81.0
Sandstone: mostly covered; very fine-grained, (IPhd-2c)	3.5
Shale: blue-gray; fossiliferous	57.0
Sandstone: top covered, thin-bedded, fine-grained, grading to siltstone (IPhd-2a)	5.0
Shale: mostly covered, gray (IPhd-1)	55.0
Sandstone: gray-brown; mostly covered, thin-bedded, silty, (IPhdss)	12.0
Shale: covered	59.0
Wewoka formation	
Sandstone: massive in lower 17 feet, then covered alternating siltstones, sands and silty shales to top, coarse-grained to silty, (IPwk-4)	53.0
Shale: mostly covered, top 10 feet grades into overlying sandstone; gray	35.0
Sandstone: brown, top 25 feet covered, lower 6 feet medium-bedded, (IPwk-3c)	31.0
Covered: sandstone and silty shale	34.0
Sandstone and shale: lensing, thin to medium-bedded, numerous silty shale lenses, mostly covered (IPwk-3b)	57.0
Covered: mostly shale and upper sandstone of IPwk-2c about	168.0
Sandstone: mostly covered, thin-bedded, fine-grained (IPwk-2c)	6.0
Shale: covered	15.0
Sandstone: thin bedded, fine-grained, many silty shale lenses and siltstone beds (IPwk-2b)	19.0
Shale: covered	23.0
Sandstone: top covered, alternating thin-bedded, fine-grained sandstones and silty gray shales, (IPwk-2a)	68.0
Shale: covered	95.0
Covered: upper part of IPwk-1 about	29.0
Sandstone: thin bedded, fine to medium-grained with numerous silty gray shale lenses (base IPwk-1)	2.5

Feet

Wetumka shale

Shale: gray; very sandy, top 18 feet has numerous thin siltstone beds, base covered (IPwt) 45.0

22. Secs. 10, 9, 8, T. 7 N., R. 8 E. Compiled east-west section through the north lines of the sections. Barometer elevations, hand level measurements, field notes used, as well as aerial photographs for distances.

Coffeyville formation

Sandtstone: gray; thin-bedded, fine-grained to silty; top eroded, (IPcf-1) about 21.0

Seminole formation

Shale: very silty, gray 80.0
Sandstone: gray; lensing, numerous silty gray shale lenses (IPsl-3) about 10.0
Shale: mostly covered, silty 50.0
Sandstone: medium to thin-bedded, fine-grained to silty, grades to underlying silty shale, (IPsl-2), about 23.0
Shale: upper very silty; gray; base covered 60.0

23. Secs. 16, 17, 18, T. 7 N., R. 10 E.: secs. 13, 14, 15, 16, 17, 18, T. 7 N., R. 9 E., secs. 13, 14, T. 7 N., R. 8 E. Compiled east-west section beginning on eroded top of Calvin sandstone in the NE cor. sec. 16, T. 7 N., R. 10 E., and continuing west through the above sections, ending atop the eroded lower sandstone unit of the Coffeyville formation. Computed from barometer elevations, hand level mesaurements, and field notes; aerial photographs used for horizontal distances and angles.

Coffeyville formation, lowermost part

Sandstone: thin-bedded, grades to gray siltstone, many silty shale lenses; top eroded (IPcf-1) 15.0

Seminole formation

Shale: base mostly covered; upper 40 feet contains many thin siltstone lenses 123.0
Sandstone: thin-bedded, fine-grained, top covered, (IPsl-3) 11.0
Shale: gray, silty 51.0
Sandstone: thin-bedded, grades to siltstone, lenses of gray silty shale, (IPsl-2) 10.0
Shale: base covered; silty, gray 83.0
Sandstone: soft, fine-grained to silty, (IPsl-1a) 11.0
Shale: covered 31.0
Covered: uppermost part of (IPsl-1), about 6.0
Sandstone: highly conglomeratic, sands grade from coarse to fine-grained, chert pebbles up to 1.6 inches, sub-rounded; massive appearance, lensing; top 6 feet channeled and filled with silt, clay, and fine chert specks 21.0
Shale silty and siltstone: alternating thin-bedded siltstone and sandy gray shale 5.0
Sandstone: irregularly-bedded, contorted, channeled, coarse to fine-grained, fine chert specks (base IPsl-1) 14.0

Holdenville formation

Shale: sandy, gray; contains many *Mesolobus mesolobus* 93.0
Sandstone: thin to medium-bedded, fine-grained 5.0
Shale: covered, very sandy 6.0
Siltstone, gray; thin-bedded (base IPhd-2c) 2.5
Covered: shale, about 60.0
Sandstone: thin-bedded, silty (IPhd-2a) 5.0
Shale: covered except for upper 10 feet; gray, silty 36.0
Sandstone: thin-bedded, fine-grained, top covered (1a=IPhd1a) 11.0
Shale: covered, about 12.0

Wewoka formation

Sandstone: mostly covered, massive toward top, (IPwk-4) about 45.0
Shale: sandy, gray; *Conularia crustula* near top, base covered 82.0
Sandstone and shale: mostly covered; alternating gray, thin siltstone and fine sandstone beds and silty shales, (top IPwk-3c) 7.0

Feet

Sandstone: orange-brown; hard, blocky, fine-grained 1.5
Covered: alternating thin-bedded sandstone and shale with 0.5-foot gray siltstone at base, (base IPwk-3c) 3.0
Shale: gray; many crinoid stems and numerous *Chonetes granulifer* and *Derbyia crassa* 41.0
Sandstone: thin-bedded, fine-grained, base covered, (top IPwk-3b) 13.0
Covered: sandstone includes IPwk-3a and IPwk-3b about 41.0
Sandstone: brown; thin-bedded, fine-grained 3.0
Shale: silty, gray 8.0
Sandstone: gray; thin-bedded, silty (north extent of IPwk-3a) 4.5
Shale: covered 120.0
Sandstone: mostly covered, thin-bedded (IPwk-2c) about 4.0
Shale: covered 28.0
Sandstone: mostly covered, thin-bedded, fine-grained, (IPwk-2b), about 15.0
Shale: covered, about 20.0
Sandstone: mostly covered; thin-bedded near base to medium-bedded at top, fine to medium-grained (IPwk-2a), about 27.0
Covered: shale, includes part of underlying IPwk-1 about 115.0
Sandstone: poorly exposed, medium to thin-bedded, weathers into blocks about 9 inches thick, medium-grained to silty (IPwk-1) about 6.0

Wetumka shale

Shale: covered about 120.0

Calvin sandstone

Sandstone: not measured: top cross-bedded and channeled

24. Secs. 20, 19, T. 7 N., R. 10 E.; secs. 24, 23, 22, 21, 20, 19, T. 7 N., R. 9 E., secs. 24, 23, 22, 20, T. 7 N., R. 8 E. Compiled east-west section beginning in the NE cor. sec. 20, T. 7 N., R. 10 E., on the eroded top of the Calvin sandstone and extending west through the above sections to the northwest corner on the eraded top of the lower sandstone in the Coffeyville formation. Compiled from barometer elevations, hand level measurements, and field notes; horizontal angles and distances taken from aerial photographs.

Coffeyville formation, lowermost part

Sandstone: light brown; thin-bedded, fine-grained to silty, top eroded 17.0

Seminole formation

Shale: gray; sandy, mostly covered 82.0
Covered: about 10.0
Sandstone: thin-bedded, contains blue-gray, medium-crystalline limestone lenses (IPsl-3) 12.0
Shale: covered 31.0
Sandstone: brown; medium-bedded, fine to coarse-grained 10.0
Shale: gray; very sandy with thin siltstone beds 15.0
Sandstone: irregular, lensing, fine-grained, few fine chert specks (this and sandstone above make up IPsl-2) 4.5
Shale: upper 45 feet contains numerous thin siltstone beds; base mostly covered 78.0
Sandstone: mostly covered, thin-bedded, fine to medium-grained (IPsl-1a) about 8.0
Shale: covered 28.0
Sandstone: lensing, many silty shale lenses, coarsely-grained to silty, fine chert specks, (IPsl-1) 37.0

Holdenville formation

Shale: gray; highly fossiliferous, many *Mesolobus mesolobus* and *Chonetes granulifer*: mostly covered near base 175.0
Sandstone: mostly covered; thin-bedded, fine-grained (IPhd-2a) 7.0
Shale: blue-gray; fossiliferous, abundant *Marginifera splendens* and *Mesolobus mesolobus* 86.0
Limestone: blue-gray; massive, hard, medium-crystalline; highly fossiliferous; weathers yellow-brown (IPhd1) 3.5

Feet

Covered: 5.0
Shale: mostly covered, gray; sandy 7.0

Wewoka formation

Sandstone: irregular to massive, locally channeled, coarse to very fine-grained; top eroded (IPwk-4) 40.0
Shale: gray; upper 55 feet contains numerous thin siltstone beds, very silty; base covered 78.0
Sandstone: due to faulting only top of IPwk-3c exposed; normal thickness .... about 13.0
Shale: covered 33.0
Sandstone: poorly exposed, thin-bedded, fine-grained, (IPwk-3b) 3.0
Shale: blue-gray; mostly covered; silty; fossiliferous 13.0
Sandstone; thin-bedded near base, irregular and cross-bedded near top, many silty shale lenses, (IPwk-3a) 47.0
Shale: gray; sandy: many *Marginifera splendens* 120.0
Sandstone: covered (IPwk-2c) .... about 2.0
Covered: shale and thin-bedded siltstone 12.0
Sandstone: thin-bedded, very fine-grained (IPwk-2b) 7.0
Shale: gray; silty 30.0
Sandstone silty: abundant fine chert specks; fossiliferous calcareous........ 0.9
Covered: shale 7.0
Sandstone: lower 16 feet thin-bedded, grading to silty shale below; upper 14 feet medium-bedded, fine-grained, light gray-brown (IPwk-2a) .... about 30.00

Sandstone unit number 1

Covered: shale 135.0
Sandstone: mostly covered (IPwk-1) .... about 6.0

Wetumka shale

Shale: covered .... about 117.0

Calvin sandstone, uppermost part

Sandstone: brown; irregular, coarse-grained to silty, only top exposed.... 18.0

25. Secs. 29, 30, T. 7 N., R. 9 E., secs. 25, 26, 27, 28, 20 and 21, T. 7 N., R. 8 E. Compiled east-west section through the above sections. Barometer elevations, hand level measurements, and field notes used. Aerial photographs used for horizontal angles and distances.

Coffeyville formation

DeNay Limestone: highly fossiliferous, sandy, weathers red-brown, medium crystalline, thins rapidly to north and disappears 0.6

Seminole formation

Shale: silty, gray 22.0
Sandstone: thin-bedded, fine-grained to silty (IPsl-3) .... about 5.0
Shale: mostly covered; silty, gray 36.0
Sandstone: thin-bedded to lensing, silty, gray (IPsl-2) 38.0
Shale: numerous siltstone beds near top 81.0
Sandstone: light brown; lensing, contorted, soft, fine-grained to silty (IPsl-1a) 14.0
Shale: covered 6.0
Sandstone: light brown; mostly covered; very fine-grained to silty (IPsl-1) .... about 44.0

Holdenville formation

Shale: very silty, gray 66.0
Sandstone: thin bedded, fine-grained (IPhd-2c) 5.0
Shale: largely covered 80.0
Sandstone: gray; thin-bedded, silty, (IPhd-2b) 3.5
Shale: very silty 18.0
Sandstone: massive-appearing, fine-grained, some cross bedding (IPhd-2a) .... about 19.0
Shale: top 20 feet contains numerous thin siltstone beds; highly fossiliferous 94.0

Feet

Limestone: silty; fossiliferous, abundant *Crurythyris planoconvexa* weather out, fine-crystalline, blue-gray on fresh break, weathers 1.9
gray-brown (IPhd-1s) 35.0
Covered: largely shale ....

Wewoka formation

Sandstone: massive-appearing, cross-bedded and channeled, coarse- .... about 40.0
grained to silty, (IPwk-4) 80.0
Shale: blue-gray; silty; fossiliferous 6.0
Sandstone: thin-bedded, silty (IPwk-3c) 65.0
Shale: mostly covered 9.0
Sandstone: gray-brown; lensing, fine-grained (top IPwk-3b to north)...... 5.0
Shale silty: gray 14.0
Sandstone: brown; medium-bedded, silty, ... 7.0
Shale: silty; contains numerous *Nucula* 10.0
Sandstone: medium to thin-bedded, silty (base IPwk-3a) 50.0
Shale: gray: silty near top; fossiliferous; base covered ....

26. Sec. 31, T. 7 N., R. 11 E., sec. 36, T. 7 N., R. 10 E. Compiled east-west section beginning from a point in road about 1700 feet southeast of the NW cor. sec. 31, and proceeding west along road to the NW cor. sec. 36. Much of detail of upper beds of this section taken in small creek valley, 0.45 miles east of the NW cor. sec. 36.

Calvin sandstone

Sandstone: yellow-brown: massive to medium-bedded, fine-grained to .... about 18.0
silty; top covered 2.2
Siltstone: light brown; medium to thin-bedded, ... 3.5
Shale silty: gray 4.0
Siltstone: tan to light brown; irregular 2.5
Sandstone: gray; very fine-grained to silty 4.5
Siltstone: cream-gray; thin-bedded, ... 6.5
Silty shale: cement gray 7.0
Sandstone: contorted, massive appearing, silty; weathers orange........ 9.5
Covered: ....
Sandstone: light brown; massive to medium-bedded, fine-grained to very 6.5
silty, ... about 35.0
Covered: 16.0
Siltstone: largely covered: thin-bedded and lensing 2.5
Sandstone: brown; medium to fine-grained, ... 7.5
Shale, silty, gray 12.0
Siltstone: yellow-white; soft, numerous silty shale lenses 14.5
Sandstone: yellow-brown; massive, fine-grained to silty 6.5
Covered: 0.9
Siltstone: yellow brown; blocky .... about 59.0
Covered: largely siltstone and silty clays 4.5
Sandstone, gray-brown, thin-bedded, very fine-grained to silty ....

Senora formation

Upper shale member

Shale: very silty near top; not measured

TOWNSHIP 6 NORTH

27. Sec. 7, T. 6 N., R. 9 E., secs. 12, 11, 10, 9, 8, 7, T. 6 N., R. 8 E. Compiled section beginning in the NW cor. sec. 7, T. 6 N., R. 9 E., extending west through the central and north portions of the above sections to the NW cor. sec. 7, T. 6 N., R. 8 E. Barometer elevations, hand level measurements and field notes used; aerial photographs used for horizontal angles and distances.

Coffeyville formation

DeNay Limestone: gray, medium-crystalline; fossiliferous; weathers 0.8
brown ....

Seminole formation

Shale: gray; covered, very silty 23.0

Feet

Sandstone: irregularly-bedded, coarse-grained to silty, some fine chert specks (IPsl-3) ... about 7.0
Covered: silty shale and conglomeratic sandstone ... about 20.0
Sandstone: channeled, highly conglomeratic, chert pebbles up to 3 inches (IPsl-2) ... about 20.0
Shale: very sandy, gray; mostly covered ... about 54.0
Sandstone: channeled, conglomeratic, cross-bedded on a large scale; chert pebbles range up to 4 inches in diameter (IPsl-1) ... about 49.0

Holdenville formation
Shale: upper 30 feet very sandy, gray; lower 23 feet mostly covered ... about 53.0
Sandstone: brown; thin-bedded, fine-grained, (IPhd-2b) ... about 8.0
Covered: shale ... 12.0
Sandstone: light gray; fine-grained (top IPhd-2a) ... 1.0
Covered: shale and thin-bedded sandstone ... 28.0
Sandstone: medium-bedded, fine-grained; weathers orange, thin shale partings ... 1.9
Sandstone: calcareous, medium-bedded, fine to medium-grained, few sandy shale lenses ... 2.1
Limestone: massive, sandy, very hard; weathers brown, blue-gray on fresh break ... 5.4
Sandstone: light-gray; thin-bedded, fine-grained to silty, grades to shale
Covered: probably shale and upper part (IPwk-4) ... 60.0
below (base IPhd-2a) ... 2.5
Shale: blue-gray; silty; highly fossiliferous, numerous *Marginifera splendens* and *Chonetes granulifer* ... 100.0

Wewoka formation
Sandstone: massive-appearing but lensing on a large scale, medium-grained to silty; channeled locally, weathers red-brown; top eroded (IPwk-4) ... about 35.0
Shale: gray; very silty near top, ... 50.0
Covered: ... about 10.0
Sandstone: largely covered, fine-grained (IPwk-3b) ... about 8.0
Shale: gray; silty, mostly covered ... 11.0
Covered: probably upper sandstone of IPwk-3a, ... about 50.0
Sandstone: light-brown, thin-bedded, very fine-grained ... 8.0
Silty Shale: gray ... 7.0
Siltstone: cream-gray; irregular, shaly ... 6.0
Sandstone: thin-bedded, silty; grades to underlying shale ... about 12.0
Shale: gray; top 25 feet silty, base covered ... 60.0

28. Secs. 10 and 11, T. 6 N., R. 10 E. East-west section beginning in small creek immediately north of the east end of small dam on reservoir 600 feet southwest of the center of section 11 and ending near the top of the eroded Calvin sandstone in the center of section 10. Detail for lower part of section taken from exposures of the sandstone in the hill in the center of section 11.

Calvin sandstone
Sandstone: gray-brown; lensing fine-grained to silty, top eroded ... 8.0
Shale, silty; almost an argillaceous siltstone, gray ... 17.5
Sandstone: massive, contorted, fine-grained to silty; weathers orange-brown, ... about 15.0
Covered: ... about 55.0
Sandstone: irregular, fine to medium-grained ... 8.0
Shale, silty: cement gray ... 12.0
Covered: largely alternating sandstone and silty shale ... 4.0
Sandstone: massive to medium-bedded; weathers light orange-brown ... 25.0
Covered: mostly silty gray shale with numerous siltstone lenses ... about 60.0
Claystone: yellow-gray; top ripple marked, numerous thin shale partings ... 8.5
Covered: mostly silty shale ... about 20.0

Feet

Siltstone: gray; thin-bedded ... 2.0
Shale, silty: ... 4.5
Siltstone: gray-brown ... 0.6
Shale, silty: ... 1.5
Siltstone: top ripple marked, becomes fine to medium-grained, farther south where it grades into the thicker massive lower Calvin sandstone (See section 29, lower sandstone in Calvin) ... 3.5

Senora formation
Shale: not measured (IPsn-2)

29. Secs. 10, 15, 22, T. 6 N., R. 10 E. Compiled south-north section through above sections. Detail of lower beds taken immediately north of bridge which crosses the Canadian River north of Calvin.

Calvin sandstone, middle and lower parts
Sandstone: contorted, channeled locally, medium-grained to very silty, in places almost a siltstone, top covered by Qt. (IPcv-1), ... about 17.0
Shale silty: gray; many siltstone lenses ... 10.0
Siltstone: gray cement ... 0.5
Shale silty: gray; numerous siltstone beds ... 7.0
Sandstone: brown; fine-grained to silty, ... 0.7
Shale silty: gray; almost argillaceous siltstone ... 2.0
Sandstone: yellow-brown; massive, contorted, fine-grained generally, but silty, ... 6.0
Shale: silty, numerous thin siltstone beds at irregular intervals ... 12.5
Siltstone: gray; very shaly ... 10.0
Sandstone: massive-appearing, highly contorted, lensing ... 25.0
Covered: probably siltstone and silty shale ... about 37.0
Shale silty; mostly covered, gray to tan ... 8.5
Siltstone: gray ... 7.0
Sandstone: weathers light brown; massive-appearing, lensing fine-grained to very silty ... 17.0
Shale silty: gray, mostly covered ... 0.6
Siltstone: ... 0.8
Silty shale: numerous thin siltstone beds at irregular intervals ... 5.0
Sandstone: very fine-grained, massive to lensing ... 3.5
Covered: ... about 39.0
Siltstone: thin-bedded; lensing, light brown ... 2.5
Shale: cement-gray, silty ... 0.7
Sandstone: massive, few silty shale partings (Base IPcv-1) ... 24.0

Senora formation
Shale: gray; very silty with numerous thin-bedded siltstone beds near top, base covered (IPsn-2) ... 41.0

30. Secs. 25, 26, 27, 28, 29, 30, T. 6 N., R. 10 E.; secs. 25, 26, 27, 28, T. 6 N., R. 9 E. Compiled east-west section beginning near the top of the Senora sandstone member in the SW cor. sec. 25, T. 6 N., R. 10 E., proceeding west through above sections through Calvin and Atwood and ending atop the eroded IPwk-2 sandstone of the Wewoka in the center of the south line of section 28, T. 6 N., R. 9 E. Detail of lower part of Calvin sandstone taken from railroad cut west of Calvin.

Wewoka formation
Sandstone: light brown; massive to medium-bedded, fine-grained; top eroded (IPwk-2) ... 24.0
Shale: gray; silty, fossiliferous ... 65.0
Covered: ... 65.0
Sandstone: brown: massive: highly conglomeratic locally, contains chert gravels up to 2 inches in diameter (IPwk-1) ... 26.0

Wetumka shale
Shale: blue-gray; silty, fossiliferous ... 70.0
Covered: ... about 50.0

Calvin sandstone
Covered: ... about 20.0

	Feet
Sandstone: light brown; medium-bedded, fine-grained	11.5
Covered:	12.0
Shale: silty, cement-gray; contains some thin-bedded cherty sandstone beds near top	23.5
Sandstone: light brown; thin bedded, and cross-bedded, fine-grained to silty	17.6
Covered: about	5.0
Sandstone: massive, contorted, fine-grained to silty; lower 8.0 feet shows minor channeling	45.0
Covered:	2.0
Sandstone: thin-bedded, fine-grained; silty shale beds up to 0.5 foot near top	3.4
Shale silty: gray; thin-bedded sandstone lenses near base	5.7
Sandstone: medium-bedded, fine-grained, very hard; contains numerous fossil plants	8.5
Shale silty: numerous thin siltstone beds throughout	39.5
Sandstone: blocky, hard, silty; top ripple marked in northwest direction	1.5
Shale: gray; silty; many limonite concretions in thin beds	3.5
Siltstone: hard; ripple marked in northwest direction	1.0
Shale: gray; silty, contains thin siltstone beds up to 0.5 foot	4.3
Sandstone: light brown; hard, fine-grained,	2.6
Shale: cement-gray: silty	1.0
Sandstone: tan, massive-appearing, lensing, fine-grained	8.6
Covered: about	18.0
Sandstone: massive, contorted, contains fine chert flakes, fine-grained; weathers orange-brown	31.0
Covered: alternating siltstone and silty shale, about	11.8
Sandstone: medium to thin-bedded, fine-grained to silty; ripple marked in northeast direction	2.5
Covered: about	1.0
Siltstone: mostly covered; alternating thin-bedded siltstone and silty gray shale (base IPcv-1)	2.8
Senora formation	
Shale: gray; upper 35 feet very silty; (top IPsn-2)	50.0
Covered: about	109.0
Sandstone: massive, contorted, fine to medium-grained; top and base covered, (Top IPsn-1) about	11.0

TOWNSHIP 5 NORTH

31. Secs. 24, 13, 14, 15, 16, 8, 5, 6, T. 5 N., R. 11 E.; sec. 31, T. 6 N., R. 11 E.; secs. 36, 25, 26, 27, T. 6 N., R. 10 E. Compiled southeast-northwest section beginning in the NE cor. sec. 24 on the top of the Thurman sandstone, passing northwest to Stuart, and then to Calvin along U. S. Highway 270 where the base of the Calvin sandstone is exposed.

	Feet
Calvin sandstone (lower part)	
Sandstone: light-brown; massive appearing, lower 15 feet cross-bedded and lensing, few fine chert specks (base IPcv-1); top eroded	36.0
Senora formation	
Shale: largely covered (IPsn-2)	159.0
Covered: (top IPsn-1)	5.0
Sandstone: massive, fine to medium-grained; exposed in railroad cut 1,000 feet east of the NW cor. sec. 36, T. 6 N., R. 10 E.	13.7
Covered: about	6.0
Shale: mostly covered	55.0
Covered:	25.0
Sandstone: appears massive, cross-bedded and lensing, fine-grained, few chert flakes	31.0
Covered:	65.0
Sandstone: brown; thin-bedded, fine-grained	1.7

	Feet
Shale: gray; scattered silt lenses	20.0
Sandstone: red-brown; fine-grained	0.9
Shale: gray; silty	3.0
Sandstone: massive, fine-grained to silty	11.5
Shale: gray; silty	6.0
Sandstone: contains irregular sandy shale lenses	2.5
Shale: gray, silty	1.6
Sandstone: gray; thin-bedded, fine-grained to silty	2.7
Shale: gray	2.0
Siltstone: gray; lensing	2.1
Silty shale: maroon and gray	8.5
Sandstone: brown; lensing, silty	2.6
Shale: red and gray; mottled, sandy	6.4
Siltstone: gray; cross-bedded	11.7
Covered:	38.0
Sandstone: lower 21 feet has alternating thin sandstone beds and sandy gray shales; grades downward into Stuart shale about	38.0
Stuart formation	
Shale: upper 50 feet very sandy; gray; base mostly covered about	134.0
Covered:	6.0
Sandstone: gray-brown; lensing, fine-grained, calcareous, some highly contorted (top IPst-2) about	11.4
Covered:	4.0
Sandstone: light brown, massive, fine-grained, few chert specks	13.6
Covered: includes some of lower IPst-2 about	14.0
Shale: few thin sandstone layers near top, largely covered about	124.0
Thurman sandstone, upper part only	
Sandstone: not measured: brown cross-bedded to contorted, medium-grained to silty	

32. Secs. 24, 25, 26, 23, 22, 27, T. 5 N., R. 11 E. Compiled east-west section through the above sections. Barometer elevations, hand level measurements and field notes used; aerial photographs used to obtain horizontal angles and distances.

	Feet
Senora formation, lower part	
Sandstone: gray; medium-bedded to massive, locally contorted, silty, fine-grained; top eroded	38.0
Stuart formation	
Shale: gray; lower 90 feet covered; silty	135.0
Sandstone: gray to brown; (top IPst-2) thin-bedded to lensing, silty about	27.0
Shale: gray; arenaceous	23.0
Sandstone: lower 17 feet medium-bedded to massive; upper 26 feet thin-bedded, silty, gray, (base IPst-2) about	43.0
Shale: covered, a about	70.0
Sandstone: largely covered, silty, yellow-orange, (IPst-1), about	6.0
Shale: silty, gray, contains many *Crurithyris planoconvexa*	18.0
Covered: shale	70.0
Thurman sandstone, upper part	
Sandstone: medium to thin-bedded, often lensing and channeled, fine-grained to very silty, brown to light gray, base not exposed, (top IPth-4)	25.0

33. Secs. 36, 35, 34, 33, 32, 31, 30, and 19, T. 5 N., R. 11 E. Compiled east-west section through the north part of sections 31 through 36 and through east part of sections 30 and 19. Barometer elevations, hand level measurements and field notes used; aerial photographs used for horizontal angles and distances.

	Feet
Senora formation, lower part (IPsn-1)	
Sandstone: thin-bedded to lensing, silty, top eroded (near top IPsn-1) about	9.0
Covered: siltstone and shale	13.0

	Feet
Sandstone: lensing, silty, light tan to brown	5.0
Shale, silty: very silty, largely covered, gray, about	77.0
Sandstone: thin-bedded, fine-grained to silty, light brown	7.0
Covered:	5.0
Sandstone: numerous silty gray shale lenses, fine-grained, gray	13.0
Shale: silty, gray	9.0
Covered: about	5.0
Sandstone: cross-bedded, silty, gray	3.0
Shale, silty: gray	7.5
Sandstone: lensing, silty, light gray	4.0
Shale: silty, gray	4.0
Sandstone: lensing, fine-grained, tan	7.0
Covered: silty shale	12.0
Siltstone: lensing, gray	2.0
Shale: gray, sandy	4.5
Siltstone: thin-bedded, cement gray	3.0
Covered:	16.0
Sandstone: thin-bedded, silty, light brown	7.0
Shale: lower 9 feet gray, upper 12 feet contains numerous thin silt beds and is maroon	21.0
Covered:	20.0
Sandstone: irregular to thin-bedded, fine-grained to silty, brown	12.0
Shale, silty: many silt lenses, maroon and gray	7.0
Sandstone: massive appearing but lensing, silty, gray	4.5
Shale: gray, silty	6.0
Siltstone: gray and maroon; lensing	10.0
Silty shale; alternating thin siltstone beds and silty gray shale	22.0
Sandstone: gray; massive appearing but lensing, fine-grained	3.0
Shale, silty: maroon and gray	9.0
Sandstone: light brown: lensing, fine-grained	6.0
Covered:	2.0
Siltstone: gray	1.0
Shale: maroon and gray; silty	9.0
Siltstone: alternating thin-bedded siltstone beds and silty gray shale lenses	11.0
Sandstone: maroon and gray; cross-bedded, appears almost massive, very silty, (base IPsn-1)	6.5
Stuart formation	
Shale: gray; largely covered: upper 9 feet very silty about	57.0
Sandstone: base thin to medium-bedded, top covered, all fine-grained (IPst-2); top eroded about	29.0
Shale: gray; silty	10.00
Covered: probably shale	74.0
Sandstone: mostly covered, thin-bedded and silty (IPst-1) about	65.0
Shale: mostly covered about	98.0
Thurman sandstone, upper part	
Sandstone: irregular, medium-grained to silty, locally; cross-bedded, few fine chert flakes; weathers orange-brown, base covered	21.0

TOWNSHIP 4 NORTH

34. Sec. 7, T. 4 N., R. 11 E.; secs. 12, 11, T. 4 N., R. 10 E. Compiled east-west section beginning in the SE cor. sec. 7 and ending in the NW cor. sec. 11. Computed from barometer elevations, hand level measurements, and field notes, with horizontal angles and distances taken from aerial photographs.

	Feet
Senora formation, middle and lower part	
Sandstone: light gray-brown; medium bedded, fine-grained; top eroded (near top IPsn-1)	7.6
Covered: mostly shale	40.0

	Feet
Sandstone: light gray medium-bedded, fine-grained	2.0
Covered: alternating sandstone and shale	8.5
Sandstone: massive, but contains a few 2 to 3 foot silty shale lenses	32.0
Covered: alternating siltstone and silty shales about	36.0
Shale silty: mostly covered	33.0
Sandstone: yellow-brown; medium-bedded, fine-grained	5.5
Covered:	25.0
Sandstone: gray; massive to lensing, silty	12.5
Shale: gray and red; very silty, many beds of limonite concretions included	60.0
Siltstone: gray, coarse	1.3
Shale: sandy, slightly calcareous,	11.5
Sandstone: yellow-brown; silty	2.5
Shale: gray; silty	31.0
Covered: about	5.0
Sandstone: massive appearing, but finely cross-bedded; crops in bluff just west of creek along west-central line of sec. 7, T. 4 N., R. 11 E.	17.5
Covered: silty shale and thin-bedded siltstones	21.0
Sandstone: gray-brown; medium-bedded to thin-bedded near base, silty (base IPsn-1)	24.0
Stuart formation, upper part	
Shale: gray; silty, many limonite concretions	96.0
Sandstone: medium to thin-bedded, often calcareous, fossiliferous, base covered	13.5

35. Secs. 25, 24, 13, 12, 1, T. 4 N., R. 11 E.: sces. 35, 36, T. 5 N., R. 11 E. Compiled south-north section beginning on the Boggy shale in the SW cor. sec. 25 and trending north through the above sections to the top of the middle Stuart sandstone unit (IPst-1) in the SW cor. sec. 36. Barometer elevations, hand level measurements, and field notes used; aerial photographs used for horizontal angles and distances.

	Feet
Stuart formation, middle and lower part	
Sandstone: thin-bedded, soft, fine-grained to silty; weathers yellow-brown (top IPst-1)	31.0
Sandstone: light brown; medium-bedded, fine-grained, contains numerous shale lenses up to 6 inches thick	6.5
Sandstone: brown; massive, hard, fine-grained, has fine chert specks in lower 2.5 feet	3.5
Covered:	11.0
Sandstone: alternating thin-bedded siltstone, sandstone, and silty gray shale, (base IPst-1)	4.8
Shale: upper 65 feet gray, silty, contains many thin zones of limonite concretions; lower 35 feet largely covered about	95.0
Thurman sandstone	
Sandstone: medium to irregularly-bedded, cross-bedded, coarse to fine-grained with many zones of fine chert flakes, top largely covered (IPth-4) about	28.0
Shale: gray; very sandy, largely covered	33.0
Sandstone: massive, highly contorted and locally channeled; contains locally a coarse chert conglomerate with sub-rounded fragments up to 2.5 inches in diameter; weathers irregularly, depending upon conglomeratic development (IPth-3) about	16.5
Covered: mostly silty gray shale	27.0
Sandstone: thin-bedded, silty, calcareous	5.4
Shale: mostly covered, silty	9.0
Sandstone: medium-bedded to irregular, fine to coarse-grained, conglomeratic; fragments of chert and quartzite up to 2 inches in diameter (IPth-2)	38.0
Silty shale: gray, some *Lindstroemella patula* and *Chonetes granulifer*	13.4

Sandstone: light brown; massive-appearing: cross-bedded, conglomeratic, chert fragments average about 3-5 mm. in diameter (top IPth-1)	8.4
Covered: silty shale and thin-bedded siltstone	29.0
Sandstone: alternating thin to medium-bedded, fine-grained to silty sandstone and silty gray shale; forms high scarp overlooking valley of Boggy shale to the southeast; finely conglomeratic locally (base IPth-1)	35.0
Boggy formation	
Shale: gray; many thin siltstone beds near top	5.6
Siltstone: gray; thin-bedded,	2.1
Sandstone: gray; thin-bedded, silty	2.6
Shale: gray; silty, some *Paraconularia crustula*	11.0
Siltstone: alternating thin-bedded siltstone and silty cream-gray shale; thin irregular beds of limonite concretions near top	6.6
Shale: light-gray; largely covered, silty, base covered in creek ....about	101.0

36. Secs. 8, 9, 4, T. 3 N., R. 10 E., Coal County; sec. 33, T. 4 N., R. 10 E, Hughes County. Compiled south-north section along U. S. Highway 75 beginning at a small bridge in the center of the east line of section 8 and ending on the eroded top of the middle Stuart sandstone in the south part of section 4. Barometer elevations, hand level measurements and field notes used; aerial photographs used for horizontal angles and distances.

Stuart formation, middle and lower part	
Sandstone: massive-appearing, cross-bedded and channeled; channels filled with fine chert fragments and clay pellets, top covered by gravel of the Gerty (top IPst-1)	9.0
Covered: mostly thin-bedded sandstone	5.7
Sandstone: massive-appearing, cross-bedded and channeled; contains fine chert fragments averaging about 1 mm. (base IPst-1)	6.1
Shale: light gray to blue-gray; silty	49.0
Covered: probably shale	26.0
Thurman sandstone	
Sandstone: cross-bedded, channeled, fine-grained, trace fine chert flakes	7.5
Covered: soft, conglomeratic sandstone and shale	21.0
Sandstone: irregular, channeled, many fine chert fragments; weathers orange-brown	22.5
Silty shale: mostly covered	16.4
Sandstone: red-brown; cross-bedded, fine-grained to silty	8.3
Covered:	4.0
Shale: red and gray; sandy	8.5
Sandstone: lensing, fine-grained, has silty gray and maroon shales	14.4
Shale: many thin silty beds in this section: mostly covered ....about	76.0
Sandstone: massive-appearing, cross-bedded and contorted; many fine chert fragments averaging 2 mm. in diameter; upper 7.0 channeled	21.5
Boggy formation	
Shale: gray; top 24 feet has numerous thin-bedded siltstone layers; has abundant *Paraconularia crustula* in a zone some 35 feet below the base of the Thurman; base not exposed ....about	60.0

37. Sec. 1, T. 3 N., R. 9 E., Coal County; secs. 36, 25, 24, 13, 12, 1, T. 4 N., R. 9 E., Hughes County. South-north section beginning in farm road ¼ mile southeast of the NW cor. sec. 1, T. 3 N., R. 9 E., Coal County and ending in the SW cor. sec. 1, T. 4 N., R. 9 E., Hughes County. Computed from barometer elevations, hand level measurements and field notes; horizontal angles and distances taken from aerial photographs.

Calvin sandstone, lower part	
Sandstone: light brown; massive to medium-bedded, fine-grained	17.0
Shale; gray; silty	2.2

	Feet
Siltstone: yellow-brown; hard, ripple marks trend to northeast (base IPcv-1)	1.8
Senora formation	
Upper shale member (IPsn-2)	
Covered: mostly silty shale	33.0
Siltstone: alternating gray, silty shale and lensing siltstones	12.5
Covered: mostly gray shale	21.0
Sandstone: gray; thin-bedded, fine-grained	2.8
Covered: largely shale; lower 10 feet contains a few thin siltstones	21.0
Lower sandstone member (IPsn-1)	
Sandstone: brown; massive, except for lower 2 feet which is thin-bedded, fine to medium-grained	11.4
Shale: gray; silty	23.0
Sandstone: silty, thin gray shale partings	3.5
Shale: contains numerous limonite concretions, many of which contain fossils	29.0
Covered: about	10.0
Sandstone: brown, irregular, channeled, fine to medium-grained, contains fine chert fragments averaging 1 to 2 mm. in diameter	17.0
Covered: probably silty shale	16.0
Limestone: highly fossiliferous, medium-crystalline; contains calcite-lined vugs and chert fragments; weathers red-brown	1.5
Shale: largely covered	16.0
Sandstone: contorted, fine-grained, contains mica flakes and fine white chert fragments	11.3
Shale: mostly covered	41.0
Sandstone: medium to thin-bedded, fine-grained to silty, lower 3 feet has silty, gray shale lenses (probable base IPsn-1)	6.5
Stuart formation	
Shale: gray, silty	4.9
Sandstone: calcareous, highly fossiliferous; weathers red-brown	0.3
Shale: gray	21.0
Sandstone: thin-bedded, fine-grained; weathers into light gray, paper thin layers	4.9
Covered:	31.0
Sandstone: hard, calcareous, fine-grained, contains sandy limestone lenses	5.3
Shale: sandy, fossiliferous	31.0
Covered: ....about	5.0
Sandstone: top covered; conglomeratic, contains chert fragments up to ½ inch in diameter	17.0
Covered:	10.7
Shale: numerous thin siltstone beds near top, fossiliferous, base covered ....about	85.0
Thurman sandstone	
Sandstone: cross-bedded, channeled, contains fine white chert fragments	9.0
Covered:	7.5
Siltstone: gray; cross-bedded	2.7
Shale: gray; very sandy, base covered by alluvium in creek	27.0

38. Secs. 27, 22, 15, T. 4 N., R. 10 E. Compiled south-north section beginning in the center of the south line of section 27 and trending northwest through above sections. Computed from barometer elevations, hand level measurements, and field notes; aerial photographs used for horizontal angles and distances.

Senora formation, lower part	
Sandstone: mostly covered; top 25 feet medium-bedded, fine-grained; lower 19 feet massive, contorted	44.0
Shale: covered ....about	94.0

		Feet
Covered:		10.0
Sandstone: mostly covered; thin-bedded, fine-grained, has some sandy limestone lenses		11.0
Shale: covered	about	64.0
Covered: alternating sandstone and silty shale		30.0
Sandstone: brown; mostly covered, silty	about	7.0
Stuart formation		
Shale: covered		60.0
Covered:		45.0
Sandstone: brown; cross-bedded and channeled, medium-grained to silty, contains fine chert flakes, base covered (IPst-1)	about	16.0

39. Secs. 33, 32, 29, 20, 19, 18, T. 4 N., R. 9 E. Compiled southeast-northwest section beginning in the upper part of the Stuart formation in creek 300 feet east of the center of the south line of section 33 and trending northwest through Citra, ending atop the eroded base of the Calvin sandstone. Barometer elevations, hand level measurements, and field notes used; vertical angles and distances taken from aerial photographs.

Calvin sandstone, lower part		
Sandstone: red-brown; massive, contorted, coarse-grained to very silty, top eroded (IPcv-1)		22.5
Senora formation		
Shale: gray; silty (top IPsn-2)		64.0
Covered: (Base IPsn-2)	about	50.0
Covered: (Top IPsn-1)	about	30.0
Sandstone: brown; medium-bedded, fine-grained		14.5
Covered: mostly silty shale	about	65.0
Sandstone: fine-grained; medium-bedded; many fossil molds on weathered red-brown surface,		11.3
Stuart formation		
Shale: gray; silty		40.0
Covered: shale		24.0
Sandstone: gray; thin to medium-bedded, silty, contains a few white chert flakes		5.5
Covered: shale		19.0
Sandstone: gray; cross-bedded, silty		11.5
Shale: gray; silty		12.6
Sandy limestone: very hard, fossiliferous, medium-crystalline, contains irregular beds of calcareous sandstone. This irregularly occurring limestone lies about 88 feet above the conglomeratic sandstone in the lower part of the Stuart in Coal County one mile to the south		6.5

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