# KANSAS GEOLOGICAL SURVEY
# OPEN-FILE REPORT 67-6

## GEOLOGY AND MINERAL RESOURCES OF WILSON COUNTY, KANSAS,
WITH SPECIAL REFERENCE TO OIL AND GAS RESOURCES

by

Holly C. Wagner

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STATE GEOLOGICAL SURVEY OF KANSAS

BULLETIN

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# GEOLOGY AND MINERAL RESOURCES OF WILSON COUNTY, KANSAS, WITH SPECIAL REFERENCE TO OIL AND GAS ~~RESOURCES~~[1]

By Holly C. Wagner
(U. S. Geological Survey)

Investigation conducted under cooperative agreement between the State Geological Survey of Kansas and the United States Geological Survey.

[1] Publication authorized by the Director, U. S. Geological Survey.

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Holly C. Wagner

# Geology and mineral resources of Wilson County, Kansas with special reference to oil and gas[1]

## Abstract

Wilson County covers about 575 square miles in the Osage Cuestas physiographic subdivision of southeastern Kansas. The area is characterized by east-facing limestone escarpments and complementary west-dipping gentle slopes. Local reversals modify the regional westward dip of 25 feet to the mile and form domal structures that are the sites of flat-topped, limestone-capped mounds carved largely by Quaternary erosion. Gravel deposits, composed principally of chert derived from cherty Permian limestone formations about 50 miles to the west and deposited during late Tertiary and Quaternary time, lie upon bedrock surfaces at four general levels.

[1] Publication authorized by the Director, U.S. Geological Survey.

FRONTISPIECE.--Channel sandstone in the lower part of the Ireland Sandstone Member of the Lawrence Shale. State Highway 96 roadcut near the SE cor. sec. 8, T 28 S, R 14 E.

Strata exposed in the county are about 650 feet thick, are early Late Pennsylvanian in age, and comprise (downward) the Oread Limestone, Lawrence Shale, Stranger Formation, Weston Shale, Stanton Limestone, Vilas Shale, Plattsburg Limestone, Lane-Bonner Springs Shale, Iola Limestone, Chanute Shale, Drum Limestone, Cherryvale Shale, and Dennis Limestone. Each limestone formation is divided into 2 to 5 members. Strata encountered in the subsurface during test drilling for oil and gas are about 2700 feet thick and include shale, sandstone, and limestone of the Kansas City, Pleasanton, Marmaton, and Cherokee Groups of Middle and Late Pennsylvanian age, cherty limestone and dolomite of Mississippian age, the black Chattanooga Shale of Mississippian and Devonian(?) age, and dolomite and dolomitic limestone of Ordovician and Cambrian age. These strata are underlain mainly by granite of Precambrian age.

Accumulation of oil and gas is controlled partly by structure and partly by stratigraphy. Gas is obtained from structurally high areas; oil is most commonly obtained off-structure west of the crests of domes but may be found on the crest or on a flank or in a saddle between two structures. Linear productive areas that probably are controlled by ancient sandbars or sand-filled channels cross the general structural trend and ~~are productive of~~ contain oil throughout their extents. Most of the oil and gas is obtained from 4 sandstone beds in the lower part of the strata of Pennsylvanian age (Cherokee Group). Smaller amounts are from sandstones and limestones above the Cherokee Group and from porous zones at the tops of rocks of Mississippian age and of Ordovician age. The principal oil-producing zones in strata of Pennsylvanian age are the "First" and "Second Bartlesville sands." Lesser production is obtained from the "New Albany sand" of the Chanute Shale, the "Weiser sand" of the Bandera Shale, and the "Squirrel sand" of the Cherokee Group.

As of January 1960 an estimated 6 million barrels of oil and 50 billion cubic feet of gas have been obtained from the 17 oil and gas fields in the county. Depths to production of both oil and gas range from 200 to 1,700 feet, depending upon the stratigraphic position of the producing zone and the amount of uplift of the local structure. About 20 of the oil pools have been subjected to secondary recovery methods, and two of the gas pools have been converted to gas-storage reservoirs.

Other economic natural resources of the county include coal, clay, limestone, and gravel. The Chetopa and Dry Creek coal mining districts encompass more than 15,000 acres in Wilson County. About 275,000 tons of bituminous coal have been mined since 1860, and approximately 13 million tons of coal in beds 10 to 24 inches thick remain in the ground. Clay from the Weston, Vilas, and Lane-Bonner Springs Shales has been used in brick and tile manufacture at 9 brick plants since 1884. Testing of these clays has shown them to have qualities suitable to the manufacture of lightweight concrete and constructional aggregate and as a mixer in the rock wool industry. Local limestone has been used in cement manufacture, as a source of stone for concrete and road rock, and as agricultural lime. Cement manufacture utilizes about 500,000 tons of limestone each year.

## Introduction

### Purpose and Scope of Investigation

The investigation upon which this report is based is part of a continuing program of petroleum resources studies in Kansas begun in 1917 by the U.S. Geological Survey in cooperation with the State Geological Survey of Kansas. Areas for which the results of these studies were published by the State or Federal Geological Surveys are shown on Figure 1. The published results include reports by Fath (1921), Rubey and Bass (1925), Bramlette (1925), Bass (1926, 1929, 1936), Lee (1939, 1940abc, 1941, 1943, 1949, 1953, 1954, and 1956), Lee et al. (1944, 1946, 1948, and 1954ab), Leatherock (1945), Edson (1945, 1947), Maher (1946, 1947, 1948), Collins (1947), Keroher and Kirby (1948), Wagner and Harris (1953), and Wagner (1954, 1961). The geologic investigation of Wilson County reported here was undertaken to supplement current knowledge of the oil and gas producing areas of Kansas, to add to the detailed geologic mapping of the State, and to describe the stratigraphy and lithology of the outcropping formations of Wilson County as an aid in recognizing the same formations in the subsurface to the west, where they are encountered in the drilling of oil and gas wells. Because it is anticipated that the major use of this report will be by individuals and companies exploring for oil and gas, the formations are discussed in the order that they would be encountered in drilling; that is, from youngest to oldest.

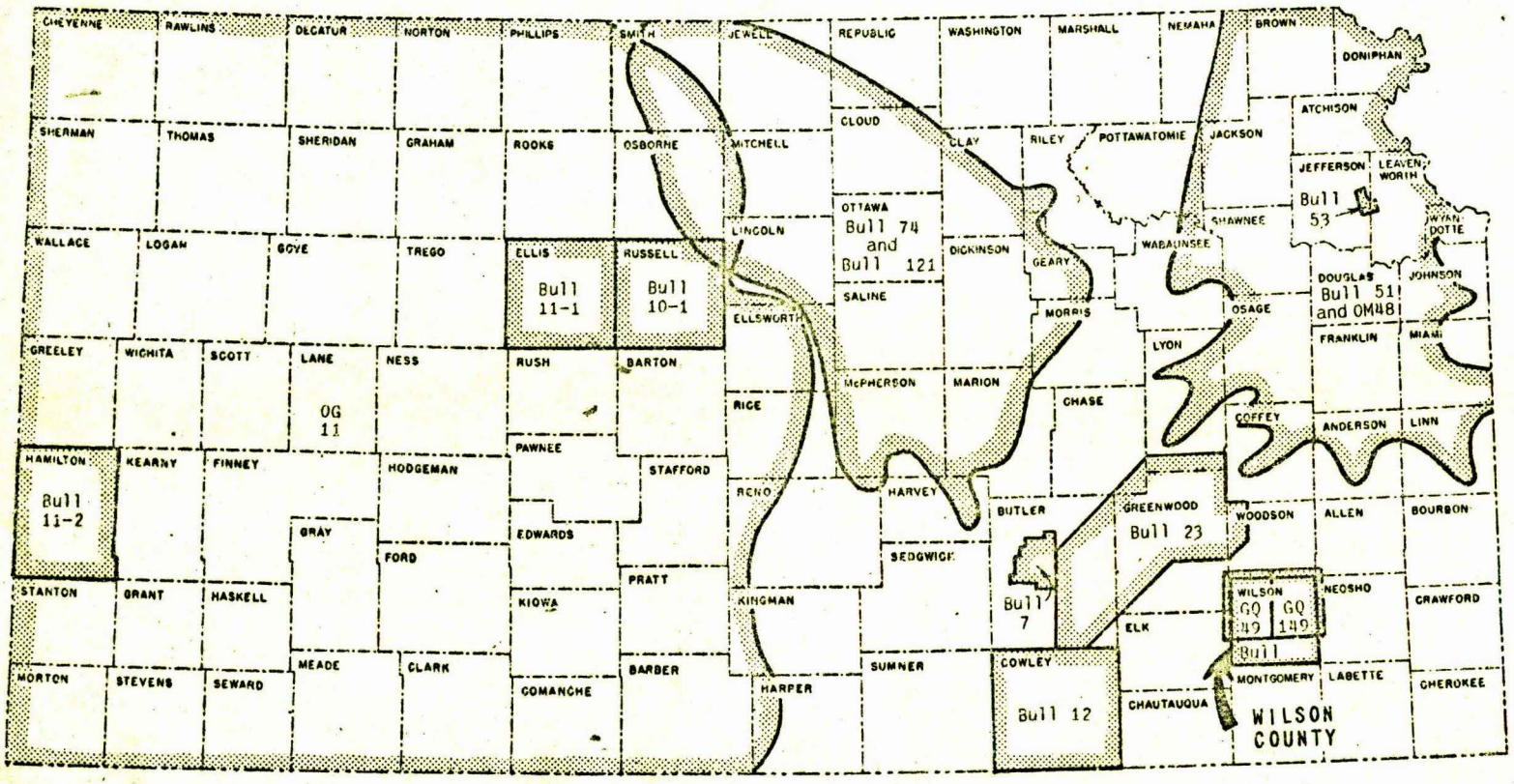


Figure 1.--Index map of Kansas showing the location of Wilson County and the areas for which map reports resulting from the cooperative Petroleum-Resources Program have been published by the State and Federal Geological Surveys. Numbers preceded by "Bull." and "OG" refer to Bulletins and Oil and Gas Investigations reports of the State Geological Survey; "OM" and "GQ" refer to Oil and Gas Investigations reports and Geologic Quadrangle maps of the U.S. Geological Survey.

The main body of the report is a detailed description of the stratigraphy and structure of the county and their relation to the occurrence of oil and gas. An outline of the tectonic and depositional history of the strata is included in the report to put into proper perspective and sequence the events and conditions which led to variations in the lithology and thickness of the units. Most of the economic part of the report relates to oil and gas; other uses of the strata are considered briefly. The treatment of each oil or gas field is separate and includes a history of discovery and a description of the producing zones. Data on many of the fields are incomplete, and the descriptions are necessarily generalized. A few analyses of oil and gas are quoted, and the available statistics on production are given.

Location and Extent of Area

Wilson County is in southeastern Kansas about 30 miles north of Oklahoma and 50 miles west of Missouri (see fig. 1). It is adjoined on the north by Woodson County, on the east by Neosho County, on the south by Montgomery County, and on the west by Greenwood and Elk Counties.

Wilson County is bounded approximately by parallels 37°23½' and 37°44' N. latitude and by meridians 95°31½' and 95°57½ W. longitude. The county is 24 miles on a side and contains about 575 square miles, or 368,000 acres.

Previous Investigations

The general stratigraphy and structure of Wilson County have been known for many years, but none of the published reports on the whole county contains detailed descriptions of stratigraphy or structure, and only general statements have been made concerning the oil and gas fields and their development.

The first published report on the stratigraphic units of Wilson County is based upon a geologic reconnaissance of the Verdigris River by Haworth and Piatt (1894), who traversed the county from southeast to northwest and noted the relative prominence of limestone and the presence of sandstone near the towns of Altoona and Benedict. The earliest map showing limestone outcrops was prepared by Haworth (1895a, map in rear; 1895b, p. 453; 1896b, end of report) and shows only one prominent outcrop, that of the Stanton and Plattsburg Limestones (the Iola Limestone of Haworth)[1], across the center of the county. At a scale of about 16 miles to the inch Haworth (1898a, p. 106) published a more refined map of the outcrop pattern of essentially the same

[1] Where terminology used in the old report differs from current terminology, or where miscorrelations were made, the correct term is used in context and the term used in the original report is in parentheses.

stratigraphic unit, and included also the Drum (Erie) limestone which crosses the southeastern corner of the county. In a report to the Kansas Academy of Science in 1897, Adams (1899, p. 58) presented a physiographic map of southeastern Kansas which shows the escarpments of the Oread (Burlington) limestone at the northwestern corner of the county, the Drum (Independence) limestone at the southeastern corner, and that of the Stanton and Plattsburg (Iola) limestones crossing the middle of the county in a northeasterly direction and branching into two escarpments north of Altoona. A more detailed map by Adams (Adams, Girty, and White, 1903, p. 28) shows three limestone units, the Stanton (Iola), Plattsburg (Earlton), and Drum. Adams correctly related the Stanton and Plattsburg limestones to the intervening Vilas shale in his statement (Adams, Girty, and White, 1903, p. 39), "These shales [Vilas] occupy the interval between the Earlton limestone and the Iola limestone . . . ," but he did not realize that the Lane shale thins rapidly in northeastern Wilson County and that he had overlooked it in that area. The error was corrected during the mapping of the Iola quadrangle (Adams, Haworth, and Crane, 1904, pl. 1), and the next published map covering Wilson County (Schrader and Haworth, 1906, pl. 2) shows fairly well the general positions of the Oread (Painterhood), Stanton (Piqua), Plattsburg (Allen), Iola, and Drum limestones at a scale of six miles to the inch. The geology and oil and gas wells of the southern third of Wilson County are shown on a map from this same report at a scale of two miles to the inch (Schrader and Haworth, 1906, pl. 1). The report discusses the oil and gas industry of the area and also contains the first moderately detailed published

description of the outcropping rocks (Schrader and Haworth, 1906, p. 11-16, 19-48). The results of this investigation also form a geologic folio report of the Independence quadrangle (Schrader, 1908). The next geologic map of Wilson County appeared in the comprehensive publication on oil and gas in Kansas by Haworth (1908, pl. 19). Most of the errors of previous reports are corrected on this map, additional units are shown, and stratigraphic terminology still in use is applied.

A second comprehensive report on the oil and gas resources of Kansas (Moore and Haynes, 1917) established, in many respects, an excellent pattern for later reports. Chief among its advantages are a concise but thorough treatment of the stratigraphy, and a county by county general discussion of geology, drilling, and production. The report includes geologic maps on which are shown the locations of oil and gas wells. The map of Wilson County (Moore and Haynes, 1917, pl. 39) contains a few modifications in stratigraphic nomenclature, but the geologic boundaries are less accurate and more generalized than on the earlier map by Haworth (1908, pl. 19). In about 1919 a program was initiated by the State Geological Survey of Kansas to prepare detailed reports on the oil and gas resources of the more important petroleum-producing counties of southeastern Kansas. The second in the series, that on Wilson and Montgomery Counties (Moore and Boughton, 1921), includes general descriptions of the geography and geology of each county, a chapter on the history of oil development, a map showing oil and gas wells drilled in each county, and brief historical descriptions of the oil and gas fields.

The first published report dealing primarily with the subsurface geology of Wilson County is by W. L. Stryker (1925), whose observations concerning the relation of Pennsylvanian sand accumulation to Mississippian topographic highs and structures are verified in the present study. Stryker (1925, p. 1209) pointed out that (a) the erosion surface on the top of rocks of Mississippian age has considerable relief, (b) this relief exercised an influence in the deposition of sand lenses in the Cherokee group and may be responsible for some of the structures in the subsurface, and (c) many of the sand lenses lie on the southwestern flank of the irregularities on the Mississippian surface. A soil survey of Wilson County by the U. S. Department of Agriculture (Kerr, Whetzel, and Higbee, 1927) contains descriptions of 23 soil types and their utilization. It includes an excellent map which shows that the distribution of the soil types reflects to a considerable degree the character of the underlying rock.

The geology of Wilson County was carefully mapped in the early 1930's by N. D. Newell in conjunction with compilation of the Geologic Map of the State of Kansas published in 1937. During this same period Newell (1933) made stratigraphic and faunal studies of several limestone units that crop out in Wilson County as part of his investigation of the stratigraphy and paleontology of the upper part of the Missourian Series in eastern Kansas. Interpretations of the faunal variations in strata of this series furnished data of considerable value in reconstructing depositional environments and the geologic history of Wilson County and the surrounding area. Other reports concerned with stratigraphic units in Wilson County contain the results of studies of

formations in the Lansing Group by Chelikowsky and Burgat (1947), Davis (written communication, 1955; 1959), Wilson (1957), Eastwood (1958), and Harbaugh (1959, 1960).

The most recent detailed maps of the northern parts of Wilson County were made by the author (Wagner, 1954, 1961) in conjunction with stratigraphic studies (Wagner and Harris, 1953). The results of those studies as well as results of a ground magnetometer survey by Hambleton and Merriam (1955) are incorporated in the present report. The chert gravel deposits in southeastern Wilson County were described by Davis in 1957.

Methods of Investigation

Field mapping in Wilson County was begun in July 1950 and completed in September 1953. Most of the longer stratigraphic sections were measured with a plane table and alidade; others were measured with a handlevel and steel tape. Collection of drillers' logs and dry-hole maps was begun in November 1950 and continued throughout the investigation. Drillers' logs were plotted graphically at a scale of 100 feet to 1 inch; the well locations were plotted on topographic base maps at a scale of 1:48,000 and contour interval of 20 feet; correlations between wells were based on key limestone beds; and cross sections, structural maps, and lithofacies maps of selected areas were prepared.

Formation contacts, coal outcrops and prospects, and other geologic data, as well as the locations of many of the productive and non-productive test wells were plotted in the field on aerial photographs at a scale of 1:20,000. These observations were later transferred from the photographs to the planimetric base map using a focalmatic vertical

projector. The base map was compiled from the Altoona and Fredonia topographic quadrangles, scale 1:62,500 of the U.S. Geological Survey, and from county maps obtained from files of the State Geological Survey of Kansas and the County Engineer of Wilson County.

Most of the megafossil identifications were made by the author in the field. A few were made in the office in consultation with paleontologists of the State Geological Survey and Department of Geology, University of Kansas. The microfossils were identified by the author and by other members of the U.S. Geological Survey.

Following local usage, the term shale is used for fine-grained, fissile, clastic rocks that break into thin, flattish plates upon weathering. The term is restricted to rocks consisting entirely of clay-size material, unless a size modifier is added. Rocks of comparable grain size that break into cuboidal fragments upon weathering are classed as claystone or siltstone, depending upon the dominant grain size. Color adjectives used in the report are from the Rock Color Chart (Goddard and others, 1948).

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Assessment and other records in the County Court House, Fredonia, and unpublished maps, measured sections, and other data in the files of the State Geological Survey of Kansas were helpful on many occasions.

## Geography

### Topography and drainage

Wilson County is in the Osage Plains section of the Central Lowland physiographic province of the Interior Plains physical division of the United States (Schoewe, 1949, p. 273, 276, and 280). The total relief in the county is slightly less than 375 feet. The highest point, about 1,125 feet altitude, is in the northern part of sec. 18, T. 28 S., R. 14 E., just south of State Highway 96; the lowest point, about 755 feet altitude, is in the bed of the Verdigris River at the south border of the county.

The general surface configuration of Wilson County is dominated by a series of northeast-trending, east-facing escarpments and intervening flat to gently undulating valleys. Each of these topographic units, termed cuestas, has two parts, an escarpment whose crest is capped by resistant limestone or sandstone, and a back slope underlain by weak shale. The base of the escarpment face is generally underlain by shale also. The abundance of these physiographic features led Schoewe (1949, p. 282) to propose an Osage Cuestas subdivision of the Osage Plains section. This subdivision includes the eastern four-fifths of Wilson County (see fig. 2); the western one-fifth of the county is in the Chautauqua Hills subdivision of Adams (1899, p. 60-61). The Chautauqua Hills are escarpment-faced low hills that are characteristically capped by sandstone upon which an abundant growth of black-jack-oaks occurs. The general impression in each physiographic subdivision is one of fairly low relief; the vertical difference between escarpment and valley seldom exceeds 200 feet. The escarpment fronts in both subdivisions are the result of differential erosion of low-dipping rocks of varying degrees of resistence.

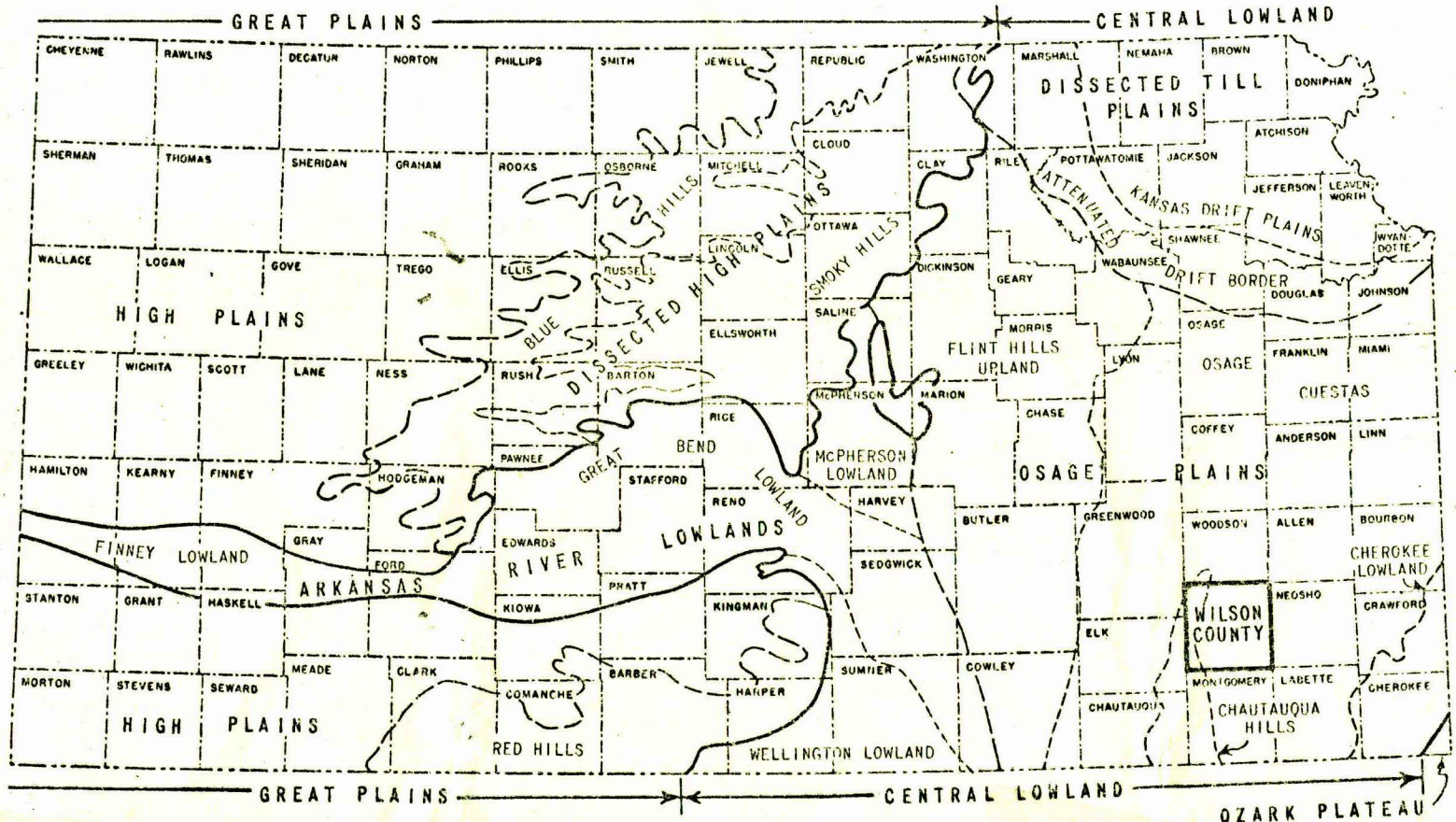



Figure 2.--Index map of Kansas showing the relation of Wilson County to physiographic subdivisions (after Schoewe, 1949, p. 276).

The topography of the county can be divided into four fairly distinct groups of landforms: (a) the high uplands or prairies, which are the cuesta uplands or the dip slopes of resistant limestone layers; (b) the broken, hilly country that extends from the borders of the uplands to the valley floors; (c) the sandstone hills, which are irregularly dissected and support a prominent jack-oak growth; and (d) the creek and river valleys, including the alluvial floors and terrace remnants. Although the uplands are chiefly dip slopes formed on limestone strata, the upland areas are covered in part with the shale that overlies the scarp-making limestone.

East and south of the bolder sandstone or limestone escarpments are erosional remnants of sandstone or limestone that project above the general level of the soft shale units. West Mound and South Mound at Fredonia, Three Mounds, Five Mounds, and Long Mound east of Altoona, and Buff Mound north of Neodesha are characteristic of such remnants.

An imaginary surface that connects the crests of the escarpments and mounds is very nearly a plane that dips gently eastward. Although hilltops locally extend above this surface, it probably represents part of an old erosional plain now being dissected by the southeastward-flowing Verdigris and Fall Rivers and their tributaries. Deposits of rounded chert that form indistinct gravel-strewn terraces at several levels along the larger streams and atop the cuesta surfaces attest to former drainages across the old erosional surface.

Nearly two-thirds of Wilson County is drained by the Verdigris River and its main tributaries, Ross Branch, Greathouse Creek, Sandy and Little Sandy Creeks, Buffalo Creek, Snake Creek, Little and Big Cedar Creeks, Chetopa Creek, and Dry Creek. Approximately one-fourth of the county southwest of the Verdigris River drainage basin is drained by the Fall River and its tributaries, Willow Creek, Rainbow Creek, Salt Creek, and Clear Creek. The remaining one-eighth of the county is drained to the southwest by the Elk River through its tributaries, Duck Creek and Sycamore Creek, and to the east by the Neosho River through Village Creek (see fig. 3).

The Verdigris and Fall Rivers head about 50 miles northwest of Wilson County in the Flint Hills Upland. Both rivers are nearly at grade in Wilson County and their flood plains are well developed. The valleys are from 1/10 mile to $2\frac{1}{2}$ miles wide; they are narrowest where they cross outcrops of thick limestone units and widest where they cross shale terranes. The valley bottoms are almost level and contain remnants of former river channels now occupied by lakes. Shafer Lake, between Benedict and Coyville, and six unnamed lakes are on the Verdigris River floodplain; two unnamed lakes are on the Fall River floodplain.

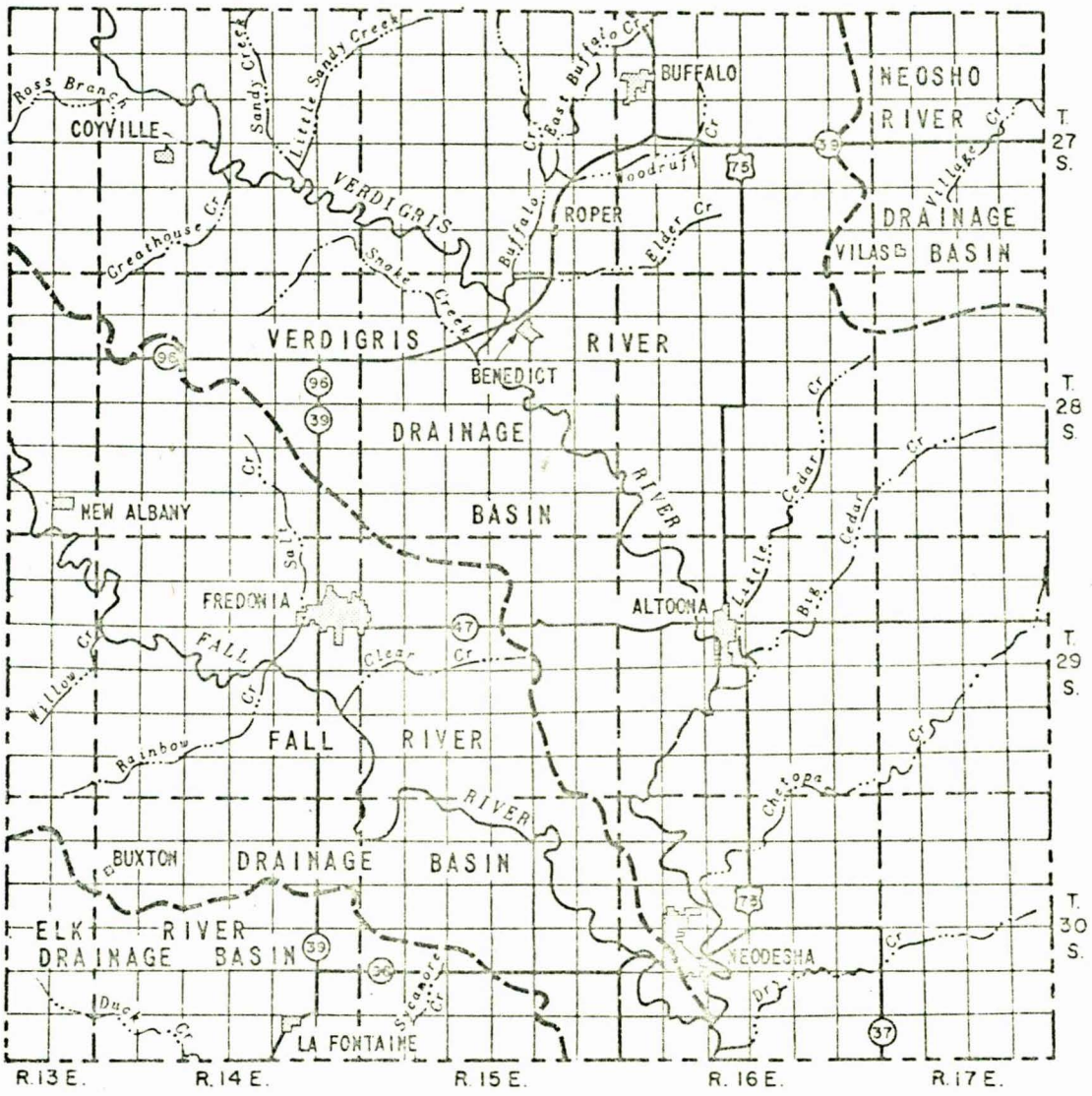
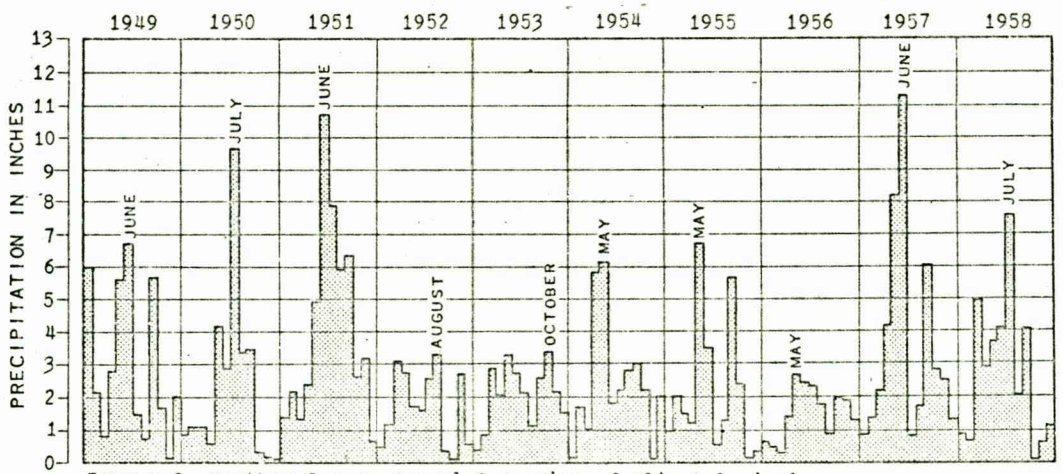



Figure 3.--Index map of Wilson County showing the general positions of drainage divides and areal extents of the drainage basins of the Verdigris, Fall, Elk, and Neosho Rivers.

Climate and Vegetation

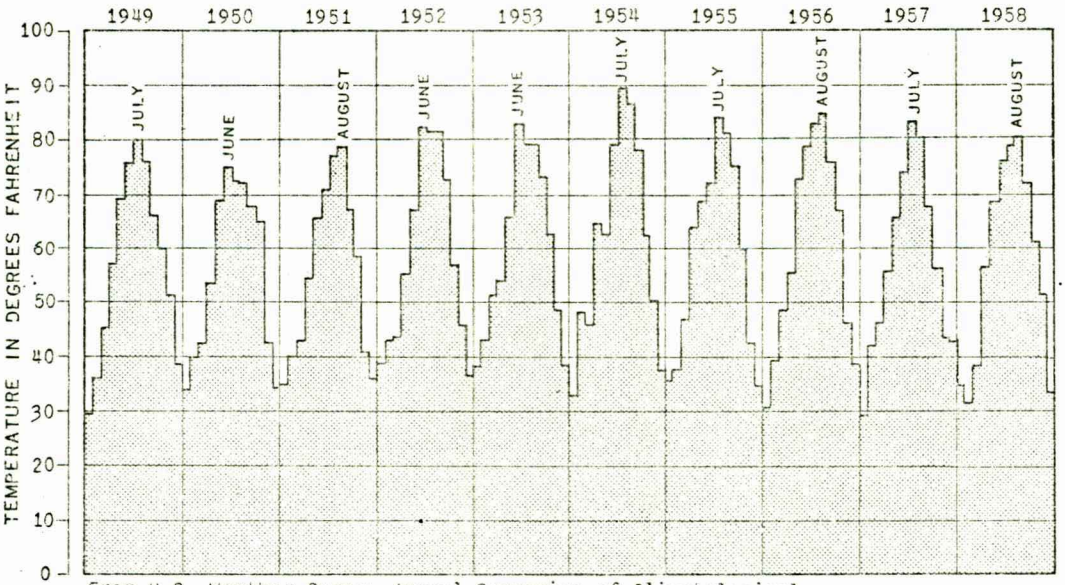
Wilson County has a humid climate characterized by moderate precipitation, reasonably mild winters, and fairly hot summers. The relative humidity is higher, the range between day and night temperatures is less, and the average annual precipitation is 10 to 15 inches greater than in the central or western parts of the State; the winters are milder and the growing season is longer than is general in areas of Kansas to the west and north (Flora, 1948, p. 1-2). Mean annual rainfall at Fredonia for the 10-year period 1949-1958 was 30.7 inches; the maximum precipitation generally occurred between May and July and the minimum between October and January (see fig. 4). The mean annual temperature for the same period was 58.0°F.; the highest temperature occurred between June and August and the lowest between December and February (see fig. 5).

The average annual precipitation at Fredonia, based on a 45-year record, is 35.15 inches, but it has ranged from a minimum of 18.15 inches in 1956 to a maximum of 55.24 inches in 1915 (see fig. 6). Much of the precipitation in Wilson County falls in relatively brief, heavy thunderstorms. The greatest rainfall recorded at Fredonia in a 24-hour period was 5.49 inches on September 23-24, 1945. The greatest snowfall in a 24-hour period was 13 inches on November 29, 1923.




From U.S. Weather Bureau Annual Summaries of Climatological Data. Month of maximum precipitation indicated

Figure 4.--Monthly precipitation at Fredonia, 1949-1958.




From U.S. Weather Bureau Annual Summaries of Climatological Data. Month of maximum temperature indicated

Figure 5.--Monthly mean temperature at Fredonia, 1949-1958.

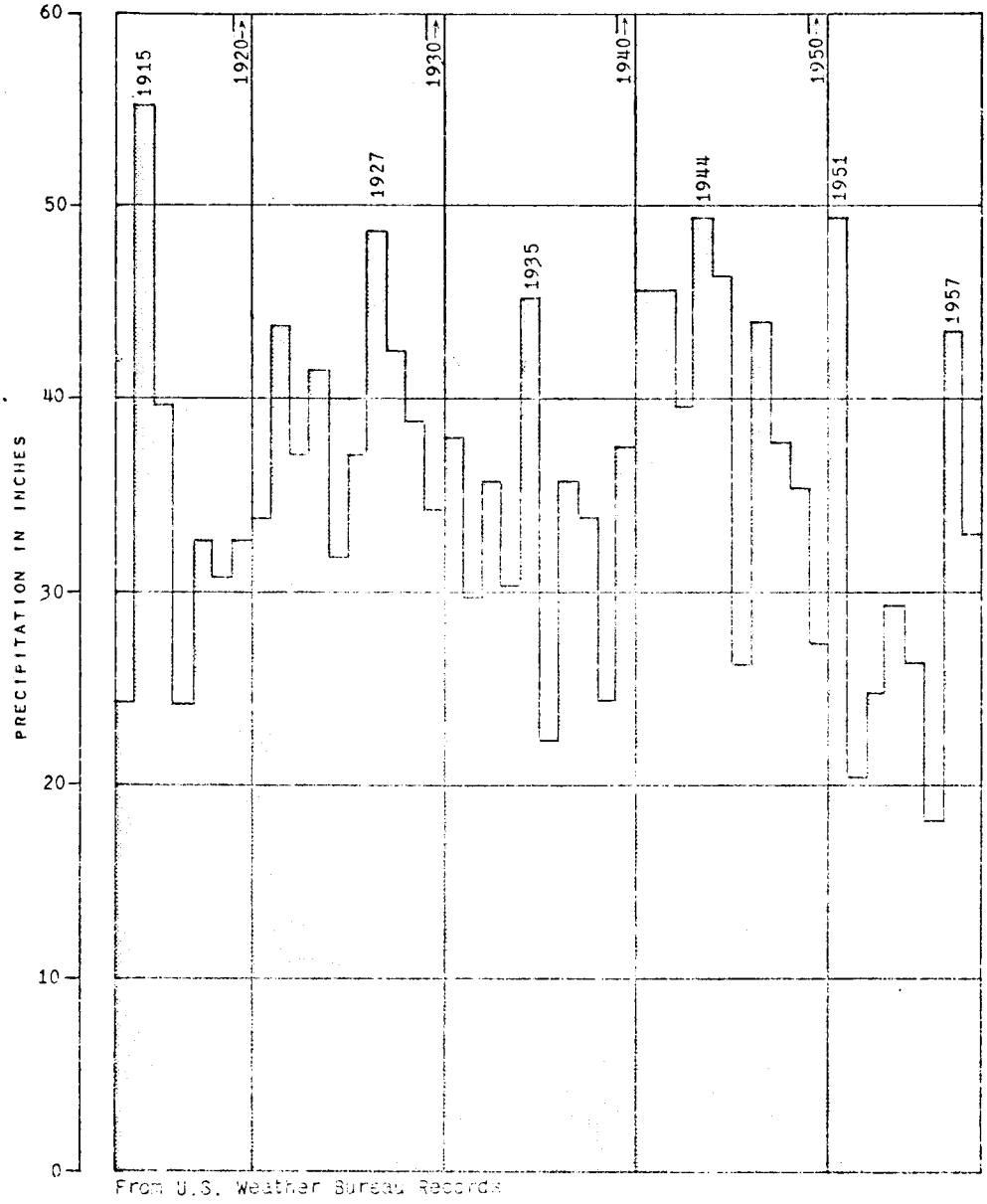



Figure 6.--Annual precipitation at Fredonia, 1914-1958.

~~heavy thunderstorms. The greatest rainfall ever recorded at Fredonia in a 24-hour period was 5.49 inches on September 23-24, 1945. The greatest snowfall in a 24-hour period was 13 inches on November 29, 1923.~~

The normal annual temperature at Fredonia is about 57.8°F. The normal monthly temperature ranges from a degree or two above freezing in January to 80 degrees in July. The highest temperature recorded was 121°F on July 18, 1936; the lowest temperature recorded was -26°F on February 13, 1905. The last killing frost of the year is generally in mid-April and the first is in mid-October, giving an average frost-free growing season of about 185 days.

Native vegetation in most of Wilson County is characteristic of the Osage Plains section of the Central Lowland. The large amount of rainfall, combined with fairly high temperatures during the summer months, produces an environment well suited to the natural growth of prairie grass, weeds, shrubs, and several varieties of hardwood trees. Grasses and weeds include rice cutgrass, yellow nutgrass, rush, waterhemp, smartweed, pigweed, morning-glory, beggartick, velvetweed, ragweed, lambsquarter, carpetweed, knotweed, and buffalo burr. The most abundant shrubs are sumac and buttonbush. Trees along the streams include blackjack oak, hickory, walnut, hackberry elm, soft maple, pecan, sycamore, ash, cherry, basswood, and some cedar and cottonwood. The sandstone of the Chautauqua Hills section in the western part of the county supports good stands of post oak and black oak with scattered blackjack oak, chinkapin oak, hickory, black walnut, and black cherry (Hale, 1955, p. 165-168).

## History, population, and industry

Wilson County is named for Hiero Tennant Wilson, one of the first white settlers in southern Kansas. The county was one of the thirty-odd counties laid out by the "bogus" legislature of 1855, but, being entirely within the reserve of the Osage Indians, it was not subject to white occupation at that time. As defined in 1855, Wilson County extended ~~somewhat~~ two miles more than eight townships north from the Oklahoma line and included all of the present Montgomery County and part of Woodson County. The legislature of 1867 removed the southern four townships, but the present boundaries of the county were not established until 1868, when the southern 2 miles of Township 26 South was placed in Woodson County (Andreas, 1883, p. 900; Gilmore, 1902, p. 818-819).

Apparently the first settlers in Wilson County were H. H. Opdike and G. J. and W. M. Caven, who settled near Coyville in April 1857. Probably more than 100 settlers had located in the county by 1860, even though the area was not removed from the Osage Indian Reservation and offered for sale until 1866. United States Census records for the county show 27 persons in 1860, 6,494 in 1870, and 13,776 in 1880. By 1880 the population was comparable to that of ~~modern~~ the present time. County records show the ~~The county~~ population ~~figures~~ for the 5-year period 1954 to 1958, inclusive, ~~are~~ to be 14,643, 14,818, 14,388, 14,236, and 14,098.

Fredonia and Neodesha, the largest towns in the county, had populations in 1958 of 3,373 and 3,959, respectively. Fredonia, the county seat, is centrally located in relation to the productive farming regions of the county and serves as the milling and storage hub. It is also the site of a large cement plant and a brick plant. Neodesha is

in the middle of the largest oil and gas field of the county and has the second largest refinery in southeastern Kansas. It also has a large crushed rock quarry. All other towns in the county had populations of less than 600 people in 1958; Altoona had 516, Buffalo had 389, Coyville had 144, New Albany had 126, Benedict had 121, and LaFontaine, Vilas, Buxton, and Roper were not reported separately. About 40 percent of the population of the county is rural.

Farming is the major occupation, and nearly 50 percent of the county was under active cultivation in 1958. Wheat, corn, and sorghum, with planted areas of 33,000 acres, 23,000 acres, and 17,000 acres, respectively, accounted for almost one-half of the total planted acreage. Other crop acreages were: barley, oats, and rye (listed in order of importance) about 26,000 acres; alfalfa, 9,000; other grains for hay, 13,000; soy beans, 3,000; and apples, peaches, pears, and cherries, 2,000. Pasturage for cattle and milk cows utilized about 40 percent of the arable land, 98,000 acres; and chicken and turkey farming was an important economic product locally. About 8 percent of the county is classed as waste land in county records.

In 1958, industries using mineral resources of the county produced about $7 million worth of goods. Schoewe (1959, p. 250) reports the value of mineral production in the county to be $6,430,262 in 1958, but this figure includes only the value of raw clay rather than that of the finished product. Commodities, in order of decreasing value, were cement, clay products, oil and gas, and stone products. Roughly 75 percent of the total mineral value produced was in cement manufacture, about 10 percent was in clay products, and slightly more

than 15 percent was in oil and gas and stone products. In 1958 the county had one cement plant, two brick plants, two rock products companies, and 339 oil properties. The refinery at Neodesha has (1958) a crude oil capacity of 23,100 barrels per calendar day.

## Accessibility

Three major rail lines, the Atchison, Topeka, and Santa Fe, the Missouri Pacific, and the St. Louis and San Francisco ~~railroads~~ cross Wilson County. Buxton, Fredonia, Benedict, and Vilas are all serviced by the Atchison, Topeka and Santa Fe through line; New Albany, Fredonia, and Neodesha are on the St. Louis and San Francisco through line; and Neodesha, Altoona, Benedict, Roper, and Buffalo are all on the through line of the Missouri Pacific, which has a branch line from Roper to Fredonia. Fredonia, thus, is at the intersections of the Atchison, Topeka and Santa Fe line and the St. Louis and San Francisco lines, and is the terminus of a branch line of the Missouri Pacific.

Wilson County has more than 100 miles of surfaced Federal and State highways. Fredonia, Neodesha, Altoona, and Buffalo are each serviced by at least two Federal or State highways (see Plate 1). U. S. Highway 75

In pocket

Figure 7. Areal geology of Wilson County, Kansas.

crosses the eastern half of the county from north to south and links Buffalo, Altoona, and Neodesha. State Highway 96 enters the county from the west, essentially connects Fredonia and Neodesha, and leaves the county at the south; State Highway 39 enters the county from the east, connects Roper, Benedict, Fredonia, and LaFontaine, and leaves the county at the south; State Highway 47 enters the county from the east, passes through Altoona, and terminates at Fredonia; and State Highway 37 enters the county at the southeastern corner and terminates at Neodesha. In addition, many miles of surfaced and well-graveled and graded county roads as well as a fairly complete network of maintained section-line roads make nearly all points in the county readily accessible by car throughout the year.

Stratigraphy*

Rocks that crop out in Wilson County range in age from Recent to Late Pennsylvanian; those penetrated in the subsurface by wells range in age from Late Pennsylvanian to Precambrian. The total thickness of the sedimentary sequence is about 2,700 feet.

Inasmuch as the petroleum industry makes a valuable contribution to the economy of Wilson County, it is anticipated that this report will be of particular interest to individuals or companies exploring for oil and gas. Therefore, the stratigraphy is discussed in the order it would be encountered in drilling; that is, from youngest to oldest.

Unconsolidated rocks of Quaternary and Tertiary age overlie Pennsylvanian strata and consist of alluvium in stream valleys and chert gravel at several levels above the flood plains of the major streams. Strata of the Pennsylvanian System consist of an alternating sequence of limestone, shale, and sandstone. The Mississippian rocks are dominantly cherty dolomitic limestone, the Mississippian and Devonian(?) strata comprise a thin, black shale and local basal sandstone, and the Ordovician and Cambrian rocks are dominantly dolomite. The recorded Precambrian rocks are mainly granite. Tabular bodies of basic igneous rock of presumed Cretaceous age intrude the sedimentary sequence in a few places.

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*Although this report is a cooperative product of the U.S. Geological Survey and the State Geological Survey of Kansas, the classification and nomenclature of the rock units is that of the State Geological Survey of Kansas and differs somewhat from that of the U.S. Geological Survey. Nomenclature changes made by the State Geological Survey of Kansas since 1960 have not been incorporated in this report.

Quaternary System

Pleistocene Series

Recent and Wisconsinan Stages

Stream valley alluvium.--Thick deposits of alluvium occur in the major stream valleys of Wilson County and constitute the most important fresh-water-bearing formation in the county. Thin alluvial deposits occur locally in nearly all stream beds of the county, but only the important occurrences in the valleys of the larger streams were mapped (Plate 1). These thicker alluvial deposits extend to depths as much as 50 feet below flood plain level and consist of poorly sorted gravel, sand, silt, and clay. Local sorting, characteristic of most flood-plain deposits, is common, and sand, silt, and clay are found laterally at the same stratigraphic position. The alluvial material is generally clay and silt in the upper part and grades downward through sandy silt to gravelly sand. Cobbles 2 to 5 inches in diameter occur in a few places near the base of the alluvium, and local concentrations of chert pebbles amid these cobbles suggest an origin from the Flint Hills to the west during the latest (Wisconsinan) stage of the Pleistocene Epoch.

Quaternary and Tertiary Systems

Pleistocene and Pliocene Series

Chert gravel deposits.--Remnants of chert gravel accumulations lying 15 to 260 feet above the present flood plains of the Verdigris, Fall, and Neosho Rivers are preserved in Wilson County. These remnants fall into four general groups lying 15 to 40 feet above flood-plain level, 50 to 120 feet above, 160 to 210 feet above, and about 260 feet above. The deposits of chert gravel, shown on the geologic map (Plate 1), were located during the course of detailed mapping of rocks of Pennsylvanian age and are believed to be representative of the distribution of the deposits. However, the chert gravel remnants may represent merely the thicker or more concentrated gravel accumulations of former streams, not former drainage systems as a whole. Also, local variations in depth of erosion and in thickness of gravel deposits filling the channels must have affected their chances of preservation. Furthermore, many of the evidences of these erosional and depositional activities are not immediately available for interpretation inasmuch as the bottoms of the deposits are rarely exposed, and the upper parts have largely been removed by erosion.

The origin of these gravel deposits has been the subject of speculation since 1885 when West (1885) attributed them to a marine invasion of Kansas in post-Permian time, possibly in the Age of Man. He postulated that the pebbles were rounded, distributed, and concentrated by wave and current action in a vast arm of an epicontinental sea. He believed that stream action could not account for the very wide distribution of the deposits. In 1896 Haworth (1896a) advanced the theory that the pebbles are residual products concentrated along the lines of outcrop of practically every chert-bearing limestone bed in the Carboniferous sequence as the less resistant materials were removed. He believed the rounding of pebbles and the large size of some deposits were due to a certain amount of downslope movement, transportation by streams, and abrasion by winds (Haworth, 1896a, p. 254, 255). Wooster (1915, p. 58) believed that the chert gravels are the resistant debris left behind in a 50- to 60-mile wide north-south belt as a result of the continual lowering of a vast peneplain surface in eastern Kansas since the close of the Paleozoic Era. Concomitant with the lowering of the surface was a shifting of the outcrops of these cherty lower Permian limestones 50 miles westward to their present outcrops in the Flint Hills. More recently authors have suggested that the chert gravels are remnants of former streams that flowed eastward and southward from an ancestral Flint Hills (Todd, 1918, p. 37; Moore and others, 1951, p. 17; Frye and Leonard, 1952, p. 184, and O'Connor, 1953, p. 7).

~~Gravel deposits 15 to 40 feet above flood plain.--~~ The youngest group of chert gravel terrace deposits in Wilson County lies approximately 15 to 40 feet above the present flood plains of the Verdigris and Fall Rivers. These deposits occur only near the present courses of the rivers and seemingly are related to a former base level of the drainage system. The distribution of the deposits indicates that the earlier stream valleys were probably broader than the present ones, and that the direction of flow perpendicular to the strike of the strata was already well established.

Deposits of the 15- to 40-foot group are generally less than 5, but locally as much as 15, feet thick. They consist of abundant subangular, grayish-orange ~~(10YR 7/4)~~ chert pebbles in a light-brown ~~(5YR 5/6)~~ matrix of clay and silt. Some chert pebbles contain fusulinids and brachiopods. Subrounded to rounded pebbles of sandstone of local origin as much as 5 inches in diameter occur with the chert pebbles which range in size from $\frac{1}{4}$ inch to 2 inches and average $\frac{1}{2}$ to 3/4 inch. The sandstone pebbles are light brown ~~(5R 5/6)~~ and very fine grained. Grains of fine- to medium-grained quartz sand are scattered throughout the matrix and locally form pods. Although generally abundant, the chert pebbles in some places occur only in thin lenses 1 to 5 inches thick, or are widely scattered through the deposit, which then constitutes a light-brown, pebbly, clayey siltstone.

of the 15- to 40-foot group

The deposits are assigned to the Illinoisan Stage of the Pleistocene Epoch based on ~~the basis of~~ their topographic position relative to the present flood plain, on their position relative to other chert gravel deposits, and on the greater percentage ~~amount~~ of pebbles of local derivation in these deposits as compared to those at higher levels ~~altitudes~~.

A somewhat higher sequence of chert gravel deposits, which locally grades downward into the 15 to 40-foot group, lies 50 to 120 feet above the flood plains of the Verdigris, Fall, and Neosho Rivers. The remnants of this sequence comprise the thickest and economically most important deposits in the county and occur only within the present drainage basins of the Verdigris and Fall Rivers except in the northeastern corner of the county where a small group of deposits lies east of and 40 or more feet below the drainage divide between the Verdigris and Neosho Rivers. This relation to the present topography precludes a past connection with the Verdigris River and indicates that the group must have accumulated in a meander of an ancient drainage system of the Neosho River.

The deposits are 3 to 20 feet thick and are lithologically similar to the lower chert gravels except that they contain less locally derived material. The chert pebbles are fairly well polished and subangular; the sandstone pebbles are subangular to subrounded (see fig. 7).

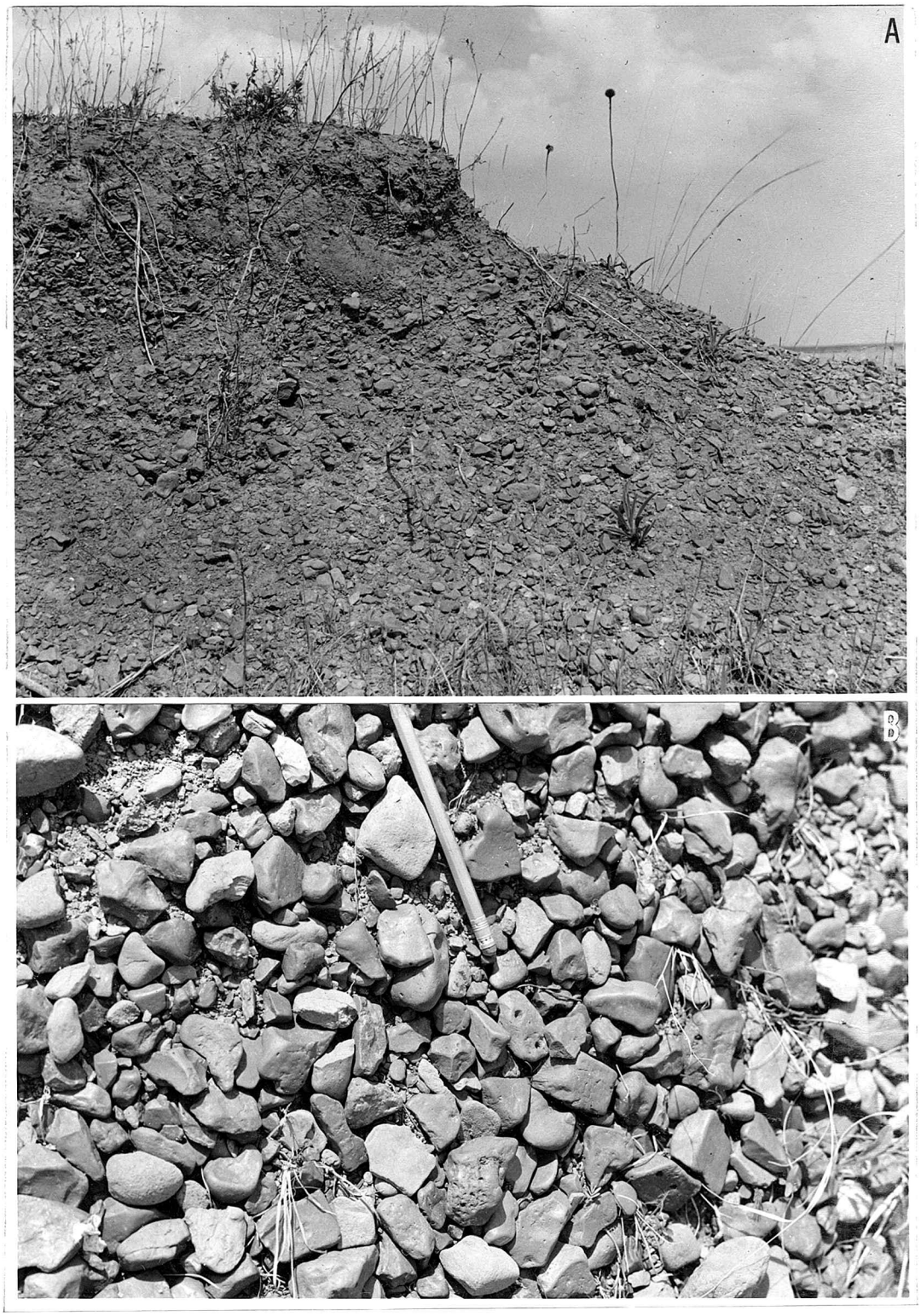


FIGURE 7.--Chert gravel deposit lying about 60 feet above flood plain of the Verdigris River. Near center sec. 19, T 28 S, R 15 E. (A) View of pit face; about 6 feet exposed. (B) Closeup of same face showing degree of roundness of chert and locally derived sandstone pebbles.

It seems probable that the drainage system represented by these deposits was established early in Pleistocene time and that the altitudes of the divide areas since then have confined all later drainage to essentially the same paths as are followed by the present rivers. The downward cutting through more than 100 feet of strata in a terrain made up of resistant limestones and sandstones and at the presumed low gradient of about 4 feet per mile would conceivably have taken many thousands of years. Later alluviation and development of a fossil soil zone in the deposits, as reported by Davis (1957, p. 249, 250), would have taken additional time. This fossil soil zone, developed on deposits that comprise his 60- to 80-foot terrace of Wilson and Montgomery Counties, is compared by Davis with a similar soil zone in the Emporia terrace in Lyon County which has been dated as Kansan in age on the basis of identification of teeth and other vertebrate remains as well as on the presence of a 3- to 4-foot lentil of Pearlette volcanic ash (O'Connor, 1953, p. 7). If Davis' statement (Davis, 1957, p. 250): "The soil color, texture, and composition are similar in both deposits and seem to be a valid basis for correlation" is warranted, the 50- to 120-foot deposits of Wilson County are also Kansan in age. Where thickest, the gravels in the lowest part of the terrace may include material deposited during an earlier stage, the Nebraskan stage of the Pleistocene epoch.

The chert-gravel deposits that lie 160 to 210 feet and 260 feet above the present flood plains of the Verdigris and Fall Rivers are similar in lithology to the lower deposits, except that they lack locally derived material. The deposits between 160 and 210 feet above flood plain are as much as 5 feet thick and consist of subrounded to subangular, grayish-orange chert pebbles in a matrix of light-brown clay and silt in which are scattered many fine- to medium-size sand grains. These deposits generally lie upon the upper surface of the resistant Stanton Limestone that forms the cuesta across the center of Wilson County, and their areal pattern bears little if any relationship to the present drainage system. The positions of the gravels on the tops of the hills and their general north-south trend in the central and eastern parts of the county suggest that the ancient river that transported them followed a meandering path along a strike valley between the thick limestone beds of the Stanton Limestone and the resistant sandstone beds of the Stranger Formation. The small deposit in the northeastern part of T 28 S, R 16 E, and several deposits in the southern part of T 26 S, R 17 E, in the southeastern corner of Woodson County less than one mile north of the Wilson County line (Wagner, 1961), suggest the presence of a parallel drainage system somewhat east of the Stanton escarpment at that time. The group of deposits that lies on the Oread Limestone near the western edge of the county at the same relative position above flood plain, suggests that other northeast-trending drainage systems were operative concurrently to the west.

The oldest chert gravels in Wilson County, about 260 feet above flood plain, lie at an altitude of 1,080 feet between the Verdigris and Fall Rivers in sec. 10, T29S,R15E. The deposit consists of 2 to 4 inches of moderately well-rounded, grayish-orange chert pebbles that are weathering out of a matrix of light-brown clay and silt in which are scattered many fine- to medium-size sand grains.

Inasmuch as no fossils have been found in the matrix of the two upper groups of chert gravels, an age assignment must be based upon other evidence. The pebbles of the higher gravels in eastern Kansas, with which the gravels in these two groups are believed to correlate, consist only of chert of types characteristic of the Herington and stratigraphically lower Permian limestones (Frye and Leonard, 1952, p. 184) and must either have been transported eastward 50 to 80 miles or have been subjected to erosion while 1,500 feet of underlying strata were removed. The chert pebbles characteristically have well-rounded corners, and the sand grains in the reddish clay matrix are also well rounded, implying transportation over a great distance or abrasion for a long period of time. Further evidence of their antiquity is provided by Frye who states (Frye and Leonard, 1952, p. 60): "The red clay matrix which fills the interstices of these gravels and the absence of limestone pebbles demonstrate that they have been subjected to prolonged weathering. In most exposures examined this red clay matrix persists through the entire thickness of the gravel and might be classed as the overthickened B horizon of an ancient soil."

The relationship of the higher chert gravels in several eastern Kansas counties to topography and to the outcrop area of the Herington and lower limestones in the Flint Hills region of Kansas is well stated by O'Connor who observed (1953, p. 7) that "the high-level chert gravels near their source beds in the Flint Hills occur in high relative positions of topography, but considerably lower than the highest elements of topography. As they are traced eastward their position in local topography becomes higher and higher. Easternmost chert gravel deposits in Anderson County, Kansas, occur on the highest topographic position of the area." The gravels occurring 160 or more feet above flood plain in Wilson County are atop the highest topographic features in the central part of the county and because of their position seem certainly to be closely related to similarly situated deposits in Allen, Anderson, and Coffey Counties.

As noted by Frye (1955, p. 83-84), the probability of a Tertiary age assignment for these higher chert gravels in eastern Kansas on the basis of topographic position can be fixed only by the sequence of younger terraces. The low Wiggam terrace is tentatively assigned an Illinoian age and the extensive Emporia terrace is securely dated as Kansan in age by its contained Pearlette volcanic ash, vertebrate fossils, and sequence of buried soils and loesses on its surface. Reconnaissance of the east-central Kansas region indicates that three terrace levels at approximately 75, 95, and 150 feet above adjacent flood plains have persistence well beyond Chase and Lyon Counties, and that a fourth level at 250 to 300 feet above adjacent flood plains is

to be correlated with the gravels of the highest divides farther east. From these data Frye reasoned (1955, p. 84) that there are two or perhaps three cycles of Tertiary erosion and alluviation, and since the bedrock involved is all Pennsylvanian and Permian in age, he believed that it was permissible to contrast 40 feet of post-Kansan bedrock incision against approximately 250 feet of pre-Kansan post-highest chert gravel bedrock incision. He concluded that the erosional history of the present topography probably started early during the Tertiary (or earlier) and records three and perhaps four cycles of erosion and alluviation during Tertiary time as well as three and perhaps four during Pleistocene time. Thus, although the upper gravels in Wilson County lack fossils, a probable Tertiary age is suggested by the roundness of the pebbles and sand grains, their deeply weathered matrix, and their topographic position.

Pennsylvanian System

The Pennsylvanian System in Wilson County contains strata of 2 ~~stages~~ series divisions, 5 groups, and 13 formations (see ~~Fig. 9~~ Table 1). The system is characterized by sequences of shale, limestone, and sandstone that represent alternating marine and nonmarine depositional environments during successive advances and retreats of the Pennsylvanian sea. Each complete sequence represents a cycle of deposition or cyclothem (Wanless and Weller, 1932, p. 1003). Some of the limestone units in the county reflect a marine transgression and regression within themselves and, together with other units, form a larger cyclic sequence termed a megacyclothem (Moore, 1936, p. 29). The cyclic deposits of Pennsylvanian age in Kansas were thoroughly discussed by Moore (1936, 1949), who presented typical schemes of cyclic deposition for beds in different parts of the Kansas Pennsylvanian and Permian sequences. Although the Pennsylvanian strata in Wilson County do not exactly fit Moore's typical cyclic scheme, they have most of its essential characteristics. Six megacyclothems ~~(Fig. 10)~~ are represented in the outcropping rocks of Wilson County.[1]

Table 1 members

[1] A report published in Kansas Geol. Survey Bull. 169 (1964, pp. 565-591) and titled "Pennsylvanian megacyclothems of Wilson County, Kansas, and speculations concerning their depositional environments" supplements the data given herein.

| SYSTEM | SERIES | GROUP | SUBGROUP | FORMATION | MEMBER |
|---|---|---|---|---|---|
| PENNSYLVANIAN SYSTEM | Virgilian Series | SHAWNEE GROUP | | Oread Limestone | Plattsmouth Ls Mbr |
| | | | | | Heebner Sh Mbr |
| | | | | | Leavenworth Ls Mbr |
| | | | | | Snyderville Sh Mbr |
| | | | | | Toronto Ls Mbr |
| | | DOUGLAS GROUP | | Lawrence Shale | Unnamed sh mbr |
| | | | | | Amazonia Ls Mbr |
| | | | | | Ireland Ss Mbr |
| | | | | Stranger Formation | Robbins Sh Mbr |
| | | | | | Haskell Ls Mbr |
| | | | | | Vinland Sh Mbr |
| | | | | | Westphalia Ls Mbr |
| | | | | | Tonganoxie Ss Mbr |
| | Missourian Series | PEDEE GR | | Weston Shale | — — — |
| | | LANSING GROUP | | Stanton Limestone | South Bend Ls Mbr |
| | | | | | Rock Lake Sh Mbr |
| | | | | | Stoner Ls Mbr |
| | | | | | Eudora Sh Mbr |
| | | | | | Captain Creek Ls Mbr |
| | | | | Vilas Shale | — — — |
| | | | | Plattsburg Limestone | Spring Hill Ls Mbr |
| | | | | | Hickory Creek Sh Mbr |
| | | | | | Merriam Ls Mbr |
| | | KANSAS CITY GROUP | ZARAH | Lane-Bonner Sprs Sh | — — — |
| | | | LINN | Iola Limestone | Raytown Ls Mbr |
| | | | | | Muncie Creek Sh Mbr |
| | | | | | Paola Ls Mbr |
| | | | | Chanute Shale | Cottage Grove Ss Mbr |
| | | | | | Unnamed Sh Mbr |
| | | | | Drum Limestone | — — — |
| | | | | Cherryvale Shale | — — — |
| | | | BRONSON | Dennis Limestone | Winterset Ls Mbr |

TABLE 1. Nomenclature of the outcropping Pennsylvanian rocks of Wilson County.

Virgilian Series

The Virgilian Series is the uppermost large time-stratigraphic unit in the Pennsylvanian rocks of Kansas. The name was taken from the town of Virgil, Greenwood County, about 20 miles to the north of Wilson County and was first used in a chart by Moore in 1931. As first defined (Moore, 1932, p. 88), it included all strata between the unconformity at the base of the Americus Limestone (Admire Group of Permian age) and the base of the Stranger Formation (Douglas Group of Pennsylvanian age). Moore redefined the upper boundary in 1936 (Moore, 1936, p. 142-143) and placed it at the unconformity at the base of the Towle Shale (Admire Group, Wolfcampian Series); the lower boundary remains as originally defined. Although no profound unconformity or distinct faunal break occurs in the rocks at the boundary between the Virgilian and Wolfcampian Series, the boundary is placed at the unconformity at the base of the Towle Shale because: (a) this unconformity is the most widespread and represents the deepest erosion of any in that section of strata, (b) this unconformity lies only slightly below the lowest strata containing Pseudoschwagerina, and (c) the lithologic characteristics of the beds above the unconformity are similar to each other and are very different from those below (Moore, 1940b, p. 303).

Evidence for a time break between strata of the Virgilian and Missourian Series is based upon both faunal and diastemic criteria. A pronounced evolutionary break occurs among the Triticites of Kansas at the unconformity between the Virgilian and Missourian Series (Moore and Thompson, 1949, p. 299). Furthermore, certain brachiopod and pelecypod species are generally restricted to or are characteristic of rocks of Virgilian age and may be considered as index fossils of the series (Moore, et al., 1944, p. 675-676).



pages 35 - 39 deleted

Unconformities also record this time break in the Midcontinent region. An angular unconformity separates Virgilian and Missourian rocks in the Ardmore basin; thick conglomerates and prevalent red-beds characterize the Virgilian-Missourian break in central Oklahoma; and erosional channels, cut as deep as 100 feet into Missourian strata, are filled with basal Virgilian sandstone in north central Texas, southern Oklahoma, and eastern Kansas (Moore, 1932, p. 88; Dott, 1941, p. 1662-1676). The locally pronounced unconformity at the base of the Virgilian in eastern Kansas is represented by sandstones and locally derived conglomerate of the Tonganoxie sandstone member of the Stranger formation that fill channels eroded 20 to 100 feet into the underlying strata (Moore, 1936, p. 147-150; Patterson, 1933, p. 13; Newell, 1935, p. 80; Lins, 1950, p. 130-136; Wagner and Harris, 1953, chart). ~~In certain areas, however, as in eastern Elk County and~~ however, In western Wilson County, the break in sedimentation between basal Virgilian sandstone and uppermost Missourian shale is obscure and may not be present ~~(Wagner, 1951, p. 38)~~ (Wagner and Harris, 1953, chart). Nevertheless, this unconformity is generally of such magnitude ~~however~~ that, when viewed in conjunction with the faunal evidence, it appears to be the best horizon to use as a dividing line between strata of Virgilian and Missourian age.

In Wilson County the upper 750 feet of strata of the Virgilian series is missing and the series is represented by about 280 feet of predominantly argillaceous strata assigned to the Oread limestone, Lawrence shale, and Stranger formation. The contact with rocks of the Missourian series is locally unconformable, but over much of the outcrop area it is gradational.

## Shawnee group

The youngest (uppermost) rocks of Pennsylvanian age in Wilson County are in the lower part of the Shawnee group which is typically exposed in Shawnee County about 90 miles to the north. Haworth (1898a, p. 93), in naming and defining the Shawnee "formation," included all strata "from the Oread limestone upward to the summit of the Osage ~~[formation]~~ shales." Moore revised the nomenclature of the group in 1931 and placed in it all strata between the base of the Oread limestone and the top of the Topeka limestone (Moore, 1931, chart). As thus defined, the Shawnee group consists of alternating thick limestone units and thick shale units that are readily distinguished from the underlying beds by lithology and from the overlying beds by the greater preponderance of limestone and the more complex but clearly repetitive sequence of cyclical units (Moore, 1949, p. 139-143).

The Shawnee group contains the following formations listed from youngest to oldest (downward): Topeka limestone, Calhoun shale, Deer Creek limestone, Tecumseh shale, Lecompton limestone, Kanwaka shale, and Oread limestone. Of these, only the Oread limestone is present in Wilson County.

## Oread limestone

Naming, distribution, and thickness.--The Oread limestone was named by Haworth (1894, p. 123) for exposures at Mount Oread, the site of the University of Kansas at Lawrence. Only the lowermost limestone unit of this report, the Toronto limestone member, was included in the Oread formation as originally defined, but subsequently Haworth (1895a, p. 278; 1895b, p. 461), Bennett (1896, p. 114-116), and Moore (1936, p. 160) extended the formation to contain six additional thin shale and limestone units. The Oread limestone now contains seven members, listed in descending order: the Kereford limestone member, the Heumader shale member, the Plattsmouth limestone member, the Heebner shale member, the Leavenworth limestone member, the Snyderville shale member, and the Toronto limestone member (see Table 1).

In Wilson County, the Oread limestone crops out only in the extreme northwestern part, where it caps high topographic prominences. Its outcrop belt, however, extends more than 300 miles northeast into Missouri, Iowa, and Nebraska and southwest 50 or more miles into Oklahoma.

The outcrop characteristics and thicknesses of the members of the Oread limestone are different in the northern and southern parts of the belt. In northern Kansas the shale members are moderately thin, and the limestone members ~~from~~ form subordinate benches on a single prominent escarpment (Moore, 1936, p. 162). In the southern part of the state the upper and lower shale members are much thicker, and the outcrop is marked by two relatively prominent escarpments separated by a distance of 1 to 3 miles. At the type locality, the thickness is about 45 feet (Moore, 1936, p. 161), but in Wilson County and immediately adjacent area the entire formation is about 130 feet thick (Wagner and Harris, 1953; Wagner, 1954). The limestone members of the Oread have been traced continuously from northeastern Kansas to Wilson County, and correlation with the type area established.

Lithologic character.--Due to the greater thickness of the upper and lower shale members, the Oread limestone in Wilson County is not the predominantly limestone unit that occurs at the type locality, but the formation is bounded by limestone units in the Wilson County vicinity also, and therefore, the lithologic term "limestone" is retained in ~~its~~ the name.

The upper two members of the Oread limestone, the Kereford limestone member and the Heumader shale member, have been removed by erosion from Wilson County but are present within 1½ miles of the northwest corner of the county (Wagner, 1954). The uppermost member, named the Kereford limestone member by Condra (1927, p. 45), is typically exposed at the Kereford quarry near Atchison, Kansas, about 120 miles to the north (Moore, 1936, p. 168). In the type area the Kereford is a "dense, somewhat arenaceous, in part oolitic and quite fossiliferous" limestone (Condra, 1927, p. 45); these characteristics are also found in an exposure immediately northwest of Wilson County, where the member consists of 6 feet of hard, sandy, algal (oolitic?), fossiliferous limestone with a clayey limestone interbed (Wagner and Harris, 1953; Wagner, 1954). The Heumader shale member, which conformably underlies the Kereford, was named for the Heumader quarry near St. Joseph, Missouri, about 140 miles to the north (Moore, 1932, p. 94, 96). Near Wilson County it is much thicker than in the type area and consists of about 50 feet of partly fossiliferous, concretionary, silty shale (Wagner and Harris, 1953; Wagner, 1954) with several siltstone and limestone interbeds. The remaining five members of the Oread crop out in the county and are discussed in greater detail below.

Plattsmouth limestone member.--First published use of the term Plattsmouth limestone was by Keyes (1898, p. 349) who gave the name to a limestone unit 30 feet thick near Plattsmouth, Nebraska. The term has since been restricted to the main limestone unit of the Oread, and therefore includes only part of the limestone sequence near Plattsmouth (Moore, 1936, p. 167).

The only remnants of the Plattsmouth limestone member in Wilson County are three small separated outcrops in sections 23 and 26, T. 27 S., R. 13 E., (see Plate 1). The unit is well exposed to the west in Greenwood and Elk Counties, where it is the thickest limestone member of the Oread, locally forms the caprock of ridges and dip-slopes, and ranges in thickness from 5 to 10 feet (average about 7 feet). Its most distinctive feature in the Wilson-Greenwood-Elk County area is a wavy-bedded appearance, well displayed along clifflike exposures (see Fig. 8A).

Figure 12. Plattsmouth limestone member of the Oread limestone in sec. 21, T. 29 S., R. 13 E.

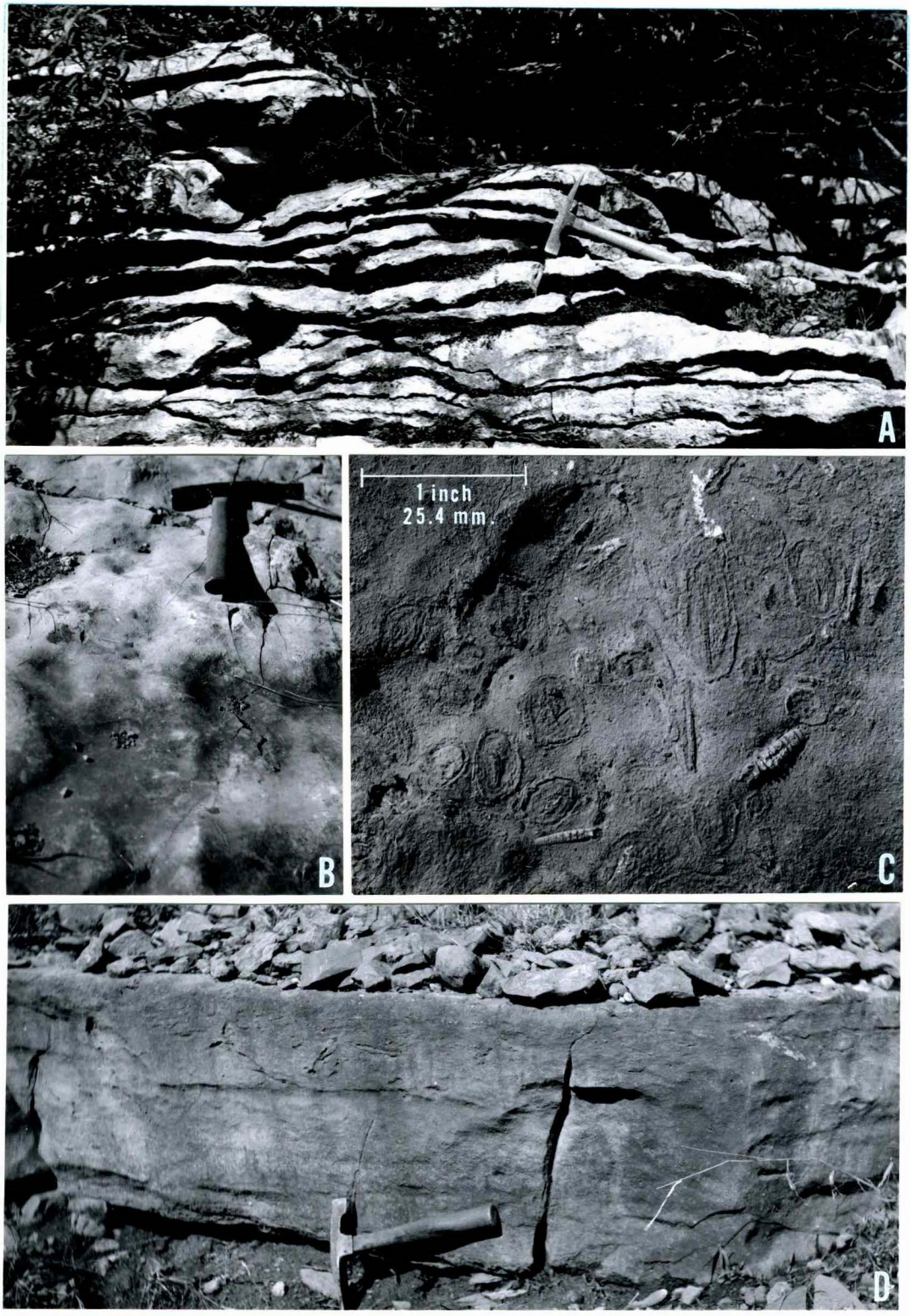


FIGURE 8.--Plattsmouth and Leavenworth Limestone Members of the Oread Limestone. Sec. 21, T 29 S, R 13 E. (A) Cliff-like exposure of the Plattsmouth showing wavy-bedded appearance. (B) Upper surface of wavy bed of Plattsmouth. (C) Weathered surface of Leavenworth showing algal bodies and crinoid remains. (D) Outcrop exposure of Leavenworth showing vertical joints.

The uppermost part of the Plattsmouth is a mottled-appearing limestone bed about 2½ inches thick. It is made up of intermixed, irregularly shaped fragments of cryptocrystalline, very light brownish-gray (5YR7/1) limestone and very fine-crystalline, light-brownish-gray (5YR 6/1) limestone. Thin seams (1/50 inch) of olive-gray (5Y4/1), crystalline calcite separate the rock into ¼- to ½-inch segments. Many of these curvilinear seams resemble cross-section views of brachiopod or pelecypod shells but have none of the internal or external features of such shells; other seams have very irregular shapes. The only recognizable fossils in the limestone are sparse small foraminifers, some of which are filled with radially oriented calcite.

Immediately underlying the mottled-appearing limestone is a very light-gray (N8), very fine-crystalline, fossiliferous limestone bed that generally weathers almost white but is locally speckled with small orange spots of iron oxide (limonite). The bed is about 5 inches thick and contains abundant fusulinids (Triticites) in a few exposures; in many other exposures both articulated and broken valves of brachiopods are abundant. The most common and best preserved brachiopods are Enteletes plattsmouthensis Newell and Marginifera cf. M. wabashensis (Norwood and Pratten).

The remaining 9 feet of the Plattsmouth member consists of 2- to 4-inch wavy beds of light-gray (N7), fine- to very fine-crystalline, fossiliferous limestone. Locally, some of the beds are medium-crystalline (almost saccharoidal) and light pinkish gray (5YR9/1). Fossils in this part of the member include the brachiopods Enteletes, Marginifera, Neospirifer, Crurithyris, Dictyoclostus, and Composita, a lophophyllidid coral, ramose and encrusting bryozoans, echinoid spines, small gastropods, and ~~the ubiquitous~~ crinoid stems.

The upper surfaces of the beds in the lower 9 feet of the member are irregular and resemble oscillation-type ripple marks (fig. ~~14~~ 8B). These irregular upper surfaces apparently contribute to the wavy bedding, but many of the irregularities shown ~~in~~ on figure ~~14~~ 8A cannot be explained by an irregular upper surface alone, and may largely reflect lithologic variations at the time of sedimentation. Small concentrations of clay ~~(kaolin)~~ in the most deeply weathered beds apparently make the rock more susceptible to weathering. Strains brought about by shrinkage during diagenesis may also have played an important part in the development of the wavy bedding for, as shrinkage during lithification took place, the rock probably adjusted along these clayey separations, and channelways were formed along which water could later diffuse and percolate. Other irregularities unrelated to clay concentration may be entirely the result of ~~such~~ shrinkage.

Heebner shale member.--The Heebner shale member was named for exposures on Heebner Creek and on the Heebner farm near Nehawka, Nebraska, where the unit is about 5 feet thick and where "the top portion of the bed is bluish and argillaceous; the lower portion is black, finely bedded, and somewhat carbonaceous" (Condra, 1927, p. 37). The Heebner is poorly exposed in Wilson County, where its outcrop position is generally covered by float from the overlying Plattsmouth limestone member. Where exposed, however, the Heebner conformably underlies the Plattsmouth and consists of about 6 feet of shale, the upper two-thirds of which is light olive gray (5Y5/2) and the remainder grayish black (N2). The upper part of the Heebner is calcareous and fossiliferous near the contact with the Plattsmouth and also in the transitional zone between the gray and black parts. The fossils consist of the brachiopods Crurithyris, Hustedia, Punctospirifer, Chonetes, Chonetina, and Enteletes amid many unidentifiable shell fragments and crinoid and bryozoan remains.

The lower 2 to 3 feet of the Heebner is a nearly black, very fissile, conodont-bearing shale that breaks upon weathering into paper-thin plates as much as 3 inches across. Finely comminuted plant remains are abundant on bedding planes in a few places. Small (1 to 2 inch) phosphatic concretions are found locally in the central part; the $P_2O_5$ content of the concretions is as much as 32 percent (Runnels and others, 1953, p. 98). Conodonts identified by L. D. Harris (Wagner and Harris, 1953) from the Heebner in Wilson County and the immediately adjacent area include Cavusgnathus, Hindeodella, Idiognathodus, Lonchodus, Ozarkodina, Streptognathodus, and Trichognathus. Other microfossils identified are the foraminifers Ammodiscus, Cornuspira, and Tetrataxis, and the ostracods Bairdia and Cavellina. Unidentified small fragments of bryozoans, brachiopods, and crinoids are present also.

Leavenworth limestone member.--The Leavenworth limestone member was named for a roadcut exposure northwest of the Federal Penitentiary at Leavenworth, Kansas (Condra, 1927, p. 38). At the type locality the Leavenworth is a dark-gray, dense, vertically jointed, fossiliferous limestone whose thickness averages about 2 feet. In Wilson County the Leavenworth ranges from 1.4 to 1.8 feet in thickness and is a medium dark-gray (~~N4~~), very fine-crystalline, fossiliferous limestone that is vertically jointed (Fig. ~~13,A~~ 8,D). The fresh rock characteristically breaks with a musical ring. Fossil remains etch out in relief on the pale-yellowish-brown (~~10YR6/2~~) weathered surface, and in many exposures the most distinctive feature of this surface is the presence of numerous dark, oval-shaped algal bodies that range in length from $\frac{1}{2}$ to $1\frac{1}{2}$ inches and in width from 3/8 to 5/8 inches (Fig. ~~13,B~~ 8,C). The algae consist of irregular concentric layers around brachiopod shell fragments, crinoid columnals, horn corals, or other shell fragments. Small unbroken shells of fusulinids and fragments of larger shells have been enclosed in the outer algal layers in some bodies. Many fossil fragments are not enclosed in algal growths, however.

Figure 13. Leavenworth limestone member of the Oread limestone in sec. 21, T. 29 S., R. 13 E.

In thin section the fine crystalline matrix is seen to be composed of a mixture of 0.02 mm crystalline calcite in which are enclosed small foraminifers (1 to 2 mm), polites ($\frac{1}{2}$ to 2 mm), and small rounded shell fragments (1 to 2 mm). The large shell fragments are coarse crystalline calcite or aragonite; calcite is by far the most common. Fine crystalline calcite permeates the algal growths, which are composed of crenulated, roughly parallel dark and light layers. The algae encase large shell fragments as much as 30 mm in length and resemble most closely Johnson's descriptions and figures of Osagia colonies (Johnson, 1946, p. 1103, and pl. 5, fig. 5) but have been called Cryptozoon and Ottonosia. Other fossil remains in the Leavenworth consist of lophophyllidid corals, echinoid spines and plates, crinoid columnals, pelecypods, gastropods, small Triticites, and brachiopods represented by the genera Marginifera, Derbyia, Composita, Juresania, and Linoproductus. Insoluble residues contain many fragments of arenaceous Foraminifera.

An inch-thick fossiliferous granulite bed occurs at the base of the Leavenworth in many exposures. Unbroken shells of brachiopods and large pelecypods are enclosed in a light-brownish-gray (5YR6/1) matrix of subangular to rounded granules of limestone. Orthomyalina and Juresania are abundant in the matrix and are generally oriented concave side down.

Snyderville shale member.--The Snyderville shale member was named by Condra (1927, p. 38) for exposures just east of the Snyderville quarry near Nehawka, Nebraska. In the type area it consists of about 12 feet of argillaceous shale; the upper part is bluish-gray, the lower part is reddish-brown. In Wilson County the Snyderville is much thicker and averages about 50 feet (see Plate 2, A).

Figure 14. Correlated sections of the Oread limestone, Stanton limestone, Plattsburg limestone, and Iola limestone in Wilson County.

The uppermost foot of the member is light-olive-gray (5Y6/1), calcareous shale in which fossils are abundant in a few localities. The fauna indicates a marine environment and includes the brachiopods Chonetes and Dictyoclostus, the mollusks Astartella and unidentified gastropods, the ostracods Amphissites, Bairdia, Cavellina, and Hollinella, the foraminifers Tetrataxis and Triticites, the algae Osagia, as well as echinoid spines, crinoid columnals and plates, ramose bryozoan fragments, and unidentified conodont remains. Fossils were not observed in the remainder of the Snyderville, and this, in conjunction with its reddish-brown color, is suggestive of nonmarine deposition for ~~the lower part.~~ all except the uppermost foot.

The next older 15 feet of the Snyderville is predominantly dark reddish-brown (~~10R3/4~~), slightly silty claystone with lenticular interbeds of pale greenish-gray (~~5GY7/1~~), silty claystone ~~interbedded~~. Irregular-shaped calcareous nodules, which are usually stained reddish brown on their outer surfaces and are brown, red, green, or white within, are locally abundant in the reddish-brown phase. A foot-thick bed of light greenish-gray (~~5GY7/1~~), calcareous siltstone occurs about 10 feet below the top of the unit; its upper surface has ~~criss-cross~~ markings that resemble mud cracks.

The middle 20 feet of the Snyderville consists predominantly of pale-greenish-gray (5GY7/1) silty claystone in which discontinuous dark-reddish-brown (10R3/4) areas are locally abundant. The reddish-brown coloration has no bedded arrangement but appears as large irregular masses. Dark-yellowish-orange ironstone concretions, ½ to 3/4 inch in diameter, are locally common. This irregularly colored unit is generally bounded above and below by locally calcareous, pale-greenish-gray (5GY7/1) to yellowish-gray (5Y7/2), very fine-grained, silty sandstone and siltstone. The upper of these beds is 5 to 7 feet thick and is composed of well-sorted, very fine-grained to silt-size, subangular quartz grains that are locally cemented with calcium carbonate. Two, and locally three, lenticular sandstone beds occur at or near the base of the middle claystone unit. The beds are yellowish-gray (5Y7/2), locally finely micaceous and calcareous, 6 to 10 inches thick, and are composed mainly of well-sorted, very fine-grained quartz. Ripple-marks and worm tracks(?) are locally common, and plant fragments were noted at one locality.

The lower 15 feet of the Snyderville consists predominantly of pale-greenish-gray (5GY7/1) silty claystone in the upper one-third and dark-reddish-brown (10R3/4) claystone in the lower two-thirds. Thin discontinuous lenses of reddish-brown claystone occur in the upper one-third, and large irregular greenish-gray areas occur in the lower two-thirds.

Toronto limestone member.--The Toronto limestone member was named by Haworth and Piatt (1894, p. 117) from exposures near the town of Toronto, Woodson County, about 5 miles north of the Wilson County line. ~~The name fell into disuse, but was revived by Moore (1936, p. 162-163) for the basal member of the Oread limestone.~~ The Toronto ranges from 2 to 7 feet in thickness and averages about 3 feet. It underlies the Snyderville shale Member with apparent conformity.

The Toronto is quite variable in lithology and fauna. The upper half of the member is commonly very light olive-gray (5Y7/1) or very pale yellowish-brown (10YR7/2) limestone that is very fine crystalline and weathers olive gray (5Y6/1) or moderate yellowish brown (10YR5/4). This upper part generally contains very abundant crinoid stems and less abundant crinoid pinnules and calyx parts, ramose and fenestrate bryozoans, broken valves of Neospirifer and Derbyia, other brachiopod fragments, productid spines, sparse lophophyllidid corals, and locally abundant fusulinids (fig. 9,A). In a few places the upper foot has a brecciated appearance in which angular fragments of dark-yellowish-orange (10YR6/6) argillaceous limestone occur in a groundmass of very pale-orange (10YR8/2) limestone. In this same unit many irregular, sinuous, dark-gray (N3) areas, probably the algae Cryptozoon, are conspicuous on weathered surfaces. The Cryptozoon(?) occur as irregular layers formed around crinoid columnals, horn corals, and other fossil fragments ½ inch to 2 inches in length. In a few exposures the uppermost part of the Toronto is a light-brown (5YR5/6), sandy, sparingly fossiliferous limestone that weathers to nodular masses.

Figure 15. Toronto limestone member of the Oread limestone at the center of the west line of sec. 36, T. 27 S., R. 13 E.

FIGURE 9.--Toronto Limestone Member of the Oread Limestone and upper and lower parts of the Lawrence Shale. (A) Weathered surface of the upper fusulinid-rich part of the Toronto. Center of west line sec. 36, T 27 S, R 13 E. (B) Weathered surface of the lower fusulinid-rich part of the Toronto at same locality. (C) Williamsburg coal (at pick) in the upper part of the Lawrence Shale separated from the base of the Toronto by calcareous shale. Near center NE$\frac{1}{4}$ sec. 23, T 27 S, R 13 E. (D) Cross bedding in the Ireland Sandstone Member of the Lawrence Shale. Near center NW$\frac{1}{4}$ sec. 25, T 27 S, R 13 E.

The lower half of the Toronto is principally a fine- to medium-grained, yellowish-gray (5Y8/1) to very pale yellowish-brown (10YR7/2), very fossiliferous limestone that weathers yellowish gray (5Y7/2) to dark yellowish brown (10YR4/2). The wavy-bedded character of this part of the member is emphasized by weathering. Fossils occur throughout, but the fossil content varies in type and abundance both horizontally and vertically. Locally, as in sec. 36, T. 27 S., R. 13 E., single beds in the lower part of the member are made up almost entirely of fusulinids (fig. 9,B), and in sec. 23, T. 27 S., R. 13 E., the rock is largely coralline growths. The fauna of the lower part of the Toronto contains many fusulinids; pelecypods such as Myalina, Aviculopecten, and Aviculopinna; brachiopods such as Chonetes, Composita, Crurithyris, Derbyia, Dictyoclostus, Hustedia, Juresania, Meekella, Neospirifer, Punctospirifer, and Rhipidomella(?); ostracods such as Amphissites, Bairdia, and Hollinella; a lophophyllidid coral and the coral Syringopora; high- and low-spired gastropods; fenestrate, ramose, and encrusting bryozoans; and the ubiquitous crinoid stems. The fusulinids were identified as being predominantly Triticites secalicus (Say) but include also a form which appears to be intermediate between Triticites secalicus oryziformis Newell and Triticites secalicus (Say) (D. A. Myers, written communication, December 16, 1959).

In a few places the lowermost part of the Toronto is a 2-foot, wavybedded, light-gray, very fine grained, sparsely fossiliferous limestone, whose lower surface is a plane and whose contact with the underlying shale is abrupt. In most places, however, the basal part is argillaceous, contains profuse fusulinids and grades downward through 3 to 5 inches of calcareous, fossiliferous, nodular shale into the underlying Lawrence Shale (Fig. 9,c).

Stratigraphic and structural implications.--The lithologies, faunas, and thicknesses of the different members of the Oread Limestone can be used to reconstruct in a general way the environment of deposition of each member, and to interpret local vertical movements of the land surface or sea bottom as well as regional changes in sea level during Oread time. ~~This~~ Use of this information also makes possible a resume of the geologic history of the entire sequence of Paleozoic and younger rocks of Wilson County.

The fauna of the Plattsmouth Limestone Member, consisting of fusulinids, calcareous brachiopods, corals, and bryozoans, indicate that the member was deposited in marine water ranging in depth from less than 100 to 200 or more feet; the oscillation-type ripple marks suggest that the Plattsmouth formed below active current movement but in the zone of bottom agitation; and the shaly zones that contribute to the development of wavy bedding suggest that a small amount of fine terrigenous material was contributed to the environment from time to time. The echinoid spines, small gastropods, and abundant crinoid stems in the lower part indicate that, at the beginning of deposition of the member, the water was as shallow as 50 to 100 feet and that the currents were strong enough to move debris of granule size.

The greater amount of clay relative to calcareous fragmental material in the upper calcareous gray shale part of the Heebner member suggests shallower water nearer to shore. The underlying black, platy shale part, with ostracods and profuse conodonts, suggests a poorly circulating, organic-rich, acidic environment. A prolific growth of seaweed possibly provided this organic matter and produced a dampening effect on wave action and water circulation (Weller, 1957, p. 351). Phosphate, which probably migrated to nuclei during diagenesis to form the concretions, may have accumulated as a result of bacterial decomposition of organic debris (Barnes, 1957, p. 304-305) in an estuarine or lagoonal environment (Emery and Stevenson, 1957, p. 690-691).

The thin, algal, fusulinid-bearing Leavenworth Limestone Member indicates a rather rapid and complete oscillation of sea level over a very large area. The presence of fusulinids in the middle part indicates that a water depth of about 200 feet was reached; the heavy-shelled pelecypods in the granulite bed at the base and the great abundance of algae in the upper part indicate shallow-water conditions at the beginning and end of the cycle.

The presence of red and green shales that lack marine fossils in all except the uppermost part and the local occurrence of calcareous siltstone and ripple-marked sandstone lenses that contain a few plant fragments suggest that the Snyderville Shale Member accumulated at tide level or slightly above sea level much of the time. At no time was the altitude of the land surface in Wilson County sufficient to allow the development of deep scour channels. The variation in thickness of the Snyderville member probably reflects local warping of the land surface during accumulation of this thick argillaceous unit.

The basal member of the Oread reflects chiefly marine conditions, but the upper sandy facies of the Toronto is interpreted as indicative of a nearby land area, and the brecciated appearance of the uppermost part in a few places is thought to reflect local desiccation of calcareous muds and subsequent inundation and filling of the cracks with similarly constituted material. The lithology of some beds suggests that currents moved the fragments into local pockets prior to or during the subsequent inundation. Generally, beds in the upper part of the member are indicative of near-shore marine conditions in a receding sea whose hypersaline waters supported a population of marine plants (algae) and invertebrate animals (crinoids, bryozoans, brachiopods, and solitary corals). The lower part of the Toronto member in most places in the county is composed almost entirely of fusulinid remains, but locally, the fauna includes all the constituents of the normal transgressive succession (ostracods, pelecypods, gastropods, bryozoans, brachiopods, corals, and fusulinids). Laterally, the equivalent of this fauna is found in the calcareous shale of the upper part of the Lawrence Shale. Apparently a concentration of calcium carbonate sufficient to form limestone occurred only locally during the early stages of transgression, and argillaceous material was predominant in most of western Wilson County.

## Douglas group

The "Douglas formation" was named for Douglas County, Kansas (Haworth, 1898a, p. 93), where it is typically exposed, and was defined to include all strata between the top of the Oread limestone and the top of the Stanton [Garnett] limestone. Elevation of the unit to group status and redefinition to its present boundaries was initiated by Moore (1931, chart), who placed in the group only the strata bounded above by the base of the Oread limestone and bounded below by the unconformity at the base of the Stranger formation. As thus defined, the Douglas group consists chiefly of clastic rocks. ~~This definition is now in use in the states of Iowa, Kansas, Missouri, Nebraska, and Oklahoma.~~

The Douglas group in Wilson County averages about 200 feet in thickness and consists of alternating sandstone, siltstone, shale, and thin limestone units. It contains two formations, the Lawrence shale above and the Stranger formation below.

## Lawrence shale

Naming, distribution, and thickness.--The Lawrence shale was named for exposures at Lawrence, Douglas County, Kansas, by Haworth (1894, p. 122), who assigned to it 210 feet of shale and interbedded sandstone and limestone. Later, the name Lawrence was restricted to strata above a regional unconformity near the middle of the formation (Moore, 1936, p. 155). As thus restricted, the formation consists of 100 to 150 feet of shale with a thin limestone member, the Amazonia, near its top and a thick sandstone member, the Ireland, at its base. These members, as well as the uppermost thin coal bed and persistent limy maroon shale near the top (Moore, 1936, p. 156-157), are present in Wilson County, where the formation averages about 70 feet in thickness. Its thickness ranges from more than 100 feet in the southwestern part of the county to about 60 feet in the northwestern corner (Plate 3,A).

In Pocket

Figure 16. Correlated sections of the Lawrence shale, Stranger formation, Weston shale, Vilas shale, and Lane-Bonner Springs shale in Wilson County.

Lithologic character.--The Lawrence shale ranges from almost entirely shale in the northwestern corner of the county to predominantly massive sandstone in the southwestern part. The upper part of the formation presumably maintains its shaly character; the difference in lithology results almost entirely from the addition of a thick sandstone body in the lower part (see Plate 3,A).

Unnamed shale member.--The upper part of the Lawrence Shale consists of about 25 feet of gray and varicolored nodular shale that includes a 3-inch coal bed near the top. The uppermost 2 to 3 feet is medium-light-gray (N 6) to light-olive-gray (5Y 6/1), very calcareous, fossiliferous, nodular claystone that generally grades upward into the Toronto Limestone Member of the Oread (see fig. 9, C).

Figure 17. Uppermost and lowermost parts of the Lawrence Shale in Wilson County.

Fusulinids are extremely abundant in most exposures of this uppermost part, together with a few other foraminifers of the genus Tetrataxis. Also present are the brachiopods Chonetes and Dictyoclostus, the ostracods Bairdia and Amphissites, and the unidentified broken remains of ramose bryozoans, brachiopods, crinoids, corals, and echinoid spines and plates. The lower 18 inches of this unit is only sparingly fossiliferous, but concentrations of pelecypods occur locally.

A thin coal bed conformably underlies this fossiliferous shale and is found consistently about 3 feet below the top of the Lawrence shale. The coal is correlated with a minable coal, called the Williamsburg coal, that occurs at essentially the same stratigraphic position near Williamsburg, Franklin County, Kansas. The coal is 2 to 4 inches thick in Wilson County, and generally contains argillaceous layers at the middle and near the top. About one-third of the coal bed is vitrain and fusain, about one-third is attrital coal, and about one-third is argillaceous (bony) coal. Approximately 12 inches of dusky-blue (5PB3/2), plastic claystone (underclay?) immediately underlies the coal bed.

Mottled light-gray (N7) and moderate-reddish-orange (10R6/6) claystone 8 to 10 feet thick occurs below the underclay(?) and is underlain by 2 to 5 feet of dark-reddish-brown (10R3/4) claystone in which large blotches of pale-olive (10Y6/2), slightly silty claystone occur. Reddish-brown and nearly white calcareous nodules 1/8 inch to 6 inches in length, as well as small euhedral gypsum crystals, are common in this claystone unit. The lower 6 feet of the unnamed shale member consists of dark-reddish-brown (10R3/4) and moderate-olive-gray (5Y4/2), slightly silty claystone from which weather many small ironstone concretions.

Limestone beds correlated with the Amazonia limestone member crop out about 20 feet below the top of the Lawrence shale at 6 isolated localities in Wilson County. In the SW¼ SE¼ sec. 26, T. 27 S., R. 13 E., the Amazonia is 5 inches thick and consists of yellowish-gray (~~5Y8/1~~), medium-grained, sparsely fossiliferous, sandy limestone. The sand grains are mostly fine-grained quartz, are moderately well sorted, and are subangular and nearly equant. Fossils include crinoid stems, productid spines, fenestrate bryozoans, brachiopod shell fragments, and Osagia(?). Farther north, in the SE¼ NE¼ sec. 23, T. 27 S., R. 13 E., the limestone bed is 8 to 10 inches thick, and is very light gray (~~N8~~), porous, and very fossiliferous. It is made up almost entirely of ~~[illegible]~~ brachiopods and pelecypods (Juresania) ~~and~~ (Aviculopecten), ~~and~~ productid spines, crinoid stems, ramose bryozoans, and unidentified shell fragments. In two exposures in the N½ NW¼ sec. 23, T. 27 S., R. 13 E., the Amazonia is an iron-stained, very light olive-gray (~~5Y 7/1~~) to very pale yellowish-brown (~~10YR7/2~~), fossiliferous limestone. The bed is about 1½ feet thick and consists of well bedded, sandy, finely micaceous limestone. In the upper part, crinoid stem segments with star-shaped centers are particularly conspicuous, and abundant Aviculopecten occur near the middle of the bed in conjunction with Nucula(?). Other fossils include the brachiopods Juresania, Derbyia, and Chonetes; encrusting, ramose, and fenestrate bryozoans; productid and echinoid spines; crinoid [calyx ~~[illegible]~~] parts; and small horn corals. Near the SW. cor. sec. 13, T. 27 S., R. 13 E., the Amazonia is a light-brownish-gray (~~5YR6/1~~), medium-crystalline, slightly fossiliferous limestone. It contains unbroken

Amazonia limestone member.--The Amazonia limestone member, named for exposures near Amazonia, Andrew County, Missouri (Hinds and Greene, 1915, p. 31, 170), consists, near the type locality, of gray, even-bedded, sparsely fossiliferous, fine-grained limestone 4 to 9 feet thick. It lies about 24 feet below the top of the Lawrence shale.

Ireland sandstone member.--The Ireland sandstone member was named by Moore (1932, p. 93) for exposures on the Ireland Farm, 5 miles southwest of Yates Center, Woodson County, Kansas. The type locality is only 8 miles north of Wilson County, and the member there is lithologically the same as in Wilson County. According to Verville and others (1958, p. 26), "In this part of Kansas the Ireland sandstone is regarded as including beds that lie next below the Amazonia limestone." As, thus defined, remnants of the Ireland member in Wilson County range in thickness from 15 to 110 feet, and comprise 1 to 3 sandstone beds separated by silty or sandy shale units. The shale units thin and thicken laterally, and in many places are missing. Where the shale units are absent, the sandstone beds form a sandstone unit as much as 50 feet thick. In fresh exposures the shale units range from light gray (~~N7~~) to light olive gray (~~5Y6/1~~); they weather to yellowish gray (~~5Y8/1~~) and moderate yellowish brown (~~10YR5/4~~). The shale units are generally silty, but may be very silty or sandy. The upper sandstone beds are 5 to 10 feet thick and form breaks in slope or prominent escarpments. They are commonly grayish orange (~~10YR7/4~~) to moderate brown (~~5YR4/4~~) and have well-developed ripple marks; worm(?) tracks are locally abundant. The sandstone beds are composed almost entirely of well-sorted, subrounded, very fine-grained quartz, and are in part cemented by small concentrations of limonite, which give a speckled appearance to the rock; mica flakes are ~~few~~ sparse and restricted to certain beds in a few areas. Casts of crinoid stems, low-spire gastropods (Worthenia(?) and others), pelecypods (Allorisma, Nuculana, Schizodus(?), and Aviculopecten), and Crurithyris and unidentified other brachiopods were found in a few places in the upper sandstone beds and in the upper part of the lower sandstone bed.

remains of the brachiopod Chonetes, fragments of other brachiopods, and crinoid columnals. A unit of impure, poorly bedded, finely micaceous limestone represents the Amazonia near the center of the west line of the SE¼ sec. 14, T. 27 S., R. 13 E. It is ripple marked and has only a few fossils, mostly crinoid ~~fragments~~ stems and brachiopod fragments that occur in small pockets.

The lower sandstone bed averages about 20 feet in thickness, but fills channels, some of which were apparently cut more than 90 feet into the underlying rocks. The base of the Ireland is poorly exposed in most places, and the channels are generally recognized only by differences in elevation of the base. The basal contact of the Ireland is well shown, however, in a roadcut on State Highway 96 (Frontispiece) ~~(Fig. 18)~~ about 6 miles northwest of Fredonia (SE¼ SE¼ sec. 8, T. 28 S., R. 14 E.). The even bedding in the upper 12 feet of this exposure is both lenticular and truncated. The sandstone beds are composed almost entirely of subrounded, well-sorted, nearly equant, fine to very fine quartz grains; angular fragments of carbonized wood occur on bedding planes in the lower foot. Irregularly distributed elongate pods of siltstone and sandstone that contain much finely broken carbonaceous matter occur in the lower 2 feet of sandstone in the roadcut, and fragments of light olive-gray (~~5Y6/1~~) shale are abundant in the basal 2 inches of the sandstone. Where thickest, the lower part of the Ireland generally displays cross-bedding (Fig. ~~9,D~~). Fragments of Calamites are common locally.

~~Figure 18. Roadcut exposure of the lower part of the Ireland sandstone member of the Lawrence shale.~~

The Ireland forms the capping of many ridges and dip slopes, and supports a relatively dense growth of oak trees. It has several perennial springs, and, next to river gravels in the Fall and Verdigris Rivers, is the best source of potable water in Wilson County.

Stratigraphic and structural implications.--The fusulinid-bearing, fossiliferous, calcareous, clay shale that overlies the thin coal bed in the uppermost part of the Lawrence Shale indicates a transition from a vegetation-covered, low-lying land area to a deep-water marine environment. The presence of pelecypods above the coal, and of ostracods and thin-shelled brachiopods as well as the remains of thick-shelled brachiopods, bryozoans, crinoids, corals, and echinoids, supply good evidence of marine transgression. Prior to this transgression, plant debris, some of which was in large fragments (vitrain) but most of which was finely comminuted (attrital coal) and interlaminated with clay (bony coal), attests to coal swamp conditions.

The red and gray claystone with calcareous nodules and small gypsum crystals in the unnamed shale member suggest that alternating near-shore marine and brackish water or dry land environments preceded the coal-forming stage. The several lithologic types and faunas of the Amazonia Limestone Member indicate that a brief, shallow encroachment of the sea filled separated local basins and allowed the development of different marine organisms in these basins and the deposition of different materials in each. The lenticular shales and sandstones below the Amazonia suggest that the shoreline of the sea remained in the Wilson County area for a time sufficient to allow channels as deep as 100 feet to be cut. The channels were filled with sand and silt derived from a vegetation-covered land area that supplied a quantity of carbonaceous fragments among which were large pieces of Calamites. The vegetation was presumably drowned when the sea swept into the area for a short period and laid down a blanket of sand in which were engulfed the remains of gastropods, pelecypods, small brachiopods, and crinoid stem fragments. Local influxes of clay-size, silt-size, and sand-size debris led to the accumulation of interfingering deposits of sand and shale of variable thicknesses. Such areas of shoreline erosion and sand deposition are important to the accumulation of petroleum.

Data regarding local structural movement during Lawrence time are scant. Channels 100 feet deep were cut into the underlying shale, but uplift of the land or recession of the sea that brought about the erosion most likely was regional rather than local.

## Stranger formation

Naming, distribution, and thickness.--The Stranger formation was named for exposures in bluffs on the east side of Stranger Creek in sec. 3, T. 12 S., R. 21 E., Leavenworth County, Kansas, about 100 miles north of Wilson County. The name appeared in a chart by Moore (1931), but the unit was first formally described by Newell (1935, p. 79-82), who included in it only about 70 feet of strata below the persistent, gray Haskell limestone member. Moore (1936, p. 147) pointed out that "a more desirable boundary for the top of the formation is the marked hiatus at the base of the * * * Lawrence shale" and revised it to its present use. The Stranger formation contains five members, in descending order the Robbins shale member, the Haskell limestone member, the Vinland shale member, the Westphalia limestone member, and the Tonganoxie sandstone member (see ~~fig. 10~~ Table 1). All five members are present in Wilson County where the Stranger formation has an aggregate thickness of about 200 feet. The formation occupies an outcrop belt as much as 5 miles wide that extends from the southwestern corner of the county to the middle of the north line (see ~~fig. 7~~ Plate 1). The formation is bounded above and below by erosional unconformities.

Lithologic character.--The Stranger formation is predominantly clastic rocks; the upper half is chiefly shale, and the lower half is mainly sandstone and siltstone. The Haskell, Vinland, and Westphalia members form an excellent stratigraphic marker at the outcrop in Wilson County because in combination they form a distinctive sequence as follows: a thin, compact, gray limestone with dark, irregular, elongate bodies throughout (the Haskell), is underlain by a yellowish-gray shale that contains well-preserved large Myalina valves at the top (the Vinland), and a brown, Osagia-bearing impure limestone at the base (the Westphalia).

Robbins shale member.--The uppermost member of the Stranger formation, the Robbins shale member, was named by Moore and Newell (Moore, 1936, p. 153-154) for exposures about 5 miles north of Wilson County on the Robbins farm in sec. 11, T. 26 S., R. 15 E. At the type locality, the member is a marine argillaceous shale of variable thickness (Moore, 1936, p. 153). In Wilson County, it is predominantly a light-olive-gray (5Y5/2), slightly silty, locally fossiliferous shale that is characterized by beds and lenses of small ironstone concretions. It averages about 80 feet in thickness in the county, but ranges from 50 feet in the northern part to as much as 120 feet in the southern part (see ~~fig. 10, B~~ Plate 3, B). The change in thickness was caused by erosion, which apparently removed the upper 50 to 100 feet.

The upper 20 to 50 feet of the Robbins is light-olive-gray (5Y5/2) to moderate-olive-brown (5Y4/4), silty to sandy shale that characteristically contains abundant moderate-yellowish-brown (10YR5/4) to dark-yellowish-orange (10YR6/6), oval ironstone concretions. A thin sandstone bed or sandy concretionary bed is present locally in this unit in the northern part of the county 5 to 15 feet below the overlying Ireland. Two additional thin beds of moderate-yellowish-brown (10YR5/4) sandstone or sandy siltstone occur in the middle 20 to 30 feet of the Robbins in the central part of the outcrop belt and form local topographic benches.

At three localities fossiliferous zones consisting of 2 to 3 thin beds of limestone or a 5-foot unit of very fossiliferous clay shale occur in the member. In a roadcut at the center of the west line of sec. 12, T. 29 S., R. 13 E., the Robbins shale member contains well-preserved brachiopods and other fossils about 55 feet below the top. Included are Chonetes, Chonetina, Composita, Crurithyris, Derbyia, Dictyoclostus, Hustedia, Marginifera, Punctospirifer, Worthenia, a gastropod that closely resembles Hypselentoma, Nuculopsis, a horn coral, ramose bryozoans, and many crinoid stem segments. Three thin fossiliferous limestone beds separated by shale and siltstone occur about 20 feet below the top of the Robbins in the railroad cut under the bridge at the SW cor. sec. 11, T. 30 S., R. 13 E. The beds are medium gray (N5) where fresh, and light brown (5YR5/6) and friable where deeply weathered. They are slightly silty to sandy and micaceous and contain such fossils as Chonetes, Condrathyra(?), Crurithyris, Derbyia, Dictyoclostus, Linoproductus, Marginifera, Neospirifer, Nuculopsis(?), unidentified gastropods, crinoid stem segments, fusulinids, and Osagia(?). Coalified organic fragments occur locally in the sandy phase of the limestone. In the NW cor. sec. 25, T. 29 S., R. 13 E., the Robbins contains Chonetes and several productid brachiopods about 45 feet below the top. The contemporaneity of these three fossil zones is doubtful, but they establish a marine environment during at least part of Robbins time.

The shale in the lower 30 to 40 feet of the Robbins is moderate greenish gray (5GY5/1) to yellowish gray (5Y7/2) and slightly silty. Ironstone concretions are fairly common in the upper part of this portion of the member, but are less abundant toward the base, where the shale becomes dark and fissile and contains small phosphatic concretions in the lower few inches in many outcrops. A 2-inch bed of dark-yellowish-orange (10YR6/6), very fine-grained sandstone forms the basal bed of the Robbins shale member locally in the SE¼ sec. 5, T. 27 S., R. 14 E.

Haskell limestone member.--The Haskell limestone member was named by Moore for exposures near the Haskell Institute at Lawrence, Kansas (Moore, 1932, p. 93), where it crops out as a single ledge of hard, bluish-gray, fine-grained limestone without shale partings (Moore, 1936, p. 153). In Wilson County, the Haskell is generally a single hard bed, 1 to 2 feet thick; but locally it has a brecciated-appearing, shaly limestone unit in the middle and lower parts and is as much as 8 feet thick (NW¼ SW¼ sec. 19, T. 28 S., R. 14 E.). The Haskell conformably underlies the Robbins shale member throughout Wilson County.

In the northern and southern parts of the county the Haskell is generally less than 2 feet thick and is chiefly hard, medium-gray (N5) limestone that weathers light olive gray (5Y6/1) and is vertically jointed (see fig. 10,A). Petrographically the matrix appears as

Figure 10 near here

Figure 19. Haskell limestone member of the Stranger formation.

cryptocrystalline calcite in which minute fossil fragments are concentrated locally in pockets. Larger fossil fragments, many of which are surrounded by algal coatings, are common throughout. The coatings are a sequence of irregular, crenulated layers that surround the fossil fragment and maintain the general shape of the fragment. They resemble closely the Osagia pictured by Johnson (1946, pl. 4, fig. 4) and, as in his illustration, are associated with Nubecularia. Small oolites are present in the matrix, but are rare. Fibrous calcium carbonate (aragonite?) composes the outer rinds of a few of the oolites and the middle parts of some shell fragments. The outer parts of the shell fragments are crystalline calcite; the long directions of the crystals are oriented perpendicular to the shell edge and to the fibrous calcium carbonate. The most common fossils are crinoid stems and large Osagia or Cryptozoon?; less abundant are long, slender fusulinids (usually near the top), lophophyllidid corals, ramose bryozoans, fenestrate bryozoans, the brachiopods Hustedia, Crurithyris, Chonetes, and Composita, and productid spines. Insoluble residues contain the arenaceous foraminifers Tolypammina and Ammovertella, and a few fine- to medium-size quartz grains that are regenerated, but show etched and pitted surfaces.

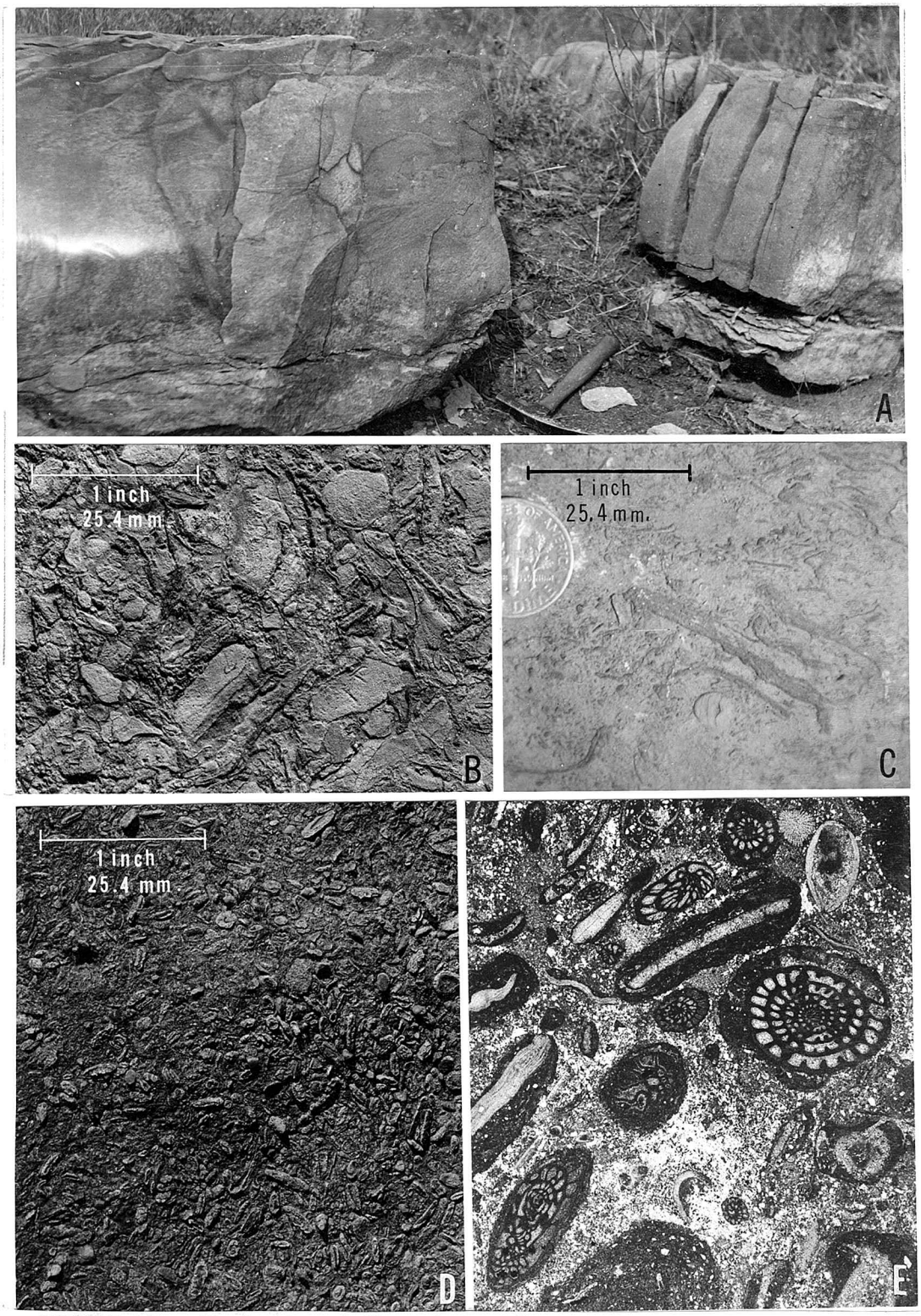


FIGURE 10.--Haskell and Westphalia Limestone Members of the Stranger Formation. (A) Typical exposure of Haskell showing vertical jointing. Myalina near hammer is from the uppermost part of the Vinland Shale Member. SW cor. sec. 34, T 26 S, R 14 E. (B) Weathered surface of the Haskell showing brecciated facies. NW¼ sec. 12, T 29 S, R 13 E. (C) Weathered surface of the Haskell showing crenulated algal bodies. SW¼ sec. 23, T 29 S, R 13 E. (D) Weathered surface of the Westphalia showing abundant algae (Osagia) and fusulinids (Triticites). Near SE cor. sec. 23, T. 28 S, R 13 E. (E) Thin section of the Westphalia showing Osagia and Triticites in a very fine grained silt and calcite matrix. Ordinary light (X 10).

The Haskell thickens markedly in the west-central part of the county, from 2½ miles north to 3 miles south of New Albany. The additional thickness consists of platy or shaly limestone that in most places appears to overlie the single hard bed, but in other places may underlie it. The shaly limestone crops out as thin, wavy-surfaced limestone plates that are light gray (~~N7~~) and yellowish gray (~~5Y7/2~~). The weathered surface has a brecciated appearance (see Fig. ~~10~~, B) produced by ½-inch to 1-inch angular areas of pale yellowish-orange (~~10YR8/6~~) limestone in a matrix of very pale-orange (~~10YR8/2~~) limestone. Thin veinlets, 1/8-inch wide, of olive-gray (~~5Y4/1~~) calcite generally separate the cryptocrystalline fragments from the matrix. In thin section, the matrix appears as very fine-crystalline, limonitic calcite containing scattered crenulated Osagia (Cryptozoon?) and small fragments of brachiopod(?) shells and coarse-crystalline calcite (crinoid stem fragments?), as well as a few small oolites with radial structure in the outer part and concentric structure throughout. Enclosed in this matrix are cryptocrystalline limestone fragments in which are found the shells of small Foraminifera, large Osagia (Cryptozoon?), brachiopod shell fragments, and crinoid remains (see Fig. ~~10~~,C). A few small spheres of iron oxide were noted in the matrix, but most of the iron is now dispersed as limonite stain. The veinlets of calcite resemble cross-section views of brachiopod shells, but their pattern is too complex for that origin.

In a few places, the basal 2 inches of the Haskell is a hard, medium-crystalline limestone that is sandy and micaceous and contains a pelecypod fauna. Large Myalina occur with small oolites and fragments of brachiopods, fenestrate bryozoans, and crinoids.

Vinland shale member.--The Vinland shale member as originally named by Patterson (1933, p. 17) included strata now placed in the underlying Westphalia limestone member (see Newell, 1935, p. 82). In the type area near Vinland, Douglas County, Kansas, the Vinland consists of about 14 feet of gray, calcareous, and sandy marine shale that conformably underlies the Haskell limestone member. In Wilson County the Vinland is a light-olive-gray (5Y5/2), partly calcareous claystone that averages about 9 feet in thickness, but ranges from 4 to 18 feet. It underlies the Haskell with abrupt contact and is very fossiliferous in the uppermost 3 to 12 inches. Almost characteristically, this upper part of the Vinland contains many unbroken valves of the large pelecypod Myalina, in conjunction with Chonetes and fragments of other small brachiopods, ramose bryozoans, corals, echinoid spines, and crinoid columnals. The ostracods, Bairdia, Hollinella, and Cytherella(?) and the foraminifer Ammodiscus (Wagner and Harris, 1953) occur in association with the Myalina. A few miles north of Buxton, the uppermost part of the member is sandy.

The uppermost calcareous unit is underlain by 2 to 15 feet of light-olive-gray (5Y5/2) to yellowish-gray (5Y7/2), very slightly silty claystone that breaks, upon exposure, into quarter-inch squarish fragments. The only fossils observed in this part of the member are a few plant remains on bedding surfaces, but the next underlying foot is generally fossiliferous and grades downward into the Westphalia limestone member. This lower foot of the Vinland is light-olive-gray (5Y5/2) to yellowish-gray (5Y7/2), slightly silty claystone that locally contains either abundant brachiopods or Osagia and fusulinids. In the SE¼ sec. 5, T. 27 S., R. 14 E., the faunal assemblage includes abundant algae (Osagia), the fusulinids Pseudostaffella(?) and Ozawainella(?), and the foraminifer Tetrataxis intermixed with small gastropods, brachiopod fragments, echinoid spines, bryozoans, and ostracods (Wagner and Harris, 1953). identified by

Westphalia limestone member.--The Westphalia limestone member was named by Moore and Newell (Moore, 1936, p. 150-151) for outcrops a few miles north and east of Westphalia, Anderson County, Kansas. In the type area, the Westphalia is a thin, brown, fusulinid-bearing limestone characterized by abundant Triticites secalicus oryziformis Newell (Newell, 1934, p. 425; Moore, 1936, p. 150). In Wilson County the Westphalia averages about 3 feet in thickness, is brown, and contains these fusulinids, but in this area it is more characteristically an algal (Osagia) limestone. In the middle part of the outcrop area in Wilson County, however, it has a 6- to 12-inch limestone-rubble zone near the center, is sandy at the base, and is as much as 6 feet thick.

The upper 2 to 3 feet of the member, which is the most widespread part, consists of moderate-yellowish-brown (10YR5/4) to pale-yellowish-brown (10YR6/2), impure, fossiliferous limestone. Small (1/10- to 1/5-inch) bean-shaped algae (Osagia) and sparsely interspersed slender fusulinids (see Fig. 10, D) show in relief on the moderate-yellowish-

Figure 20. Westphalia limestone member of the Stranger formation.

orange (10YR7/6) to pale-brown (5YR5/2), weathered surface. In an exposure along the north side of State Highway 96 in the SE¼ SW¼ sec. 9, T. 28 S., R. 14 E., this upper part of the member is a mass of flattish, oval Osagia in a fine-crystalline matrix. Staining with Alizarine Red S as outlined by Friedman (1959, p. 87-97) reveals that the matrix in a thin section from this locality is dolomite, and that many of the fossils have been somewhat selectively dolomitized. Most of the algae have a core of crystalline dolomite covered by several successive crenulated, wrinkled layers of cryptocrystalline calcite. Algal layers have also formed around the calcium carbonate of fusulinids, echinoid spines and plates, ramose bryozoans, and small shell fragments. Angular silt-size quartz grains are sparsely scattered throughout the rock. Some are held between the algal layers; others lie within the outer row of chambers of fusulinids, and others are scattered in the matrix. Insoluble residue from this part of the member contains arenaceous foraminifers in about the same abundance as quartz grains and also a few flakes of muscovite mica. The foraminiferal genera Ammodiscus, Ammovertella, Glomospira, and Tolypammina are represented. The quartz grains are etched and pitted.

The lower 1 to 2 feet of the Westphalia limestone member is generally pale yellowish brown (~~10YR6/2~~) and weathers grayish orange (~~10YR7/4~~). The lower part is much more impure than the upper part and contains an appreciable amount of terrigenous material in the calcareous matrix. Impurities of clay size are most common in outcrops in the northern part of the county; impurities of silt and sand size are most abundant in outcrops in the southern part. In some localities the argillaceous and arenaceous constituents predominate, and the rock is an algal mudstone or sandstone. At the northern border of the county (secs. 2, 5, and 6, T. 27 S., R. 14 E.), the algae (Osagia?) in the lower part of the Westphalia are much larger ($\frac{1}{2}$ inch to 1 inch in length) than those in the upper part. They form multiple-layered coatings of about 2 to 20 irregularly crenulated layers around fusulinids, echinoid spines, oolites, elongate iron-oxide cores, and shell fragments (Fig. 10, E). Staining and petrographic study show no dolomite in the Westphalia in this area; the matrix is cryptocrystalline calcite and clay. Angular silt-size grains of quartz are abundant throughout the matrix and within the algal growths and outer chamber of fusulinids. ~~(See fig. 20, B).~~ Most of the shell fragments are calcite; some, however, are aragonite ($2V=20° \pm 5°$, optically negative, high birefringence, fibrous). Insoluble residues of samples from the northern edge of the county contain numerous Tolypammina and Ammovertella amid limonite-cemented siltstone fragments, tabular crystals of barite(?) coated with limonite, regenerated and pitted grains of clear and cloudy quartz, and flakes of muscovite mica. Near the base of the member in this area, fusulinids are very abundant, and a large

algae, provisionally identified as Collinia, occur locally. In the central part of the outcrop area in the county, the lower part of the Westphalia ranges from grayish red (~~10R4/2~~) to dark yellowish orange (~~10YR6/6~~) and weathers pale grayish red (~~10R5/2~~) to moderate yellowish brown (~~10YR5/4~~). Ironstone concentrations are common, and a more varied fauna occurs near the base ~~of the Westphalia~~. The brachiopods Composita, Crurithyris, Hustedia, Neospirifer, Punctospirifer, and Juresania; the pelecypods Astartella, Aviculopecten, and Nuculana; the gastropods Bellerophon and Worthenia; and fragments of fenestrate and ramose bryozoans, crinoid columnals, and unidentified shells are abundant locally in the southwestern part of the county where the Westphalia is sandy and thin or missing. Limonitic clay and etched fine-grained quartz in approximately equal amounts compose about 95 percent of the insoluble residue of a specimen from sec. 24, T. 29 S., R. 13 E. The remainder consists of a few flakes of muscovite mica, several granules of ~~clean~~ siltstone, a few grains of pyrite, and the broken tests of the foraminifers Ammovertella and Hyperammina. A thin section from near the base of the Westphalia in sec. 25, T. 29 S., R. 13 E., is of a granule or sandy limestone. About one-fourth of the rock is abraded fossil fragments, about one-third is reworked granules of siltstone and limestone, about one-third is subangular fine-grained quartz, and the remainder is fine-grained crystalline calcite matrix. The fossil fragments include parts of echinoid spines and plates, ramose bryozoans, fusulinids, Osagia, ~~small~~ high-spire gastropods, and brachiopod(?) shells. Granules of siltstone are

fairly well rounded and are composed mainly of angular silt-size quartz in a limonitic, argillaceous, calcareous matrix. Granules of limestone, also fairly well rounded, are less abundant. Some are fossiliferous limestone; others are unfossiliferous, argillaceous limestone. The quartz grains range from angular to round (average about subangular). Most of them have sharp extinction; however, a very few have wavy extinction in polarized light.

Where the Westphalia is 5 to 6 feet thick south of New Albany, a foot of sparsely fossiliferous limestone rubble (possibly deeply weathered, calcareous nodules or concretions) in a clayey limestone matrix occurs between the upper and lower parts of the member. This rubble unit is generally very pale orange, except where excessive iron staining has changed it to pale yellowish orange or dark yellowish orange.

Tonganoxie Sandstone Member.--The first use of the term Tonganoxie was in a stratigraphic diagram (Moore and others, 1934, chart) in which Moore used this name for the basal member of the Stranger Formation. Moore (1936, p. 147) later designated the type locality as the area east of Tonganoxie and described the sequence as including heavy, cross-bedded, micaceous, channel sandstones, micaceous sandy shales, and several coal beds. He considered the formation to represent nonmarine fluviatile deposition upon broad coastal plains. The member apparently fills channels or grades laterally into shale and ranges in thickness from nearly 100 feet in northeastern Kansas to only 3 or 4 feet in the southeastern part of the State (Moore, 1936, p. 148-150).

In Wilson County, the Tonganoxie lies conformably beneath the Westphalia Limestone Member and contains contemporaneous facies represented by massive channel sandstone and thin-bedded sandy shale. Where the Tonganoxie has the greatest amount of sandstone, as in the west-central part of the county, it grades upward through unfossiliferous calcareous sandstone into the sandy Osagia-bearing limestone of the Westphalia; in areas where the Tonganoxie is primarily siltstone and claystone, as in the northern and southern parts of the county, the upper contact is relatively abrupt but conformable.

The upper part of the Tonganoxie is principally interbedded yellowish-gray (5Y7/2), micaceous siltstone and light-olive-gray (5Y6/1), silty claystone with thin yellowish-gray (5Y8/1), very fine-grained, micaceous sandstone interlaminations. In the upper part of the member, siltstone and claystone occur in about equal amounts, but in the lower part, siltstone and sandstone predominate, and the section consists of (a) alternating 1½-inch beds of yellowish-gray (5Y7/2) to pale-orange (10YR7/2), micaceous siltstone and ½-inch beds of very slightly silty, pale-yellowish-brown (10YR6/2) claystone, or (b) grayish-orange (10YR7/4), massive, fine- to medium-grained sandstone. Ripple marks are well developed in the siltstone beds of the upper part at many places, and where they occur, the average thickness of the siltstone beds increases to about 2 inches. Interbedded claystone fills the ripple troughs, and usually covers the crests with a half-inch layer. (See Fig. 21, A.) Where ripples are lacking, the bedding

Figure 21. Upper part of the Tonganoxie sandstone member of the Stranger formation.

is regular and smooth (see Fig. 11, B). Small flakes of muscovite [mica] are concentrated on the upper surfaces of the siltstone layers. In thin section, the siltstone is a mesh of well-sorted interlocking quartz grains. Other minerals make up less than 5 percent of the rock, and consist of muscovite, magnetite(?), chert, topaz, biotite, and plagioclase, in order of abundance. The mica flakes are oriented parallel to the bedding and are concentrated along bedding planes.

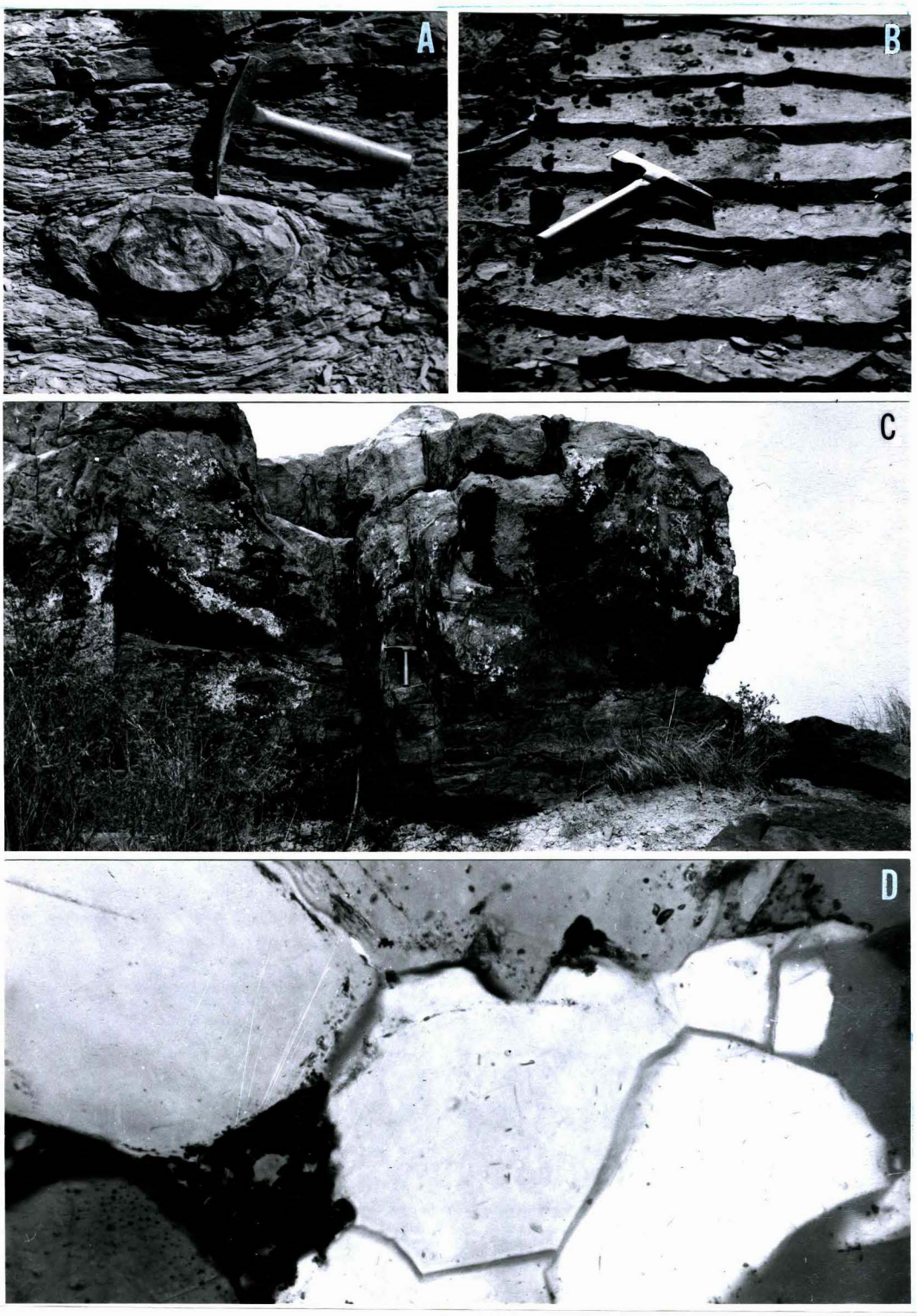


FIGURE 11.--Tonganoxie Sandstone Member of the Stranger Formation. (A) Concretion in sandstone in the upper part of the Tonganoxie. SW$\frac{1}{4}$ sec. 17, T 27 S, R 14 E. (B) Well-bedded siltstone facies in upper part of Tonganoxie. Near SW cor. sec. 6, T 27 S, R 15 E. (C) Erosional remnant of massive basal sandstone of the lower part of the Tonganoxie at South Mound, Fredonia. (D) Thin section of specimen from South Mound showing sharp, interpenetrating contacts between quartz grains. Crossed nicols (X 200).

A thin section of the interlaminated, well-bedded, argillaceous siltstone has about 15 percent clay that fills the interstices between the angular quartz grains and apparently forms a coating around most of the grains. About 80 percent of the rock is quartz. Many of the quartz grains are in embayed contact with adjacent grains of quartz and chert. A few quartz grains have wavy extinction, and some contain inclusions. Muscovite, chert, plagioclase, biotite, and topaz make up the remainder of the rock. Locally, the well-bedded siltstone near the top of the member contains a few beds of concretionary, very fine grained sandstone (fig. 11,A). The beds, which are as much as $2\frac{1}{2}$ feet thick, are pale grayish orange (~~10YR8/4~~), very micaceous, and composed almost entirely of very fine grained, well-sorted, subangular quartz grains.

Where the channel-filling facies of the Tonganoxie is not well developed in the county, the lithologies described above extend down to the top of the Weston shale, and the contact with the Weston is gradational. Elsewhere, coarser-grained rocks occur in the lower part of the Tonganoxie, and the contact with the Weston is abrupt.

The channel-filling facies of the Tonganoxie is as much as 60 feet thick, but averages only about 30 feet. It is best displayed as the cap-rock on South Mound (Fig. 11,C) and West Mound, the

Figure 22. Basal part of the Tonganoxie sandstone member of the Stranger formation.

erosional remnants at Fredonia, and in the oak-covered hills about 3 miles southwest of Fredonia and about 2 miles northeast of Coyville. Where thickest, the sandstone is silty and clayey near the top. It lies with sharp contact on the Weston shale (see Fig. 11,C) and generally has a zone of angular fragments, or boxwork of limonite, at the base. Thin-section studies of sandstone collected from South Mound at Fredonia indicate a coarsening of grain size and an increase in angularity of the grains downward through the 10 feet of ~~exposed rock~~. ~~The sandstone is~~ poorly sorted ~~throughout~~ Sandstone. In the upper and middle parts of the unit, ~~it~~ The sandstone ranges from very fine to medium grained, but averages fine grained in the upper part and medium grained in the middle part. In the lower part, it ranges from very fine to coarse grained, and averages medium grained. Quartz is the ~~predominant~~ mineral throughout the unit and makes up nearly 90 percent of the grains. About one-third of these grains have embayed contacts; some are interpenetrating and stylolitic (see Fig. 11,D). Many grains have fine inclusions, and a few have undulatory extinction. Chert grains are the next most abundant constituent of the sandstone, and range from less than 5 percent in the upper part of the sandstone at South Mound to about 10 percent in the lower part. Other constituents,

which make up considerably less than 1 percent of the rock, include magnetite, muscovite mica, hypersthene, zircon, topaz(?), and plagioclase feldspar. Limonite and clay commonly fill the interstices between grains and are more prevalent in the middle and lower parts. Small spots of limonite give a speckled appearance to the rock. The Tonganoxie is essentially monomineralic but unlike most monomineralic sandstones, which have well-rounded grains due to much transport and reworking, many of the quartz grains in the Tonganoxie are tabular, angular fragments indicating either that solution has modified previously rounded corners to sharp angles or that the grains came from a nearby pure quartz source area and were subjected to almost no abrasive action prior to deposition.

Stratigraphic and structural implications.--Lack of fossils in the upper shale of the Robbins indicates that, while deposition of clay-size material was taking place, the sea water was not amenable to abundant marine life or its preservation. Ironstone concretions in the upper part of the member possibly reflect local concentrations of iron that collected in a lagoonal or restricted bay environment. Sandy limestone beds, one of which contains abundant fusulinids, indicate that a fairly deep-water marine environment was present in Wilson County during part of Robbins time. The small areal occurrence of these beds suggests that the limestone-forming environment may have been confined to bays or arms of the sea. The presence of sand in the limestone suggests that currents strong enough to carry sand grains entered the area intermittently. The black, fissile, conodont-bearing shale at the base of the Robbins indicates that a quiet, relatively stagnant water environment, in which phosphate was concentrated, was in effect at the start of Robbins time, and the local presence of basal sandstone shows that sand was introduced into certain small areas at the beginning of Robbins time. The variable thickness of the Robbins shale member is presumably due principally to beveling by erosion following important uplift of the land surface in the northern part of the county and withdrawal of the sea in early Lawrence time.

The lithology and fauna of the Haskell limestone member indicate a depositional sequence much like that of the Leavenworth limestone member of the Oread. The faunal change from ~~colites,~~ corals, bryozoans, and brachiopods to fusulinids, and then to algae indicates that the environment changed from shallow water to relatively deep water, and then to shallower supersaline water. The breccia in the member is the result of the exposure, desiccation, and redeposition of the lime muds. The argillaceous material in the basal part of the Haskell indicates the modification of a near-shore muddy environment to one in which calcareous material predominated.

The large pelecypods, ostracods, small foraminifers, brachiopods, bryozoans, echinoids, and solitary corals in the fauna of the calcareous shale deposited in late Vinland time indicate a near-shore muddy marine environment. The plant debris and silt of the unfossiliferous lower part of the Vinland show a much less calcareous and a nearer ~~near-~~shore habitat with vegetation along the shoreline or along streams that reached the sea.

The presence of fusulinids and algae from base to top of the Westphalia seems to indicate that throughout Westphalia time the water depth was only slightly less than 180 feet, and thus fulfilled the deep-water requirement of the fusulinids and the photosynthetic requirement of the algae. The local limestone rubble may reflect storm-wave action leading to the formation and concentration of limestone cobbles in mid-Westphalia time; or they may merely represent nodules that formed later. The restriction of basal sandy limestone to the southern part of the county implies introduction of sand-size material from a southerly direction at the start of Westphalia time and in conjunction with the local occurrence of pelecypods and gastropods may indicate the approximate position of the Westphalia shoreline.

Prior to this limestone deposition, the county was the site of shoreline or continental deposition of clastic rocks. Vegetation supplied organic fragments to the sand, and much fine muscovite mica was introduced. The basal sand was deposited in channels cut deeply into the near-shore muds, and the wide range in size of clastic debris and winnowing action of currents led to the deposition of sand in some areas and of silt and clay in others. Well-developed ripple marks may indicate shallow-water deposition.

## Missourian series

First application of the term Missouri in geological literature was by Keyes (1893, p. 85), who used "Missouri terrane" in a geographic sense to replace the Upper Coal Measures of Broadhead (1873, p. 6). The type locality was defined by Keyes (1893, p. 85) as the northwestern part of the State of Missouri. The name Missouri received broad sanction, and in 1947 was adopted formally by the State Geological Surveys of Iowa, Kansas, Missouri, Nebraska, and Oklahoma as the Missourian series (Moore, 1948, p. 2020-2021). By definition, it includes all strata from the unconformity at the base of the Douglas group, or its equivalent, to the unconformity at the base of the Pleasanton group, or its equivalent (Moore, 1949, p. 67, 69; Greene and Searight, 1949, p. 9; Condra and Reed, 1943, p. 50; Dott, 1941, p. 1659, 1670).

fusulinids by Thompson is reported by Moore (1948, p. 2020), Thompson (1948, p. 22-24), and Moore and Thompson (1949, p. 291-296) who show in text and diagrams the distinct faunal break in fusulinid genera at the base of the Missourian and also ~~show~~ indicated the ranges of American fusulinid genera.

The upper limit of the Missourian series is placed at the disconformity at the base of the Stranger formation (Douglas group). This disconformity ~~has been~~ was discussed under the Virgilian series. The character of the unconformity at the lower limit of the series is well shown by outcrop sections prepared as the result of field work in Kansas by Jewett (1941, pl. 1; 1945, pl. 4), in Missouri and Iowa by Cline (1941, fig. 2), and in Oklahoma by Oakes (Oakes and Jewett, 1943, fig. 1). Further justification for a series break at this stratigraphic position is furnished by the presence of a distinct faunal break at approximately this horizon, as stated by Hinds and Greene (1915, p. 6) and Moore (1936, p. 52, 69). Furthermore, Jewett (1941, p. 299) notes that the upper limit of the occurrence of the brachiopod Mesolobus is a few feet below the base of the Hepler sandstone, the basal formation of the Pleasanton group. Verification is also provided by Dott (1941, p. 1661, 1663, 1666-1668, 1672-1673) who notes that division between the Desmoinesian and Missourian in the Midcontinent region is based on the disappearance of the brachiopod genus Mesolobus, the bryozoan genus Prismopora, certain important fusulinids, and other fossils. In this same respect, Moore (Moore and others, 1944, p. 671-672) states that "the boundary between the Desmoinesian and Missourian series is the most sharply defined and easily located datum surface in the Pennsylvanian system" and lists the ranges of the different fusulinids and other faunas showing that the base of the Missourian is the upper limit of the fusulinids Fusulina and Fusulinella, the coral Chaetetes, the bryozoan Prismopora, and the brachiopod Mesolobus. Additional work on the

The outcropping rocks in Wilson County that are included in the Missourian series are in the Pedee, Lansing, and Kansas City groups. In surface exposures in the county, these groups comprise the following formations listed in descending order: Weston shale, Stanton limestone, Vilas shale, Plattsburg limestone, Lane-Bonner Springs shale, Iola limestone, Chanute shale, Drum limestone, Cherryvale shale, and Dennis limestone (see Table 1).

## Pedee group

The term Pedee was introduced by Moore (1932, p. 93, 97) for the dominantly argillaceous strata underlying the unconformity at the base of the Virgil series and overlying the dominantly calcareous strata of the Lansing group. The term was taken from Pedee Branch in the vicinity of Weston, Missouri, about 120 miles northeast of Wilson County, and was first clearly defined in its present usage in 1936 (Moore, 1936, p. 137-138). The group consists of the Iatan limestone at the top and the Weston shale below. The Iatan limestone is not present in Wilson County where the maximum thickness of the group is about 140 feet.

## Weston shale

Naming, distribution, and thickness.--The Weston shale was named for exposures near Weston, Platte County, Mo. (Keyes, 1899, p. 306), and includes the beds between those now termed the Iatan and Stanton limestones. The Iatan limestone is not present in Wilson County, however, and the Weston shale there comprises all strata between the Stranger formation and the Stanton limestone. Where the base of the overlying Stranger formation is conglomeratic, the top of the Weston is sharply marked by a local erosional unconformity. Elsewhere in the county, the Weston grades upward through a silty facies into the Stranger without any apparent break in sedimentation. Accurate measurements of the thickness of the Weston in the county is difficult because of ~~its~~ poor exposures, lack of marker beds, and ~~the~~ broadness of outcrop belt. The thickness apparently ranges from about 120 to 140 feet. ~~Despite a silty unit at the top, the Weston is utilized in brick and tile manufacture at both Fredonia and Buffalo.~~

Lithologic character.--The uppermost 30 feet of the Weston is composed of interbedded, medium olive-gray (5Y4/2), and moderate yellowish-brown (10YR5/4), silty shale in which are incorporated beds of grayish-orange (10YR7/4), micaceous, very fine grained, thin-bedded sandstone 1/8 inch to 6 inches thick. The sandstone beds contain carbonaceous remains on bedding planes. A 20-foot unit of alternating medium olive-gray (5Y5/1) and moderate yellowish-brown (10YR5/4), slightly silty shale separates the silty shale and micaceous sandstone from an underlying clay shale about 90 feet thick. Thin silty shale beds show as thin bands in weathered outcrops of this unit (see Fig. 12,A).

Fig. 12 near here

Figure 23. Middle part of the Weston shale at West Mound, Fredonia, Kans.

The underlying 90-foot unit is the part of the Weston used for ceramic products. It consists of medium olive-gray (5Y5/1) clay shale that is vertically jointed and fissile so that it breaks easily into rectangular cuboidal fragments (see Fig. 12,B). Ironstone concretions occur in lenticular beds and as separate oval bodies in the upper part of this lower unit. The concretions are dark yellowish orange (10YR6/6) to moderate red (5R4/6), and one from South Mound at Fredonia contained a gastropod.

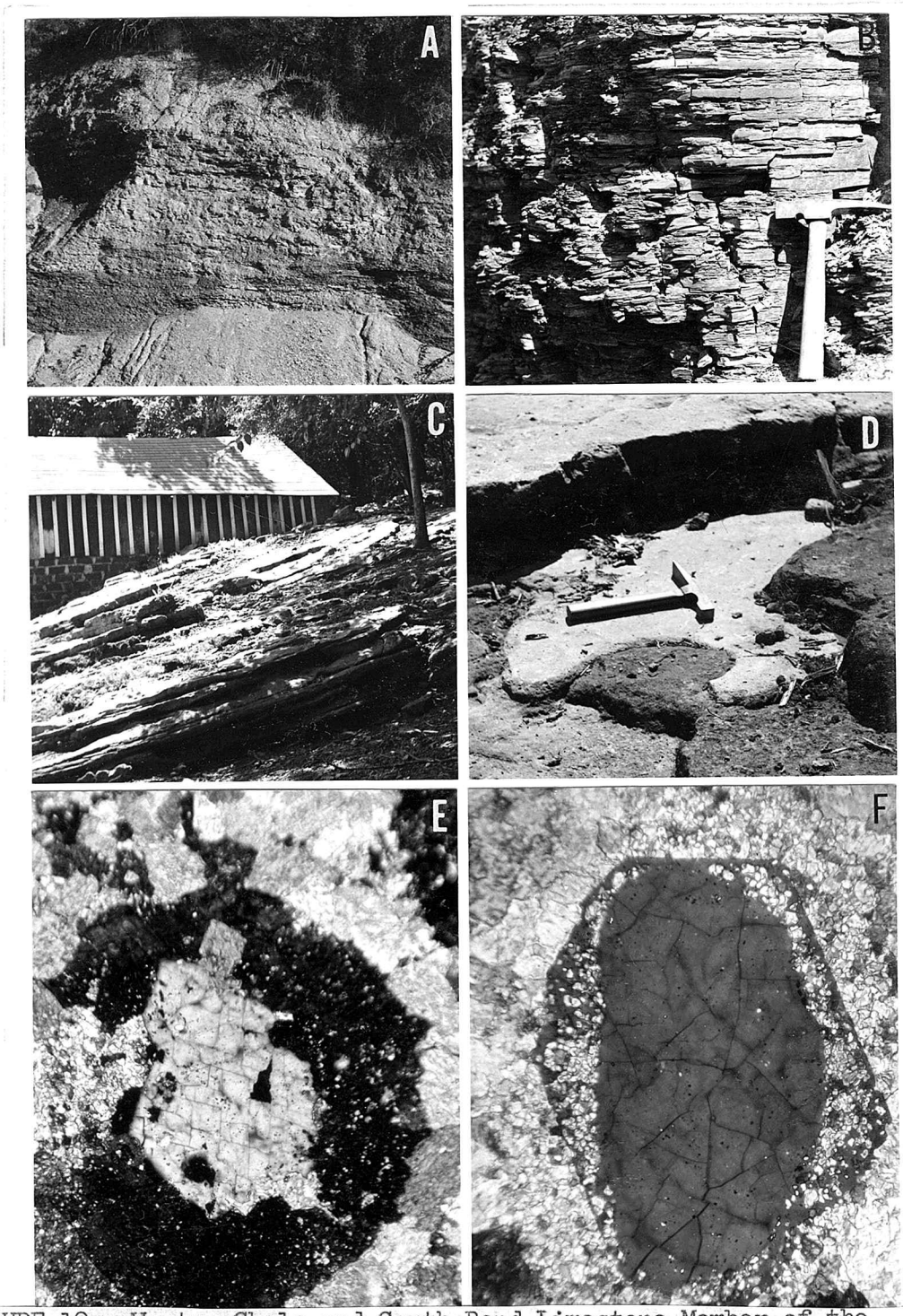


FIGURE 12.--Weston Shale and South Bend Limestone Member of the Stanton Limestone. (A) Weathered outcrop of Weston Shale in brick plant pit at West Mound, Fredonia. (B) Exposure in same pit showing well-developed bedding and jointing. (C) Outcrop of sandy South Bend showing strong east dip of beds. NE cor. sec. 24, T 29 S, R 14 E. (D) Detail of contact relations between sandstone (dark) and sandy limestone (light) in the South Bend at the same locality. (E) Thin section of the South Bend showing a partly euhedral quartz grain at the center of an oolite. Inner (dark) ring of oolite is largely limonite; outer ring is coarsely crystalline calcite. Very finely crystalline calcite has partly replaced the limonite and quartz. Crossed nicols (X 160). (F) Thin section of South Bend showing euhedral regrowth on original rounded quartz grain in limestone matrix. Euhedral regrowth is partly replaced by very finely crystalline calcite. Crossed nicols (X 160).

Stratigraphic and structural implications.--The small carbonaceous fragments incorporated in sand and silt debris at the end of Weston time in the northern part of Wilson County suggest that deposition was near a shore along which vegetation was present. The greater amount of sand and silt in the upper beds in the northern part of the county may reflect a sediment supply whose product in the southern part of the county was removed by uplift and erosion. The coarser fraction from the upper part of the Weston near Fredonia could have been reworked and concentrated into beds in the northern part of the county. The marine origin of the middle part of the Weston is strongly suggested by the presence of an unabraded marine gastropod as the nucleus of one of the ironstone concretions. The nearly pure clay and its accumulation into thin even beds that lack ripple marks or other sedimentary structures suggests that the environment of deposition in middle and early Weston time was one of quiet, marine waters far from shore or strong current action.

## Lansing group

The term Lansing was introduced by Hinds (1912, p. 7) to include all strata between the base of the Weston shale and the top of the Iola limestone. The limestone unit termed Iola at that time is now known to be the combined Frisbie and Argentine limestone members of the Wyandotte limestone (Moore, 1949, p. 111, 113). The type locality of the Lansing group is Lansing, Leavenworth County, Kans. (Hinds and Greene, 1915, p. 155). After several periods of modification, the upper limit of the group was again placed at the base of the Weston shale and the lower limit at the top of the Bonner Springs shale (Moore and Condra, 1932, chart). As thus defined, the Lansing group is characterized by dominance of limestone, and consists of two limestone formations, the Stanton limestone above and the Plattsburg limestone below, separated by a shale unit, the Vilas shale (see Table 1). This definition of the group was unanimously adopted by the State Geological Surveys of Iowa, Kansas, Missouri, and Nebraska in 1947 (Moore, 1948, p. 2031, 2033, 2034). All three formations are present in Wilson County where the group averages about 150 feet in thickness.

## Stanton limestone

Naming, distribution, and thickness.--The name Stanton was applied by Swallow (Swallow and Hawn, 1865, p. 6; or Swallow, 1866, p. 74) to the limestone sequence exposed near Stanton, Miami County, Kans. Workers in nearby areas believed this sequence to be the limestone next above the Vilas shale, but later mapping (Newell, 1935, p. 74, 76) showed that the limestone correlates ~~not with the upper limestone of the group but~~ with the lower limestone of the group, the Plattsburg limestone, rather than with the upper limestone. By that time, however, the name Stanton had for many years been employed for the upper limestone and was well established through usage in geologic reports on the Pennsylvanian strata of Kansas, Missouri, and Nebraska (see Haworth, 1908, p. 101, 104; Hinds and Greene, 1915, p. 156; Condra, 1930, p. 32-34, 36; Moore, 1936, p. 131-132). Its use for the upper limestone of the group was approved at the Interstate Conference in 1947 (Moore, 1948, p. 2031, 2033) and is so used herein.

Along its outcrop in eastern Kansas, the Stanton ranges in thickness from 20 feet to more than 100 feet (Moore, 1936, p. 132), and in Wilson County it is 15 to 65 feet thick. It is the major escarpment-forming unit in the county, and crops out diagonally from the northeast corner to the center of the south boundary. The Stanton limestone controls to a marked degree the topography of its outcrop area because of its resistance to erosion. The configuration of the upper surface of the formation cannot be used as a reliable datum to analyze deeper structure, as it may merely reflect a greater amount of limestone deposition in Stanton time. Some areas of high topography in the Stanton outcrop area are sites of structural upwarp, however.

The Stanton limestone lies with general conformity upon the Vilas shale, but locally, shallow channels were cut into the top of the Vilas.

The Stanton is subdivided into three limestone and two shale members named (downward): the South Bend limestone member, the Rock Lake shale member, the Stoner limestone member, the Eudora shale member, and the Captain Creek limestone member (see Table 1).

Lithologic character.--The Stanton limestone is predominantly a limestone unit in Wilson County. The more prominent limestone types represented in its members include oolitic, sandy limestone; wavy- and thin-bedded limestone; brecciated-appearing limestone; massive, cavernous-weathering limestone; and hard, gray algal or oolitic limestone. All limestone members are fossiliferous, but some are more so than others. The shale members are thin and locally are so calcareous that their separation from the limestone members is arbitrary.

South Bend limestone member.--The name South Bend, taken from the town of South Bend, Cass County, Nebr., was applied by Condra and Bengtson (1915, p. 23) to a limestone that was later found to correlate with the Iatan limestone (Condra, 1930, p. 11). The name was then transferred to the limestone unit next lower in the section, the uppermost member of the Stanton. In the type area, at quarries 2 miles northwest of South Bend, the member is nearly 10 feet thick and consists of gray, massive, fossiliferous (fusulinid-bearing) limestone that is cherty in the upper part and oolitic in the middle part. In Wilson County also, the upper limestone unit of the Stanton is a fusulinid-bearing, oolitic limestone. The South Bend apparently ~~conformably~~ underlies the Weston shale, conformably, but rests unconformably upon the underlying strata and locally lies on the upper part of the Stoner limestone member (see Plate 2, B).

The South Bend is 5 to 20 feet thick, and where thickest, it is a sandy limestone that contains lenticular sandstone units (NE. cor. sec. 24, T. 29 S., R. 14 E.) and is locally strongly cross bedded. Inclination of the strata (Fig. 12, C) may in part represent initial dip of beds, and may in part reflect folding along the Fredonia anticline. The abrupt contacts between sandy limestone and sandstone (Fig. 12, D) seemingly represent both current scouring and contemporaneous deposition of sandstone and sandy limestone (see Fig. 13).

Figure 24. South Bend limestone member of the Stanton limestone at the northeast corner of sec. 24, T. 29 S., R. 14 E.

Figure 25. Diagram showing the interrelationship between sandy limestone and sandstone in the South Bend limestone member of the Stanton limestone.

Pockets and channels cut in the underlying sandy limestone and sandstone were filled by sandstone.

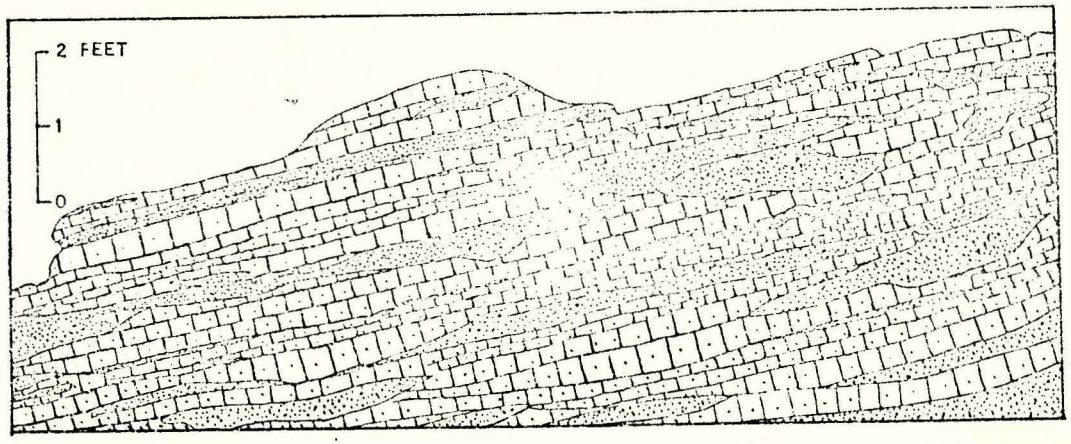


Figure 13.--Diagram showing the interrelationship between sandy limestone and sandstone in the South Bend Limestone Member of the Stanton Limestone.

The upper part of the South Bend is an oolitic, fragmental limestone in which the oolites and shell fragments are incorporated into a microcrystalline calcite matrix. Thin sections show that many of the oolites are composed of radially oriented calcite, a few have concentric rings, and many are largely limonite. The oolites commonly range from about 0.2 to 0.5 mm in diameter, but in some areas, they reach 1.0 mm. The limestone contains medium-size quartz grains, both as centers of oolites and individually within the limestone matrix (see Fig. 12, E, F). Locally, the quartz grains are etched, of fine-

~~Figure 26. South Bend limestone member of the Stanton limestone.~~

grain size, and scattered. About 10 percent of the oolites have quartz grains at their centers. The majority of the quartz grains ~~were~~ are euhedral, but they have been dissolved and replaced at their margins by dolomite or calcite, or both (see Fig. 12, E, F). A few of the quartz grains in the matrix are well-rounded with little embayment. Others are deeply dissolved and appear as elongate angular grains with a well-developed rim of dolomite and calcite. Undulatory extinction in the quartz grains is uncommon. Zircon and chert form a very small percentage of the grains. Fragments of brachiopod, pelecypod and gastropod shells are scattered throughout the unit in conjunction with fusulinid remains and a few pebbles of finely oolitic limestone. The insoluble residue of the more oolitic facies contains several genera of arenaceous Foraminifera, including Ammovertella, Tolypammina, Glomospira, and Hyperammina(?). Other constituents of the residue are euhedral, pitted or broken quartz grains, muscovite mica, and a few siltstone granules.

Pebbles and fragments of limestone and shale are common in the basal part of the South Bend. The unit is much more sandy in this part and locally consists of as much as 15 feet of sandy limestone and sandstone. Bedding is irregularly interrupted by sandstone lenses (Fig. 12, C, D, and Fig. 13). Some sandy limestone beds contain large angular fragments of claystone ($2\frac{1}{2}$ to 3 inches in length) in a medium-grained matrix of crystalline calcite and detrital quartz. Thin sections show that the claystone contains a few small mica flakes and quartz grains in a flocculent appearing clay matrix. Fragments of fossiliferous limestone and of brachiopod shells are locally present. Quartz is by far the most abundant detrital mineral. The grains are all deeply embayed, and most are rimmed by dolomite. Inclusions occur in most of the quartz grains, and wavy extinction is present, ~~occurs~~, but ~~is~~ uncommon. Other mineral grains, composing about 10% percent of the detrital minerals, include chert, muscovite, biotite, zircon, quartzite, and plagioclase feldspar. The insoluble residues of the basal part contain no arenaceous Foraminifera. The quartz grains are angular, fairly well sorted, and many are pitted and have a frosted appearance. Mudstone or claystone fragments and small grains of muscovite, biotite, hematite(?), and feldspar compose the remainder of the residue.

The fauna of the South Bend is sparse in most exposures. Fusulinids (Triticites) are generally present, but scattered; small pelecypods and gastropods (bellerophontids and archaeogastropods) occur locally. Newell (1933, pl. 1 and p. 140) lists the following forms as being more or less common in the South Bend (Kaw) member in the cement plant quarry at Fredonia:

Coelenterata

Syringopora cf. multattenuata

Brachiopoda

Rhipidomella carbonaria

Punctospirifer kentuckiensis

Hustedia sp.

Meekella striatocostata

Derbya sp.

Streptorhynchus affine

Dielasma bovidens

Pelecypoda

Streblopteria? hertzeri

He later recorded (Newell, 1937, p. 53) the presence of a paratype of Aviculopecten gradicosta in the cross-bedded, sandy, oolitic facies of the South Bend near Fredonia.

Rock Lake shale member.--Original use of the name Rock Lake was by Condra (1927, p. 59) for a shale bed exposed in the vicinity of Rock Lake, Sarpy County, Nebraska. At that time this shale was thought to be much higher in the section. In a later publication, however, Condra (1930, p. 11, 27) stated correctly that the Rock Lake is the upper shale member of the Stanton limestone. At the type locality, the member is about 6 feet thick and consists (downward) of 24 inches of bluish, argillaceous shale, 12 inches of dark maroon shale, 6 inches of greenish, sandy shale, 8 inches of maroon shale, and about 24 inches of calcareous shale (Condra, 1927, p. 157). At the outcrop in eastern Kansas, most of the Rock Lake consists of reddish-brown to dark-buff sandy shale or soft sandstone, and the contact at the base of the shale in many places is irregular, suggesting a slight disconformity (Moore, 1949, p. 119).

In Wilson County a period of erosion seems to have immediately preceded deposition of the Rock Lake member, for it apparently lies unconformably upon the Stoner limestone member (see Plate 2, B). The Rock Lake itself was apparently removed over much of Wilson County by erosion prior to deposition of the South Bend limestone member. Possibly, the interbedded sandy limestone and sandstone here placed in the basal part of the South Bend limestone member is a facies of the Rock Lake, and not of erosional significance, but because these beds are predominantly limestone, they are placed in the South Bend member in this report.

The Rock Lake is poorly exposed in Wilson County. At only a few places is a shale bed found at the stratigraphic position occupied by the Rock Lake elsewhere. At the northeast corner of the town of Fredonia, shale lies below the basal reddish sandstone of the South Bend limestone member. It consists of about a foot of very light olive-gray (5Y6/2), clay shale underlain by a foot of dark-yellowish-orange (10YR6/6), clay shale. About 1½ miles north of this exposure, the conglomeratic phase of the overlying South Bend contains clay fragments that were probably derived from shale of the Rock Lake. A very calcareous, fossiliferous shale at this stratigraphic position in the NW¼ of sec. 6, T. 27 S., R. 15 E., and SW¼ of sec. 31, T. 26 S., R. 15 E., is correlated with the Rock Lake. A microfauna collected from these exposures by Harris (Wagner and Harris, 1953), included the foraminifers Endothyra, Climacammina, Textularia, Tetrataxis, Glyphostomella, and undetermined fusulinids, and the ostracods Bairdia and Amphissites. Megafossils included crinoid columnals, ramose bryozoans, echinoid spines and plates, and brachiopod(?) shell fragments. Newell (1933, p. 136, 139) recorded abundant large echinoid spines and plates, which he referred to Echinocrinus cf. trudifer in the Rock Lake (Wolf Creek) member in central and northern Wilson County.

Stoner limestone member.--Condra (1930, p. 11-12) proposed the name Stoner for the middle limestone member of the Stanton because the name then in use for that member was preoccupied. The type locality was designated as the area extending from the old Burlington Railroad quarries, about 2 miles northwest of South Bend, Nebraska, southeastward through the Stoner farm (Condra, 1930, p. 36). At the type locality, the Stoner is about 15½ feet thick and consists of an upper light-gray to bluish-gray, somewhat argillaceous, wavy-bedded limestone about 2 feet thick, below which is 9½ feet of bluish-gray, dense, massive, fossiliferous limestone with considerable fine calcite, underlain by a thin, bluish-gray shale 2½ feet thick, and 1½ feet of bluish-gray, dense fossiliferous limestone at the base. The Stoner limestone member in Wilson County has many of these characteristics. Parts of it are wavy-bedded, parts have considerable fine calcite, and most of it is light gray to medium gray and ~~very~~ fossiliferous.

In Wilson County, the Stoner is 5 to 30 feet thick, and where thickest, it has at the top a light-gray (#), irregularly bedded, sparsely oolitic, finely crystalline limestone unit 5 to 15 feet thick. It contains fusulinids only locally. A fauna collected by Newell (1933, p. 110) from this unit at the cement plant quarry at Fredonia contained many species unknown elsewhere, and a few genera not previously recorded from the Midcontinent region. Concerning these forms, Newell (1933, p. 110) stated:

> "This novel fauna may represent an assemblage that had developed in some other faunal province, possibly in west Texas or the Cordilleran region, and except for a temporary invasion was prevented from reaching the northern Mid-continent by a faunal barrier, either of inhospitable environment or of land."

Newell, in listing the fauna, also pointed out (1933, p. 136):

> "The outstanding features of this fauna are the exotic orthoids and the peculiar assemblage of gastropods."

The fauna is as follows:

*Michelinia* sp.

*Composita* cf. *trilobata*.

*Dielasma bovidens*

*Parenteletes cooperi*?

*Schizophoria* cf. *texana*

*Echinoconchus semipunctatus*

*Juresania ovalis*

*Meekella striatocostata* cf. *ventricosa*

Derbya cf. deercreekensis

Pleurophorus cf. subcostatus

Pleurophorus n. sp.

Pseudomonotis cf. kansasensis

Pteria longa

Conocardium n. sp.

Myalina kansasensis

Myalina cuneiformis?

Euconospira cf. planibasalis

Lepetopsis? peregrina n. sp.

Lepetopsis parrishi

Helictostylus girtyi n. sp.

Ptychomphalus cf. persimplex

Pithodea broadheadi?

The holotype of a new crinoid, Elibatocrinus leptocalyx was obtained and described by Moore (1940a, p. 38, 39, 41, 53) from the Stoner at the same cement plant quarry.

The oolitic facies appears to have accumulated in depressions bordering the Fredonia anticline (see ~~Fig. 14~~ Plate 2, B).

The lower and more widely distributed part of the Stoner (see ~~Fig. 14~~ Plate 2, B) consists principally of blotchy-appearing, medium-gray (~~N5~~) and yellowish-gray (~~5Y7/2~~), thin-bedded, wavy-bedded, and locally cross-bedded, fossiliferous limestone (see Fig. ~~14, A~~), and averages about 15 feet in thickness. In many places, thin beds within the Stoner are medium- to coarse-crystalline coquinoid limestone made up entirely of crinoid columnals and plates (Fig. 14, B), echinoid plates, fenestrate bryozoans, or pelecypod and brachiopod fragments. Identifiable fossils include such genera as Meekoporella, Composita, Juresania, Neospirifer, Schizophoria, and Syringopora. In many places, relatively unfossiliferous, very fine-crystalline limestone predominates, and much of the Stoner is a brecciated-appearing unit of angular areas of light brownish gray (~~5YR6/1~~) in a matrix of yellowish-gray (~~5Y7/2~~) limestone. Fusulinids occur locally near the top of this part of the member, and sinuous areas of coarse-crystalline calcite that closely resemble in form the alga Cryptozoon are abundant in some areas. Vugs and fractures filled with ~~sparry~~ clear calcite are also conspicuous at many places.

Fig 14 near here

~~Figure 27. Stoner limestone member of the Stanton limestone.~~

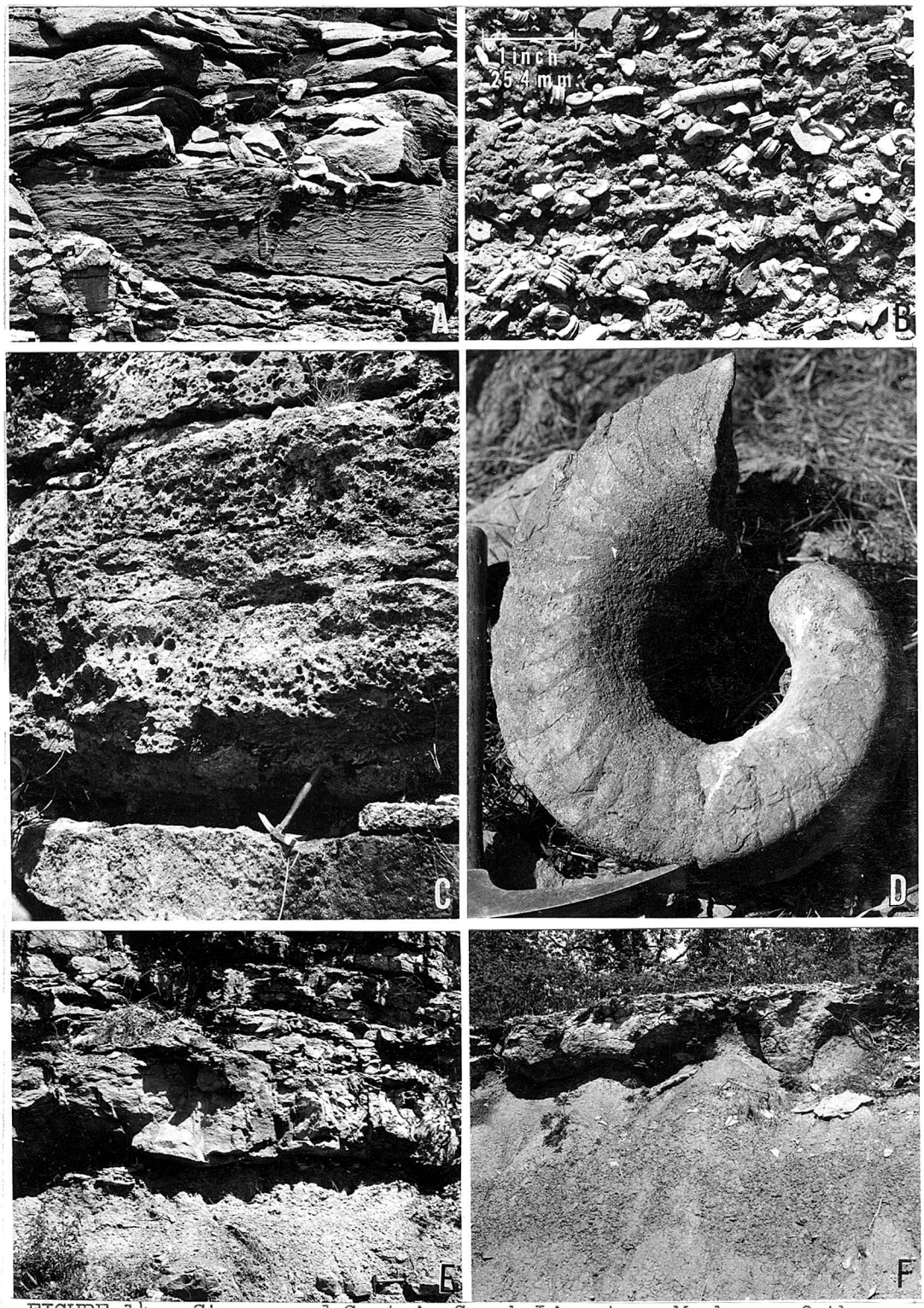


FIGURE 14.--Stoner and Captain Creek Limestone Members of the Stanton Limestone. (A) Exposure of the Stoner showing even bedding (top), cross bedding (middle), and wavy bedding (bottom) on weathered vertical-joint face. State Highway 47 roadcut 2 miles west of Altoona. (B) Crinoid-fragment coquina in the Stoner. Near center of south line, sec. 14, T 29 S, R 14 E. (C) Typical pitted, cavernous exposure of the Captain Creek. Near center of sec. 27, T 29 S, R 15 E. (D) Large nautiloid cephalopod from the Captain Creek east of Fredonia. (E) Relatively even-surfaced basal contact of the Captain Creek. Pick is at thin limestone bed in upper part of Vilas Shale. West line $NE\frac{1}{4}$ sec. 26, T 28 S, R 15 E. (F) Irregular basal contact of the Captain Creek filling scour channels cut into the top of the Vilas Shale. $NE\frac{1}{4}$ sec. 18, T 29 S, R 16 E.

Eudora shale member.--This member of the Stanton limestone was named by Condra (1930, p. 12) "from good exposures east of Eudora, Kansas" about 85 miles north of Wilson County. Near the type locality the Eudora member is about 6 feet thick and consists of 3 feet of gray, argillaceous shale underlain by about 1½ feet of black, very fissile shale and about 1½ feet of greenish-gray argillaceous shale at the base. In Wilson County the Eudora consists generally of greenish-gray shale, but locally it is partly black, platy shale. In most places it is made up of 2 to 5 feet of light-greenish-gray (~~5GY8/1~~), very slightly silty, calcareous shale that grades laterally into clayey limestone. In exposures 2 miles west of Altoona and near the northeastern corner of the county, 1 to 3 feet of almost black, very fissile, platy shale occurs near the center of the Eudora. The black shale breaks into paper-thin ~~laminae~~ plates on whose surfaces flattened orbiculoid brachiopods are locally abundant. In a few places the lower 6 to 12 inches is a thin-bedded, very argillaceous limestone that contains the remains of large pelecypods. Other fossils, most abundant in the lower and upper parts of the Eudora, include crinoid columnals, horn corals, encrusting bryozoans, echinoid spines, and brachiopod and mollusk fragments. Identifiable specimens include Neospirifer, Composita, Hustedia, Dielasma, and Syringopora. Newell (1933, p. 133) reported that between T. 22 S. and the middle of T. 32 S., the calcareous, nearly white, nodular phase of the Eudora is characterized by a distinct ~~[facies]~~ fossil assemblage. A few of the species are otherwise unknown in the Midcontinent region, or are quite rare, so that this faunule represents a novel facies. The fauna at one locality may be

considerably different from that at another place but is characterized by the following species (Newell, 1933, p. 133-134):

Lophophyllum profundum

Lophophyllum westi

Dibunophyllum valeriae

Lecythiocrinus cf. olliculaeformis

Erisocrinus typus

Chonetina flemingi

Lissochonetes geinitzianus var. plattsmouthensis

Rhipidomella carbonaria

Punctospirifer kentuckyensis

Marginifera wabashensis

Marginifera lasallensis

Wellerella n. sp.

Squamularia perplexa

Teguliferina armata

Ambocoelia planoconvexa

Hustedia acuticosta

Avonia knighti

Dictyoclostus americanus

Neospirifer cf. cameratus

Orthonychia parva

Griffithides cf. scitula

Jeffords (1947, p. 34, 52, 54) recorded two additional corals from the Eudora shale member in Wilson County; Lophophyllidium coniforme from sec. 21, T. 29 S., R. 15 E. (p. 34), and Stereostylus milichus from the Santa Fe railroad cut near Vilas (p. 52, 54).

Captain Creek limestone member.--The basal part of the Stanton limestone was named the Captain Creek limestone member by Newell (1935, p. 76) for outcrops along Captain Creek, near Eudora, Douglas County, Kans. This member name was adopted in 1947 by the State Geological Surveys of Iowa, Kansas, Missouri, and Nebraska (Moore, 1948, p. 2031). Near the type locality, the Captain Creek is about 5 feet thick and is a gray to dark-gray, massive and evenly bedded limestone with sugary to dense texture. Individual limestone beds are ordinarily more than 8 inches thick. The member generally has a mottled bright blue and pink brecciated appearance at the upper surface and characteristically contains Enteletes pugnoides in the upper part (Newell, 1935, p. 77).

In Wilson County, the Captain Creek member is chiefly a medium-gray (N5), massive- to thick-bedded, cavernous limestone 10 to 15 feet thick (fig. 28). This cavernous limestone unit generally forms

Figure 28. Captain Creek limestone member of the Stanton limestone.

escarpments, weathers almost white, and is deeply pitted with holes ½ inch to 2 inches in diameter. A conspicuous vertical joint system separates the rock into a series of large blocks 3 to 20 feet across. Crystalline calcite veinlets 1/16 inch to 3/8 inch in width cut the medium-grained matrix. The unit locally has, at or near the top, an 8-inch zone of thin-bedded, somewhat argillaceous, red-blotched limestone that contains large (two-inch) pelecypods. The most abundant fossils in the cavernous limestone are crinoid columnals, fenestrate bryozoan fronds, and the remains of such brachiopods as Enteletes, Hustedia, and Neospirifer. Corals and fusulinids are locally common. Newell, in his study of the stratigraphy and paleontology of the upper part of the Missouri series in eastern Kansas, reported (1933, p. 131) that at any good exposure between T. 10 S. and T. 32 S., the Captain Creek member is characterized by the following forms: most abundant are Enteletes pugnoides, Marginifera wabashensis, Triticites neglectus, Composita ovata, Cancrinella boonensis, and Acanthopecten cf. carboniferus; less common are Myalina kansasensis?, Juresania nebrascensis, Enteletes hemiplicatus var. plattsburgensis, and Dictyoclostus portlockianus var. crassicostatus. At the cement plant quarry at Fredonia, Enteletes pugnoides, Cancrinella boonensis, and Triticites neglectus are locally abundant.

The lower 2 to 5 feet of the Captain Creek member consists of yellowish-gray (5Y7/2), fine- to crystalline, algal and oolitic(?) limestone. Locally, in the central part of the outcrop belt, it is apparently missing. Where thin, this basal unit of the Captain Creek is a single vertically jointed massive bed; elsewhere, it is made up of 2 or 3 vertically jointed beds. Thin sections of this unit show that it consists of a mass of small ($\frac{1}{4}$ to $\frac{1}{2}$ mm) spheres, most of which are flattened and have dark centers. None show radial structure, and all appear to be small algae (Osagia). Fossils occur in local concentrations; the most spectacular are large nautiloid cephalopods (Fig. 14, D), possibly Domatoceras, from the basal part of the member east of Fredonia. Several crystal-filled casts of these cephalopods were seen in the State Highway 47 roadcut, about 2 miles west of Altoona. At outcrops in sec. 34, T. 28 S., R. 15 E., and sec. 23 and 33, T. 30 S., R. 15 E., the lower part of the Captain Creek member contains beds of hard, brittle, medium-gray (N5) to grayish-orange (10YR7/4), partly argillaceous limestone in which thin, dark veinlets (?) of calcite are abundant. Limestone beds containing similar veinlets occur locally in the upper part of the Vilas shale (see Fig. 15, C).

In most places in Wilson County the Captain Creek member of the Stanton limestone lies conformably upon the Vilas shale. Locally, however, limestone of the Captain Creek fills depressions cut several feet into the upper surface of the Vilas. Where the Captain Creek is conformable with the Vilas, the bedding both above and below the contact is parallel to the contact (Fig. ~~29, A~~ 14, F). Where the contact

Figure ~~29~~. Contact between the Stanton limestone and the Vilas shale.

between the two units is unconformable, the calcareous marine sediments of the Captain Creek fill irregular, steepwalled scour channels cut several feet into the underlying Vilas shale (Fig. ~~29, B~~ 14, F).

~~Stratigraphic and structural implications.--~~ The stratigraphy and structure of the Stanton Limestone and other formations of the Lansing Group in Wilson County and adjacent areas are the subject of papers by Chelikowsky and Burgat (1947), Wilson (1957), Winchell (1957), Davis (1959), and Marbaugh (1959, 1960). Chelikowsky and Burgat (1947, p. 95) attributed the changes in thickness of the Stanton Limestone and Vilas Shale between Fredonia and Altoona to variations in sedimentation and subsequent differential compaction. An abnormal thickness of sandstone in the Vilas Shale was required by their interpretation. Wilson (1957) considered the Stanton Limestone deposits in Wilson and Montgomery Counties ~~to~~ as representing barrier-reef development during Stanton time. He ~~apparently~~ recognized similar reefs in each limestone member of the Stanton Limestone, and stated (1957, p. 433): "The three reefs overlap slightly so that the total average width of the reefy sediments in the Stanton Formation is probably less than five miles." He admits (Wilson, 1957, p. 435) that "The reef-building organisms could not be definitely identified by the writer. Algal deposits were present in much of the strata and were believed to represent the major frame-building organisms although individual forms could not be identified." Wilson also believed (1957, p. 435) that the thinning and absence of the formation was caused by wedging out of the talus sediments at the reef front. Winchell (1957, p. 130, 132) credited the variations in thickness in part to development of algal reeflike bodies; Davis (1959) considered the thickness variations as representing reef-development during Plattsburg and Vilas time; and Marbaugh (1959, p. 326-327) interpreted

the thickness variations as due in part to local structural warping and in part to deposition of an extensive lens-shaped marine bank.

In the present study of Wilson County, distinctive reef-facies were not observed in the South Bend Limestone Member, and the absence of a solid reef core in any of the members of the Stanton, as well as the coincidence of the thinning of the members of the Stanton directly over the Fredonia anticline (see ~~fig. 24,~~ Plate 2, B), suggest strongly that the thinning and absence of the formation are related to structural uplift and erosion rather than to wedging out of reef talus or other mechanism. The sedimentary facies represented in the Stanton Limestone can be accounted for by deposition during transgressions and regressions of the sea, accompanied by local structural uplift along the Fredonia anticline, and development of bordering structural sags.

Stratigraphic and structural implications.--

The fusulinid-bearing, poorly bedded, sandy, oolitic South Bend Limestone Member probably reflects a nearshore calcareous marine environment in which sand grains and other small objects were continually being agitated and coated with calcium carbonate during oscillation by wave action. Quartz sand was probably transported along the shore by currents and was deposited into inclined strata in sandy-lime bars at the shoreline and in the foreset beds of local delta fronts at the seaward ends of channels. Potholes and irregular scours were cut locally into these bars and deltas by currents during periods of excessive activity, and were soon again filled with sand (see figs. 12, 12C, and 13). The position of these inclined strata of the South Bend in relation to the Fredonia anticline suggests that a part of the inclination may have resulted from local upward movement on the anticline. The ~~local~~ presence of abundant fusulinids in a few places indicates that large quantities of these small animals were swept into Wilson County to be eventually entrapped in the sandy calcareous sediments as they accumulated. The clay fragments in the basal sandy limestone of the South Bend suggest that in earliest South Bend time a marine-shale environment was brought slightly above sea level, and that the marine clay, which was exposed and desiccated to form a mud-cracked surface, furnished the fragments.

The ostracods, echinoids, and fusulinids of the fauna of the Rock Lake member suggest that fusulinids can tolerate the same environment as the other elements of the fauna or that the fusulinids were brought into this muddy environment to die. The variation in thickness and absence of the member throughout most of the county suggests that a general lowering of sea level or considerable local uplift and attendant erosion immediately followed Rock Lake deposition.

The lithology of the Stoner limestone member indicates that it accumulated in a marine environment well suited to the deposition of nearly pure limestone. The oolites in the upper part of the Stoner reflect a well-agitated, relatively shallow water ~~saline~~ environment. The absence of the oolitic facies atop the northwest-trending Fredonia anticline and maximum thickness both north and south of the anticline suggest that the oolites and fossil fragments, which may have originated in shallow water over the anticline, were carried by current action to low areas of peripheral sag adjacent to the uplifted area. Remnants of the oolitic facies atop the anticline were presumably removed by erosion prior to deposition of the Rock Lake shale member. The local concentration of certain fossil types, to the exclusion of all others, in the lower part of the Stoner member suggests that the sea floor ~~at~~ at that time was a series of local depressions separated by barriers that made possible the development of environments especially suited to certain life types. Locally, only the remains of crinoids furnished the material that accumulated to form ~~thick~~ thin beds of limestone; ~~E~~lsewhere, only fenestrate bryozoan remains were supplied; and ~~(still elsewhere)~~ in other places, brachiopods flourished, or pelecypods, or echinoids. The locally large concentrations of brecciated-appearing limestone are probably the result of fluctuations of sea level, and occasional periods of strong wave action.

The greenish-gray calcareous shale of the upper part of the Eudora member represents a muddy transition from the carbonate-rich environment of deposition of the Stoner member to the restricted lagoonal conditions of middle Eudora time. Bottom-dwelling pelecypods as well as horn corals, bryozoans, echinoids, and brachiopods formed the fauna of the calcareous shale. Earlier, orbiculoid brachiopods flourished in the local quiet-water environment now represented by the very fissile black shales of the middle part of the Eudora. The calcareous gray shale at the base of the Eudora indicates that a short period of less restricted argillaceous sedimentation preceded the quiet, lagoonal environment of middle Eudora time.

The Captain Creek lithology reflects a carbonate-rich marine environment. The porous, cavernous, sparingly fossiliferous limestone of the upper part of the member records a general, but shallow invasion of the sea. The waters presumably were so highly charged with carbonate that flocculating masses of calcium carbonate formed on the sea floor, incorporated the few available calcareous marine organisms, and lithified to form an open-textured calcareous rock. The locally fossiliferous, brecciated-appearing parts of the Captain Creek suggest that periodically, local storms may have stirred up these masses and brought in shell fragments or have brecciated the slightly lithified mass. Reduction in water agitation allowed these materials to settle into a thick limestone deposit. The abundant algae or oolites in the lower part of the Captain Creek reflect shallow, relatively well-lit, highly charged saline waters. The irregular surface at the top of the underlying Vilas Shale may have formed through the action of tidal currents which operated between high and low tides and cut scour channels that were filled by the algal-oolitic limestone at the base of the Captain Creek as the sea encroached upon the land.

The local absence of the Captain Creek member is due either to uplift and nondeposition along the crest of the Fredonia anticline during Captain Creek time or uplift and erosion at the end of Captain Creek time. Progressive, but periodically accelerated, uplift and nondeposition or erosion (or both) apparently characterized much of Stanton time, having occurred during the deposition of the Stoner and Rock Lake also.

## Vilas shale

**Naming, distribution, and thickness.**--Haworth (1898a, p. 51) credited G. I. Adams with the suggestion that the shale sequence well represented in the northeastern part of Wilson County around the town of Vilas be designated the Vilas shale.

The formation crops out across the county from the northeast corner to the center of the south line (see ~~Fig. 2~~ Plate 1), and is as much as 110 feet thick in the triangular area between Vilas, Benedict, and Altoona (see ~~Fig. 16~~ Plate 2, C). It thins rapidly both east and west of Altoona; about 6 miles to the east it is only 5 feet thick, and about 4 miles to the west it is only 8 feet thick. It appears to be missing south of Fredonia, but thickens again markedly at the boundary of Wilson and Montgomery Counties.

Lithologic character.--The most nearly complete exposure of the Vilas shale is in roadcuts along the east lines of the SE¼ of sec. 11 and the NE¼ of sec. 14, T. 28 S., R. 16 E., about 3½ miles southwest of Vilas. At this locality, the Vilas lies conformably below the Stanton limestone and is about 107 feet thick. The uppermost 3 feet is light-grayish-orange (10YR8/4), fossiliferous, calcareous shale containing crinoid columnals and sparse low-spire gastropods amid fragments of brachiopods, and pelecypods, and bryozoans. At the base of this uppermost 3 feet is a 6- to 12-inch medium-gray (N5), nodular, algal limestone bed. The next underlying 18 feet of shale is dark bluish gray (5B4/1) to light olive gray (5Y6/1), non-silty, and unfossiliferous. Near the center of this 18 feet of shale are several thin beds of calcareous clayey concretions, some of which are seamed with veinlets of black calcite. The lower 85 feet of the Vilas at this exposure rests conformably on the Plattsburg limestone and consists of light-olive-gray (5Y5/2), unfossiliferous, slightly silty, locally micaceous shale that contains several thin beds of ironstone concretions in its upper and lower parts.

The uppermost part of the Vilas is generally calcareous and locally contains an abundant microfaunal assemblage intermixed with the remains of crinoids, echinoids, gastropods, pelecypods, bryozoans, and brachiopods. The microfauna consists of the ostracods Bairdia and Kirkbya(?), and the foraminifers Polytaxis, Tetrataxis, and unidentified fusulinids (Wagner and Harris, 1953). The limestone bed at the base of this uppermost 3-foot unit is made up in some places of disconnected, flattish, algal(?) nodules or concretions; in other places the bed is as much as 5 feet thick and is irregularly bedded. In most of the outcrop area, the bed is a mass of algae (Osagia) and oolites. Thin sections show the algae to range in length from 1 to 20 mm and to form coatings around shell and rock fragments ranging in length from $\frac{1}{4}$ mm to 15 mm. The algal coatings on small objects ($\frac{1}{4}$ mm to 2 mm) are smooth-surfaced and thin; the coatings on larger objects (2 to 15 mm) are thicker and are commonly composed of many thin, encrusting, irregularly crenulated layers (see fig. 30, A).

Figure 15 near here

Figure 30. Limestone beds near the top of the Vilas shale.

The centers of many of the small algae are detrital grains of crystalline calcite; other centers are recognizable as shell fragments. The small algae are mainly flattened spheres or discs; the large algae generally conform to the shapes of the shell fragments around which they formed. Both of these types apparently fall within the genus Osagia as pictured by Johnson (1946, fig. 3, pl. 10; and fig. 4, pl. 4), but the larger forms closely resemble Cryptozoon from other beds.

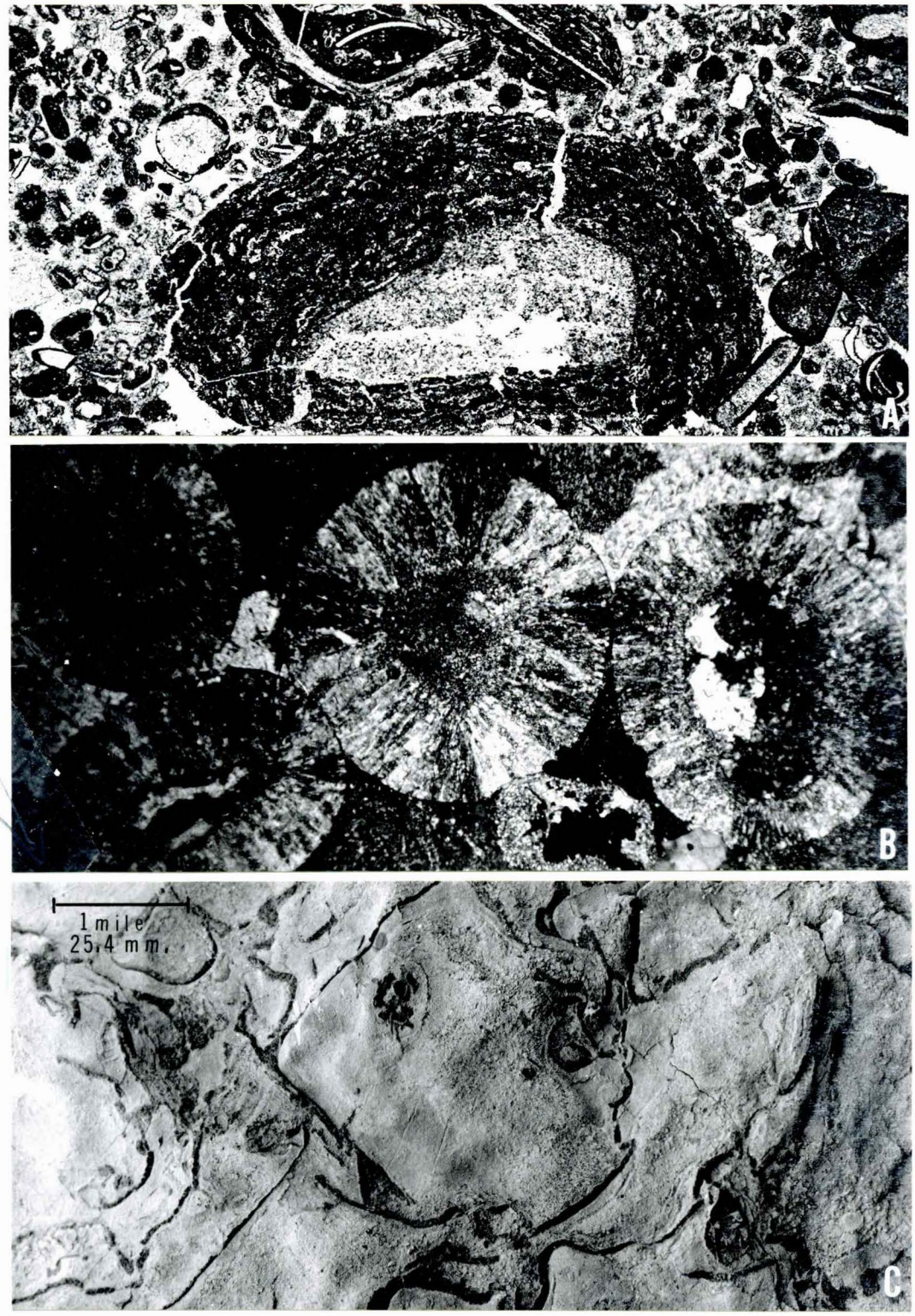


FIGURE 15.--Limestone beds near the top of the Vilas Shale. (A) Thin section of algal, oolitic limestone bed showing small algae in lower right, large algae in center, and radial oolites in matrix. Sec. 27, T 29 S, R 15 E. Ordinary light (X 30). (B) Same, showing detail of radial oolites. Crossed nicols (X 300). (C) Weathered surface of different bed showing sinuous paths of dark calcite veinlets. Sec. 33, T 30 S, R 15 E.

The oolites associated with the algae are spherical and average mm
1/4 to 1/3 mm in diameter. Unlike the algae, they show a prominent radial structure that extends all the way to the center in many oolites, but in most includes only the outer part (see Fig. 15, B). Many oolites formed around shell fragment nuclei; others formed around subround fragments of very fine-crystalline or microcrystalline limestone.

This limestone bed at the base of the uppermost 3 feet may correlate laterally with a bed containing algal limestone concretions. Newell (1933, p. 62) suggested that these concretions were colonies of calcareous algae of the sort described by George S. Gurich as Malcostroma. Newell (1933, p. 62-63) pointed out further that:

> "Most of the algal 'heads' are concavo-convex slabs 3 or 4 inches thick and a foot or two across. They lie isolated from each other in shale. In a few instances a reef-like structure or bed is formed, a foot thick or so and several feet across. These masses weather out as buff impure limestone. Fresh fractures occasionally show layers of dense, bluish limestone which shows delicate lamination. In rare instances a development of irregular, ragged stolons appears at the upper surface as in the alga Somphospongia Beede. The algal limestone is generally crusted over or overlain by a dark colored oolitic limestone which locally bears a few poorly preserved mollusks and particularly the brachiopod Punctospirifer kentuckiensis. The oolitic limestone is possibly also of algal origin since the contained fossils are commonly coated over with a lamellar limy deposit of probable organic origin."

Locally, as in secs. 27 and 31, T. 29 S., R. 15 E. and secs. 33 and 34, T. 30 S., R. 15 E., ~~this~~ the limestone unit containing the algal concretions incorporates grayish-orange (~~10YR7/4~~) limestone fragments in its lower part. Many of the fragments have an algal or accretionary coating around them; elsewhere, the fragments are closely associated with thin (1/25-inch ~~wide~~) olive-gray (~~5Y4/1~~) irregularly shaped seams or blades that may be of algal origin (see Fig. ~~30~~ 15, C). In sec. 36, T. 28 S., R. 15 E., a limestone bed at the same stratigraphic position is made up almost entirely of small brachiopod shells, probably Punctospirifer, coated with an algal encrustation and enclosed in a silty calcareous matrix. Crinoid stems, pelecypods, gastropods, and sparse fusulinids are also associated with limestone at this stratigraphic position. Jeffords (1947, p. 30) recorded the occurrence of the solitary coral Lophophyllidium coniforme in the Vilas shale at a locality 6 miles east and half a mile south of Fredonia on Highway 47.

Near the center of Wilson County, a unit of very dark-gray (~~N3~~) shale about 5 feet thick occurs locally in the Vilas shale about 30 feet above the base. It is overlain by 55 feet of yellowish-gray (~~5Y7/2~~) shale and underlain by 30 feet of light olive-gray (~~5Y5/2~~) slightly silty shale.

Stratigraphic and structural implications.--The changes in thickness of the Vilas Shale are apparently the result both of lateral variations in sedimentation and of structural uplift. The wide distribution of thin limestone beds near the top of the Vilas seems to preclude extensive erosion at the end of Vilas time as the cause of the thickness variation. Pre-Stanton erosion at the top of the Vilas occurred locally, however, and is well shown in roadcuts 2 miles west of Altoona along State Highway 47, where surge channels with rounded bottoms and nearly vertical sides were cut 2 or more feet deep into the Vilas. The channels are separated by intervening areas with tops smoothly convex upward and closely resemble present-day bay muds that have been cut to similar depths and kept fairly smooth and clean of clay debris by tidal or wave action. Vilas time may therefore have ended with the argillaceous marine sediments locally exposed to shoreline or surge channel erosion. The thin, algal, oolitic limestone bed below the fossiliferous uppermost few feet of the Vilas indicates a change from a widespread nearshore, supersaline environment to one reflecting an abundant supply of clay-size debris. The fossils in the uppermost few feet of the Vilas suggest that occasional strong waves and currents brought fragments of crinoids and bryozoans (and a few fusulinids) into the biozone of a nearshore marine fauna that included abundant small gastropods, pelecypods, and brachiopods. Locally, thin, platy calcite bodies developed at this approximate time and formed a brecciated-appearing limestone bed. The presence of limestone beds with the platy calcite bodies in the lower part of the Captain Creek member indicates that these particular environmental conditions continued into Stanton time.

The more than 100 feet of shale that underlies the thin oolitic limestone bed between Vilas, Altoona, and Benedict indicates a relatively long period of concentrated argillaceous deposition in that area. On the Fredonia anticline, however, concurrent uplift apparently reduced shale deposition and preservation to only about 10 feet, and farther south in Wilson County a facies of the Plattsburg limestone apparently took the place of argillaceous sedimentation of Vilas shale.

## Plattsburg limestone

Naming, distribution, and thickness.--The Plattsburg limestone was named by Broadhead (1865, p. 317) for exposures at Plattsburg, Clinton County, Mo. According to Moore (1936, p. 128), the Plattsburg has been traced from northwestern Missouri to a point near the Oklahoma boundary where it disappears; but it apparently reappears farther south in Oklahoma. Along the outcrop belt in Kansas, the thickness of the Plattsburg is from less than 5 feet to more than 100 feet thick. In Wilson County it crops out in a northeasterly trending belt generally near the foot of the escarpment capped by Stanton limestone. In the northeastern part of the county, it is only 1 to 10 feet thick, but in the south-central part of the county, it is as much as 115 feet thick and forms the major part of the escarpment capped by the Stanton limestone. Most of the mounds south and east of ~~that~~ the Stanton escarpment are capped by the Plattsburg limestone, ~~however~~.

Lithologic character.--The Plattsburg limestone at the type locality is a gray and ashy-blue coarse limestone 13 to 23 feet thick (Broadhead, 1865, p. 317, 327). In the outcrop area in northeastern Kansas and adjacent parts of Missouri, the Plattsburg is strikingly constant in its distinguishing features and shows little variation in lithologic and faunal characters (Newell, 1935, p. 71; Moore, 1936, p. 128). It is nearly everywhere divisible into 3 parts: a relatively thick, upper limestone (the Spring Hill limestone member), a thin shale parting (the Hickory Creek shale member), and a basal thin, blocky limestone (the Merriam limestone member).

In Wilson County all three members are readily distinguished where the formation is thick. Each member contains the sponges Girtyocoelia and Heliospongia, and where the formation is thickest, a poorly bedded, sparingly fossiliferous, oolitic, algal limestone occurs above sponge-bearing beds. Where the formation is very thin, it appears that the upper two members are missing, but exposures in that area are not continuous, and correlation between members could not be made with certainty. However, the lithology and bedding of the limestone where it is thin are more nearly like those of the Merriam member than like those of the Spring Hill member, and correlation is made on that basis.

Spring Hill limestone member.--The Spring Hill limestone member was named by Newell in 1932 (see Moore, 1936, p. 129) for exposures near the town of Spring Hill in southern Johnson County, Kans. At the type locality in a railroad cut at Spring Hill (SE. cor. sec. 14, T. 15 S., R. 23 E.), the member is about 12 feet thick and consists (downward) of: (a) 7 feet of drab to buff, granular limestone composed largely of minute fossil fragments and thin, wavy streaks of carbonaceous limestone with a Composita zone 12 inches above the middle; (b) 1.3 feet of drab, massive, oolitic, limestone; and (c) about 4 feet of drab, dense, hard, massive limestone with a shaly streak at the top and a zone of Enteletes hemiplicatus var. plattsburgensis and Marginifera wabashensis in the lower part (Newell, 1935, p. 102). In Wilson County, the Spring Hill member ranges in thickness from less than 1 foot to more than 90 feet, but averages only about 25 feet. Where of average thickness it is characterized by the sponges Girtyocoelia and Heliospongia (see ~~Fig. 31~~ Fig. 16, A, B, C, D).

~~Figure 31. Sponges of the Spring Hill limestone member of the Plattsburg limestone.~~

~~fig. 32, A~~). Where thickest it has at its top a unit of oolitic and

~~Figure 32. Spring Hill limestone member of the Plattsburg limestone.~~

algal limestone that is locally more than 65 feet thick (see ~~fig. 14~~ Plate 2, C). This unit is best developed in the south-central part of the county; it thins rapidly northward and southward, and is apparently missing locally just west of Altoona and south of Vilas.

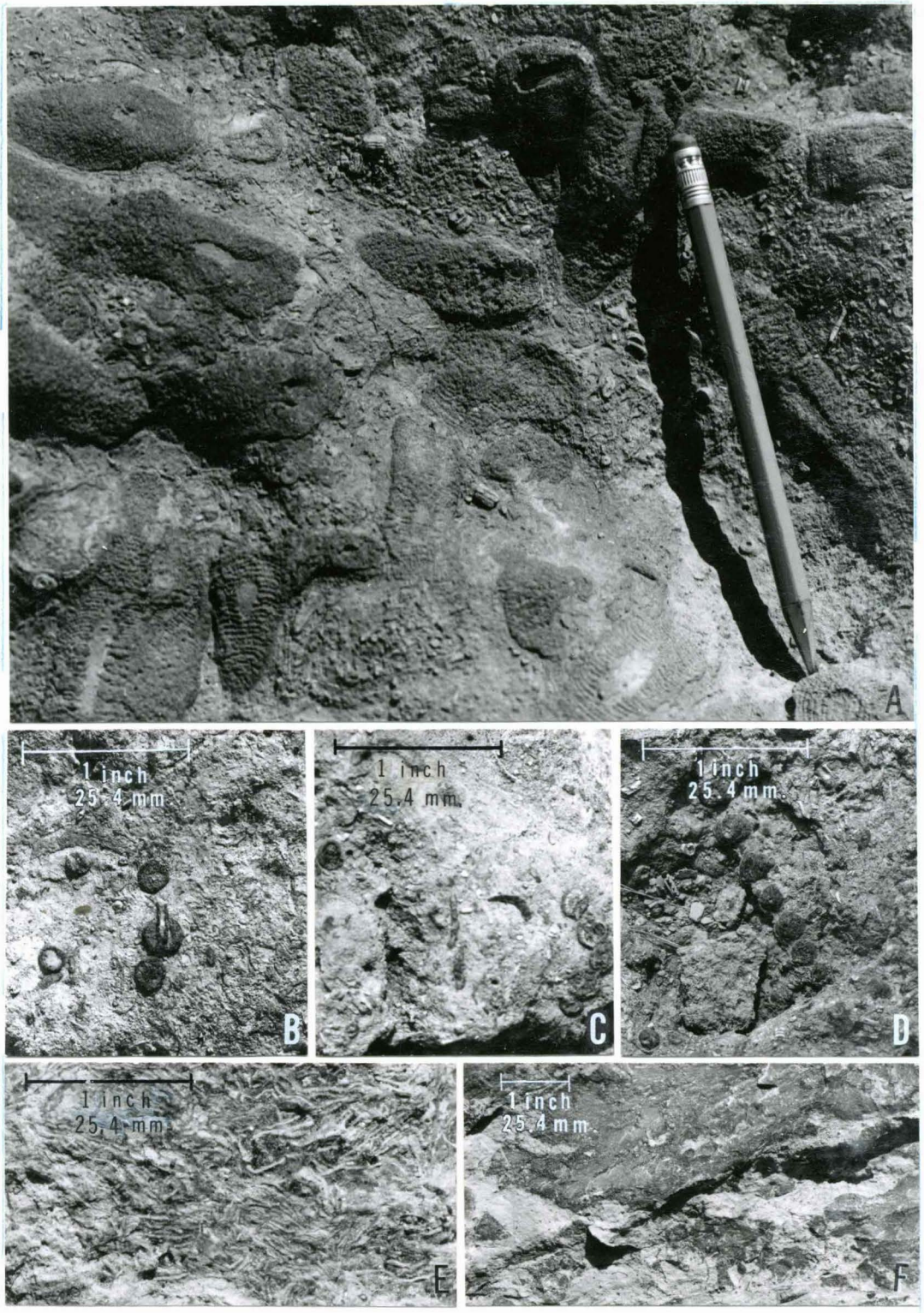


FIGURE 16.--Spring Hill Limestone Member of the Plattsburg Limestone. (A) Large sponges (Heliospongia) in typical crinoidal matrix of the Spring Hill. In quarry in sec. 33, T 29 S, R 15 E. (B, C, D) Small chain-like sponges (Girtyocoelia) in coquinoid matrix. Same locality as (A). (E) Algal(?) crenulations in upper part of Spring Hill. In quarry in sec. 6, T 27 S, R 15 E. (F) Breccia facies in upper part of Spring Hill. Same locality as (E).

The uppermost few feet of the Spring Hill member consists principally of oolites or Osagia(?) that have diameters generally less than 1/8 inch but locally as much as 1/4 inch. This oolitic part is well exposed in roadcuts just south of the Verdigris River in the NE¼ sec. 26, T. 28 S., R. 15 E., and north of the river in the NW¼ sec. 30, T. 28 S., R. 16 E. Staining with Alizarine Red S shows the rock to be calcite with but a small amount of clay and limonite and no dolomite.

The oolites, which are concentrically banded, are commonly in contact with one another and were concentrated [probably by wave action] into depressions and enclosed in a very fine-grained crystalline limestone. Thin section studies show that the rock has been moderately and somewhat selectively recrystallized. The crystal size in the oolites and in most of the calcite matrix is 0.1 to 0.2 mm, but in parts of the thin sections the matrix consists of calcite crystals as small as 0.02 mm. Crystal boundaries, either in matrix or in oolite, stop abruptly at the oolite boundary (see Fig. 17, A). Many of the oolites have a thin outer rind of calcite in which the long directions of the crystals are oriented perpendicularly to the oolite surface. However, distinct internal radial structure, characteristic of many oolites, is lacking, and the spheres may actually be of algal origin. Recrystallized calcite in the oolites forms crystals irregularly elongated parallel to the direction of the concentric bands, but the crystals cross the bands and commonly include 2 to 5 bands (see Fig. 17, B, C). Some of the concentric bands extend to the center of

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Figure 33. Spring Hill limestone member of the Plattsburg limestone.

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the oolite, but more commonly crinoid stem segments, shell fragments, or subangular microcrystalline limestone fragments form the centers. Many of the nuclei seem to have been unaffected by recrystallization.

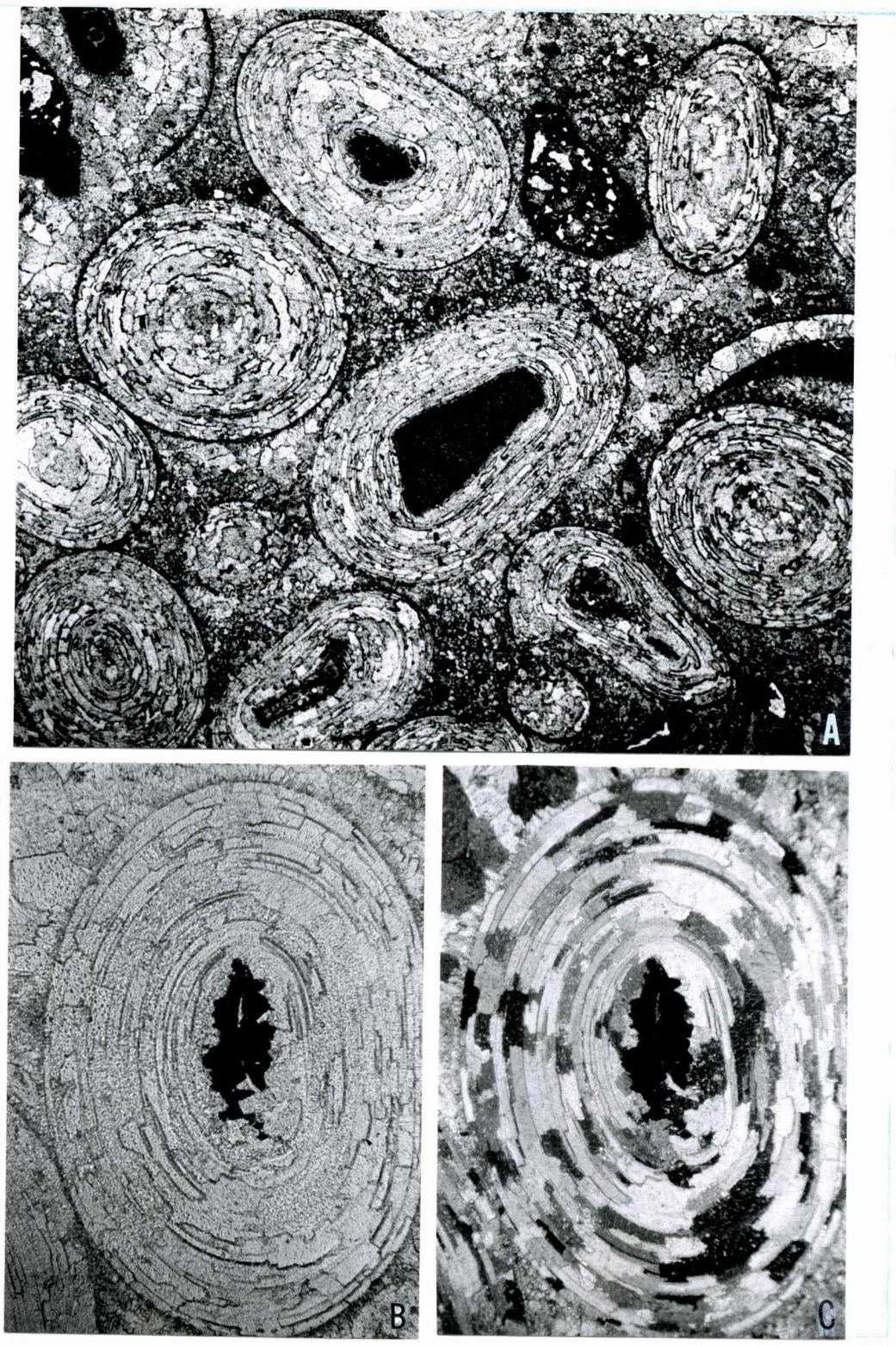



FIGURE 17.--Oolites in the Spring Hill Limestone Member of the Plattsburg Limestone. (A) Thin section of oolitic facies of Spring Hill. Sec. 26, T 28 S, R 15 E. Crossed nicols (X 30). (B, C) Thin section of concentric oolite showing recrystallization. **B**, ordinary light; **C**, crossed nicols, (X 80). Note that crystal boundaries cross concentric bands. Note also perpendicularly oriented crystals at oolite boundary. ~~in upper right.~~

Where the Spring Hill is thickest, the upper 60 feet below the oolitic part consists of irregularly bedded, sparsely fossiliferous, algal, locally oolitic limestone. Small cavities and vugs lined with clear calcite crystals are common. In places, crystalline calcite occurs abundantly in short plate-like or vein-like bodies that lie generally parallel to the bedding (see Fig. ~~32, B~~ 16, E). Many have very irregular shapes, suggesting that they may have a biologic origin, or that they may have been crenulated and fractured while in a semi-plastic condition during compaction of the enclosing sediments. Crinoid stem fragments and algal growths, some resembling Cryptozoon, are abundant in a light-olive-gray ~~(5Y 5/2)~~ limestone matrix in some exposures. Characteristically, much of the unit is a brecciated-appearing, poorly bedded limestone in which medium-dark-gray ~~(N 4)~~, irregularly shaped, very finely crystalline fragments, ½ inch to 2 inches in length, occur in a matrix of light-olive-gray ~~(5Y 5/2)~~, finely crystalline limestone. The ends of many of the fragments are serrated as though they had been violently pulled apart while semilithified and immediately enclosed in a gel-like carbonate matrix (~~see~~ Fig. ~~32, D~~ 16, F). In thin section, the fragments are seen to be composed of a foraminiferal microfauna and minute fossil debris. The matrix appears to have been predominantly silt-size grains of dolomite and calcite in which were enclosed a few very small oolites and numerous small segments of crinoid stems and fragments of shells. The weathered surface of this upper part of the Spring Hill member is generally gray and irregular.

Based on acetate peels made from the etched surfaces of samples of limestone from the Spring Hill member, Harbaugh (1959, p. 300-314) differentiated three subdivisions in the member (downward): (a) a calcarenite subdivision as much as 35 feet thick ~~at the top~~; (b) a crystalline limestone subdivision as much as 45 feet thick ~~in the middle~~; and (c) a fragment-pellet limestone subdivision that ranges from 3 to 35 feet thick ~~at the bottom~~. Harbaugh's calcarenite and crystalline limestone subdivisions apparently correlate with the ~~upper unit~~ part of the Spring Hill described above. The lower part of the Spring Hill, described below, coincides generally with this fragment-pellet limestone subdivision.

The Spring Hill is about 25 feet thick over most of the county, but is apparently missing northeast of Vilas, where the entire Plattsburg limestone is about 6 inches thick. Where of average thickness, most of the Spring Hill consists of light-olive-gray (~~5Y6/1~~) to medium-light-gray (~~N6~~), hard, clayey, very thin-bedded and irregularly bedded, fossiliferous limestone. It characteristically has abundant Heliospongia and Girtyocoelia, but also contains many crinoid fragments and less abundant Neospirifer, Derbyia, Marginifera, Crurithyris, Echinoconchus, Composita, horn corals, and encrusting and fenestrate bryozoans. Much of the Spring Hill is a detrital limestone in which many small fossil fragments are enclosed in a silt-size, argillaceous, calcareous matrix. Weathered surfaces of the rock are stained grayish orange (~~10YR7/4~~) to dark yellowish orange (~~10YR6/6~~) by iron oxide. The Heliospongia occur both in clusters (see Fig. ~~31~~ 16, A) or as fragments. The Girtyocoelia are separated pellet-size spheres (see Fig. ~~32, A~~ 16, B) or, more commonly, chains of spheres (see Fig. ~~31, B, C~~ 16, C, D). Newell (1933, p. 129) listed Heliospongia ramosa, Heterocoelia (now Girtyocoelia) beedei, Girtycoelia benjamini, Maeandrostia kansasensis, and Coelocladia spinosa from this general area. Winchell (1957, p. 131) reported a large nautiloid cephalopod from the Spring Hill member in sec. 8, T. 28 S., R. 17 E., in Wilson County.

Hickory Creek shale member. The Hickory Creek shale member was named by Newell in 1932 (see Moore, 1936, p. 129) from a stream near Peoria, Franklin County, Kans. In the general area of the type locality, the Hickory Creek member is about a foot thick and is commonly gray or yellowish calcareous shale, but in some nearby areas it is black, carbonaceous, and platy shale (Newell, 1933, p. 47-48).

Where measured in Wilson County, the Hickory Creek is from 3 to 30 feet thick (see ~~Fig. 14~~ Plate 2, C), and is consistently very finely micaceous, slightly silty, very calcareous and fossiliferous, and varies from medium light gray (~~N 6~~) or light olive gray (~~5Y 5/2~~) to yellowish gray (~~5Y 7/2~~). Thin, silty laminae locally contain plant fragments. The most common fossils are crinoid columnals and the sponges Girtyocoelia and Heliospongia. Other fossils include parts of crinoid heads, ramose and fenestrate bryozoans, horn corals, and the brachiopods Hustedia, Marginifera, Neospirifer, and Composita. The fossils weather readily from the clayey matrix, and unbroken specimens are abundant. The Girtyocoelia weather out as chains of small ($\frac{1}{8}$-inch diameter) spherical-shaped bodies or separated spheres. The Hickory Creek member grades laterally from very thin bedded, fossiliferous shale to poorly bedded, very calcareous shale and clayey limestone. Concerning the fauna of the Hickory Creek, Newell (1933, p. 129) stated that the sponges Girtyocoelia benjamini, Maeandrostia kansasensis, Heliospongia ramosa, and especially Coelocladia spinosa and Heterocoelia (now Girtyocoelia) beedei are particularly abundant in the Hickory Creek Shale Member south of the Neosho River. He stated also (Newell, 1933, p. 130) that, "In central Wilson County a number of mollusks, definitely of the geosynclinal facies, are introduced into the sponge fauna. Of particular note is the occurrence together in the southern facies of the Hickory Creek of Leiorhynchus rockymontanus and Enteletes hemiplicatus var. plattsburgensis."

Moore (1940a, p. 34, 39, 41, 42, 53) reported the collection of the holotype specimen of the [illegible] crinoid Elibatocrinus notabilis and paratype specimens of Elibatocrinus leptocalyx from the Hickory Creek at a locality 2½ miles west of Neodesha on State Highway 96. Jeffords (1947, p. 30) reported specimens of Lophophyllidium coniforme from the Hickory Creek member at several localities in Wilson County.

Merriam Limestone Member.--The Merriam Limestone Member was named by Newell in 1932 (see Moore, 1936, p. 128) for exposures in a quarry at Merriam, Johnson County, Kans. In 1956 McManus (1956, p. 3) proposed that the roadcut exposure on the west side of U.S. Highways 50 and 169, just south of the highway interchange at Merriam, be considered as the type section. The Merriam there is about 3 feet thick and consists of two thin limestone beds separated by several inches of pale-olive laminated shale. The upper limestone bed is 0.6-foot thick, is medium light gray, very fine grained, and vertically jointed, and has a few worm borings, Osagia, and fusulinids distributed throughout. The lower limestone bed is 1.6 feet thick, is medium light gray, fine grained and massive, and has an oolitic-algal (Osagia) matrix in which Composita, other brachiopods, and Myalina are common in the lower foot (McManus, 1956, p. 116-117).

In Wilson County, the Merriam is a single bed that generally is massive, vertically jointed, and very fossiliferous and is consistently slightly more than 1 foot thick, except in the southwestern part of T. 28 S., R. 17 E., where the Plattsburg limestone as a whole thins to less than 6 inches. McManus (1956, pl. 2) correlated this bed in Wilson County with the lower limestone unit of the Merriam elsewhere to the north. In Wilson County, the Merriam is light gray ~~(N7)~~ to light olive gray (~~5Y6/1~~) and weathers grayish orange (~~10YR7/4~~). It has a very fine-crystalline limestone matrix in which the remains of crinoids, sponges, brachiopods, horn corals, and bryozoans are interspersed. Locally, the lowest 2 inches is very clayey and weathers to a fossiliferous, calcareous rubble. In thin sections, the matrix of the Merriam is seen as a mass of almost cryptocrystalline calcite and clay-size calcareous debris that contains broken and worn shell fragments and a few angular silt-size quartz grains. Enclosed in this matrix are larger fragments of brachiopods, crinoid stems, echinoid spines, small foraminifers, and small and large algae.

Crinoid columnals are by far the most abundant fossils in the Merriam, but the sponges Girtyocoelia and Heliospongia are the most distinctive. Also present are the brachiopods Meekella, Hustedia, Composita, Derbyia, and Marginifera. ~~An outcrop in sec. 5, T. 29 S., R. 16 E., contains a few small fusulinids and numerous Cryptozoon-like algae.~~ Small subcircular oolites or flattened algae (Osagia) are locally abundant in the lower part of the member. Newell (1933, p. 130) reported Enteletes hemiplicatus var. plattsburgensis from the Merriam in this general area.

Stratigraphic and structural implications.--The oolitic limestone at the top of the Spring Hill member reflects a shallow-water marine environment in which small oolites or Osagia were being oscillated back and forth in carbonate-rich water by current or wave action along the shoreline of the sea or of an island in the sea, or on the bottom of a bordering shallow lagoon. The thinness and wide distribution of the oolitic unit suggests a flat or gently undulating surface whose highest point was near Vilas. The algal, brecciated-appearing, sparsely oolitic limestone that is 60 feet thick south of the Fredonia anticline and 10 feet or less thick on and north of the anticline suggests accumulation of lime-mud in a shallow marine environment. Extremely strong wave action at times apparently forced water between layers of partly lithified lime-mud, disrupted these beds, and pulled them violently apart. The fragments were then carried into deeper water where they were immediately incorporated in a partly crinoidal, almost cryptocrystalline matrix before their serrated ends could be abraded. The purity of this limestone (lack of argillaceous material) and its limited extent but greater thickness south of the Fredonia anticline suggest that limy debris from an isolated calcareous environment was transported southward by predominantly south-moving submarine currents to the center of a subsiding area where these materials encountered and intertongued with argillaceous sediment supplied from the south. The concurrent sedimentation of these two rock types presumably continued until the end of Spring Hill time with its widespread deposition of the oolite unit. Following this oolite deposition, the subsidence south of the anticline apparently ceased, and the argillaceous sediment collected north of the anticline to form more than 100 feet of Vilas Shale.

The thinness of the combined Vilas Shale and Plattsburg Limestone on the crest of the Fredonia anticline, as compared with the combined thickness of these two units adjacent to the anticline, is a measure of the amount of local downwarping that took place south of the anticline during Plattsburg time and north of the anticline during Vilas time. The lack of evidence of a solid framework built by algae, corals, or other organisms anywhere along the outcrop of the Spring Hill member in Wilson County suggests that the brecciated-appearing limestone deposit may represent debris that was disrupted and supplied from lime-mud deposits along the top and south flank of the Fredonia anticline. The greater thickness of the Spring Hill and Hickory Creek members south of the Fredonia anticline indicates that subsidence in that area began as early as Hickory Creek time. The ~~even~~ relatively constant thickness of the Merriam Limestone Member suggests that the area was stable during Merriam time. The abundance of sponges, crinoids, horn corals, and heavy-shelled and thin-shelled brachiopods in the argillaceous facies of the Spring Hill and Merriam, as well as in the shale of the Hickory Creek, indicates that these life forms could tolerate both slightly muddy and very muddy environments. The yellowish-brown-weathered color of the sponge-bearing beds indicates a higher iron content in the argillaceous sediments than was present in the deposits formed in late Spring Hill time. Locally abundant algae and oolites in the Merriam Limestone Member indicate high salinity and shallow water at the beginning of Plattsburg time.

## Kansas City group

The Kansas City group was named by Hinds (1912, p. 7) from exposures in the bluffs of the Missouri River and its tributaries at Kansas City, Mo. He classed these rocks as a formation whose upper limit was the base of the Lansing formation and whose lower limit was the top of the Pleasanton formation. These three formations have been elevated to group status, and the Kansas City group has been subdivided into three subgroups which are further subdivided into formations and members. Although the boundaries of the Kansas City group have been modified, those used in this report are nearly the same as those originally set up by Hinds, the difference being that the Lane shale is now included with the Kansas City group, rather than with the overlying group. This regrouping is advisable in Wilson County because the Lane and Bonner Springs shales are inseparable due to absence of the intervening Wyandotte limestone. This usage also conforms to that agreed upon by the State Geological Surveys of Iowa, Kansas, Missouri, and Nebraska in 1947 (Moore, 1948, p. 2028-2033). More complete treatments of boundary modifications and establishment of current boundaries of the Kansas City group are given by Moore (1936, p. 96-97; 1948, p. 2028-2033; 1949, p. 74-75), Wilmarth (1938, p. 1070, 1147), Greene and Searight (1949, p. 10-14) and Condra (1949, p. 34-42).

In Wilson County, parts of six formational units of the Kansas City group are exposed in the southeastern one-fourth of the county and comprise as much as 175 feet of strata. In the subsurface, the lower formations of the group are also present, and the group averages about 400 feet in thickness.

Three subgroups, named (downward) the Zarah subgroup, the Linn subgroup, and the Bronson subgroup (see Table 1) were established in the Kansas City group on the basis of dominant lithologic characteristics in northeastern Kansas and adjacent parts of Nebraska, Iowa, and Missouri (Moore, 1948, p. 2029). In Wilson County, the thick limestone formation in the middle of the upper (Zarah) subgroup is missing, and the shale units of that subgroup thicken markedly. Consequently, the Zarah subgroup is not dominantly calcareous in Wilson County, and both it and the middle (Linn) subgroup are dominantly clastic rocks. The lower (Bronson) subgroup is dominantly limestone, and is a good marker in the subsurface of ~~Wilson~~ the County.

The Zarah subgroup was named from the village of Zarah, in western Johnson County, at the Atchison, Topeka, and Santa Fe Railroad crossing on ~~Kansas~~ State Highway 10 (Moore, 1948, p. 2033). The subgroup includes beds between the base of the Plattsburg limestone and the top of the Iola limestone, and in Wilson County consists only of the Lane-Bonner Springs shale (see ~~fig. 10~~ Table 1). The ~~Lim~~ Linn subgroup was named from Linn County, Kans., where there are excellent exposures of all constituent units (Moore, 1948, p. 2030). The subgroup is chiefly shale, but there are also persistent thin limestone and locally thick sandstone beds. The Linn subgroup includes the Iola limestone, Chanute shale, Drum limestone, and Cherryvale shale. The Bronson subgroup, named the Bronson formation by Adams (Adams, Haworth, and Crane, 1904, p. 17), is predominantly a limestone unit, and is named from exposures near Bronson, Bourbon County, Kans. It consists of five formations, listed (downward), the Dennis limestone, Galesburg shale, Swope limestone, Ladore shale, and Hertha limestone. Only the uppermost few feet of the Bronson subgroup crops out in Wilson County, but the remainder is represented by about 200 feet of dominantly limestone strata in the subsurface.

## Lane-Bonner Springs shale

Naming, distribution, and thickness.--In northeastern Kansas the stratigraphic interval between the Plattsburg limestone and Iola limestone contains the Bonner Springs shale, Wyandotte limestone, and Lane shale. The limestone unit lenses out to the south, so that in Wilson County the two shale units are inseparable. Use of the stratigraphic name, Lane-Bonner Springs shale, for the unit between the Plattsburg limestone and the Iola limestone was suggested by Newell (1935, p. 56), who stated that it seems preferable "to indicate the combined Lane and Bonner Springs shales by the hyphenated term Lane-Bonner Springs shale, thus avoiding the necessity of using a geographic name that gives no indication of its stratigraphic relation to correlative units." Moore agreed with this suggestion and pointed out (1936, p. 117) that "disappearance of the Wyandotte limestone a short distance south of Lane makes it impossible to recognize the upper boundary of the Lane shale. Accordingly in this region the Lane is combined with overlying shale under the designation Lane-Bonner Springs shale."

Beds in the uppermost part of the shale unit below the Plattsburg limestone in Wilson County are correlated with those at the Lone Star Cement Plant quarry northeast of Bonner Springs, Wyandotte County, Kans. (see Wilmarth, 1938, p. 235; Moore 1936, p. 123). At the type locality, the Bonner Springs shale is 25 feet thick and consists (downward) of green shale 0.3 feet thick, ~~underlain by~~ a marlite bed 2.7 feet thick, ~~which in turn is underlain by~~ and 22 feet of gray to dark gray shale that is arenaceous in the middle one-third (Jewett and Newell, 1935, p. 200). The lower part of the shale unit below the Plattsburg limestone in Wilson County is correlated with the Lane shale, which was named by Haworth (1895a, p. 277) for exposures in the river bluffs near Lane, Franklin County, Kans. The unit there is as much as 150 feet thick and contains locally thick sandstones in the shales. The Bonner Springs and Lane shales in northeastern Kansas are separated by a thick limestone unit named the Wyandotte limestone for exposures in Wyandotte County, Kans. (Newell, 1935, p. 59; see also Moore, 1936, p. 119). As pointed out above, this limestone unit lenses out to the south, but it is possible that thin limestone beds in the upper or middle parts of the shale unit in Wilson County represent a southern extension of the Wyandotte limestone.

The Lane-Bonner Springs shale in Wilson County occupies low topographic positions northeast and southwest of Altoona, but east of Neodesha, it forms a thin cap on high prominences. The thickness of the Lane-Bonner Springs shale ranges from 40 to 100 feet in the county (see ~~fig. 16~~ Plate 3, D). It is thinnest a few miles east of Altoona and near the southwest corner of Neodesha.

Lithologic character.--The Lane-Bonner shale consists predominantly of medium-olive-gray (~~5Y5/1~~) to light-olive-gray (~~5Y5/2~~), unfossiliferous, silty to slightly silty shale that weathers pale yellowish brown (~~10YR6/2~~) to yellowish gray (~~5Y7/2~~) and breaks to small (~~¼~~-inch) ~~cuboidal~~ rectangular fragments. Locally, the uppermost foot of shale is grayish orange (~~10YR7/4~~), calcareous, and slightly fossiliferous. A thin limestone bed 5 to 10 feet below the top of the formation about 2 miles north of Altoona contains abundant crinoid stems and brachiopod fragments. An unfossiliferous limestone-concretion zone that occurs elsewhere at this same stratigraphic position may be the equivalent of the fossiliferous bed, or it may correlate with one or two beds of limestone concretions 5 to 10 inches thick that occur near the middle of the formation (see ~~fig. 16~~ Plate 5, D). A few miles west of Neodesha near the middle of the formation, the concretions occur in two beds, ~~that~~ are unfossiliferous, pale yellowish brown (~~10YR5/4~~), and weather yellowish orange (~~10YR7/6~~). They underlie shale beds that locally contain small, moderately abundant ironstone concretions. A 6-inch bed of pale-yellowish-brown (~~10YR5/4~~), septarian-limestone concretions near the middle of the formation about 4 miles east of Altoona probably correlates with one of the beds west of Neodesha. The septarian concretions are slightly argillaceous, cryptocrystalline calcite with ¼-inch seams of dark-colored ~~sparry~~ calcite irregularly radiating outward from their centers.

Two siltstone layers, each about 1 inch thick, occur locally in the upper 20 feet of the shale. Both are finely micaceous, and the upper layer contains plant fragments. Small ironstone concretions generally occur abundantly above the siltstone beds. A few miles northeast of Altoona, several thin layers of ironstone concretions occur in the lower half of the formation. The concretions are $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter and are grayish yellow to pale yellowish orange.

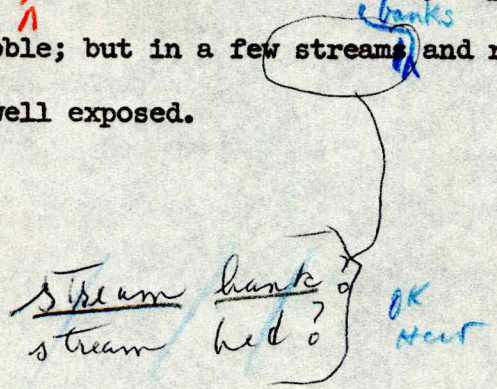
Stratigraphic and structural implications.--The fossils in the upper foot of shale and in the limestone bed near the top indicate an environment suitable to marine life for that part of Lane-Bonner Springs time. The remainder of the shale is lithologically much like the Vilas and Weston Shales, which are of marine origin, and the environment in Wilson County was probably marine also but generally inhospitable to marine plant or invertebrate animal life. The zones of unfossiliferous limestone concretions in the upper and middle parts of the formation may have formed through migration of calcium carbonate to nuclei during diagenesis or represent times of local concentration of calcium carbonate in an absence of marine life at the time of clay deposition. The siltstone beds with plant fragments in the upper part of the shale suggest concentrated inflow of silt-size debris from a nearby vegetation-covered land area.

Because the limestone beds west of Neodesha and east of Altoona are unfossiliferous and occur either 5 to 10 feet below the top or 35 to 60 feet above the base of the Lane-Bonner Springs shale, neither could be definitely correlated with the fossiliferous limestone bed north of Altoona, which is about 5 feet below the top and 35 feet above the base. Therefore, although the variation in thickness of the formation, (from 40 to 100 ~~or more~~ feet) ~~in areas west of Neodesha and east of Altoona to about 40 feet in the area north of Altoona,~~ probably ~~represents~~ reflects local structural movement, its time of occurrence could have been either early or late in Lane-Bonner Springs time.

## Iola limestone

Naming, distribution, and thickness.--The Iola limestone was named by Haworth and Kirk (1894, p. 109) for exposures at the town of Iola, Allen County, Kans., about 15 miles northeast of Wilson County. At the type locality, the Iola limestone is about 30 feet thick and is composed chiefly of light-bluish-gray, irregularly bedded, thin-bedded, fine-grained limestone that is separated from a basal, dark-bluish-gray ~~and more~~ massive 2-foot unit by a few inches of shale (Moore, 1936, p. 113). Throughout its outcrop area in Kansas, the Iola consistently is made up of three units, listed (downward), the Raytown limestone member, the Muncie Creek shale member, and the Paola limestone member (Moore, 1949, p. 102-103).

In Wilson County, exposures of the Iola limestone are poor, and over a large part of the presumed outcrop area, it does not crop out, either because it is absent or because it is covered by downhill-float from the overlying shale. The presumed position of the Iola in these areas is shown on the geologic map by a single dashed line. In other areas, the formation is commonly represented only by rounded limestone rubble; but in a few streams and roadcuts, all three members are well exposed.



The Iola apparently underlies the Lane-Bonner Springs shale conformably, but overlies the Chanute shale unconformably. In the east wall of the Dunbar strip mine (SW cor. sec. 21, T. 29 S., R. 17 E), the basal member of the Iola lies upon siltstone beds of the Chanute shale with a discordance of about 10° (see Fig. 18, A).

Figure 18 near here

Figure 34. Angular discordance between bedding of the Iola limestone and the Chanute shale.

discordance was apparently local.

Where well exposed in the county, the Iola ranges in thickness from 6 to 10 feet and averages about 8 feet.

Lithologic character.--In Wilson County, as elsewhere in eastern Kansas, the Iola limestone can be readily divided lithologically into three members (see Plate 2, D): the Raytown, a thick limestone at the top; the Muncie Creek, a gray to black shale in the middle; and the Paola, a thin, hard limestone at the base.

Raytown limestone member.--The Raytown limestone member was named for exposures near the village of Raytown, Jackson County, Mo. by Hinds and Greene (1915, p. 7, 27-28, 118). They placed it in the upper part of the Chanute shale and described it as a gray, thin-bedded limestone unit 3 to 6 feet thick that overlay a black shale. Newell, in tracing the Iola limestone northward from the type locality, found that only the upper part of the limestone at Iola correlated with the bed at Raytown (Newell, 1935, p. 51). The name has since then been used for the upper limestone member of the Iola.

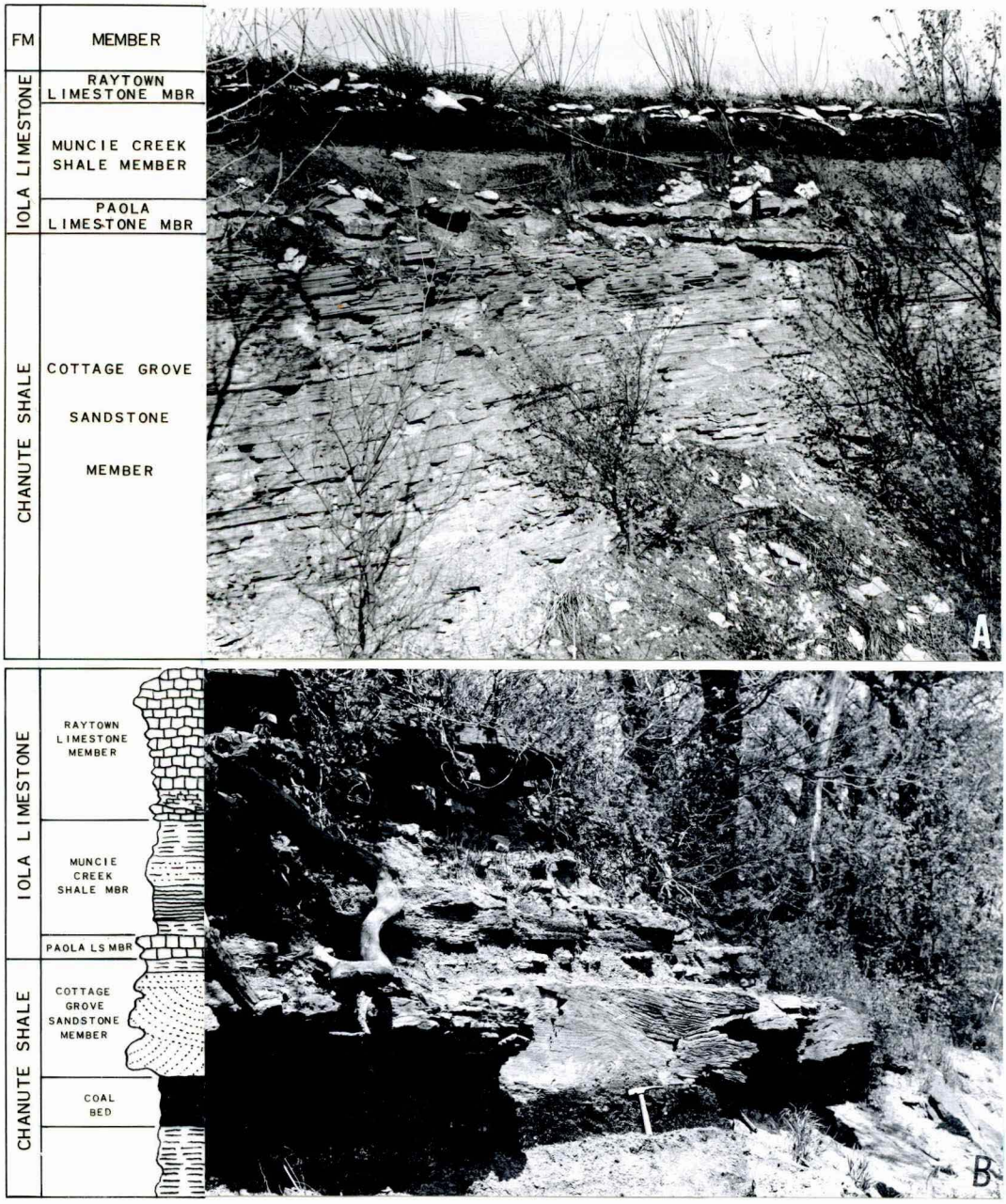



FIGURE 18.--Iola Limestone and Chanute Shale. (A) Angular discordance between bedding of the Iola Limestone and the Chanute Shale in the Dunbar strip mine, SW cor. sec. 21, T 29 S, R 17 E. Exposure is about 15 feet in height. Coal bed is below rubble at bottom of photograph. (B) Iola Limestone and upper part of Chanute Shale at Mill Street Bridge, Neodesha.

Where measured in Wilson County, the Raytown ranges in thickness from 4 to 9 feet and averages nearly 5 feet. It changes laterally from 5½ feet of predominantly clayey, fossiliferous limestone to about 4 feet of ~~slightly~~ calcareous, unfossiliferous sandstone. Locally, where clay becomes a dominant constituent, the Raytown is largely a calcareous, fossiliferous shale (see ~~fig. 14~~, Plate 2, D).

In the eastern and southern parts of the outcrop area, the Raytown is a grayish-orange (~~10YR7/4~~), medium- to thin-bedded, very fine-crystalline limestone that weathers to blocky plates (see ~~Fig. 35, A~~, 18, A, B). It contains the brachiopods, Chonetes, Juresania,

Figure 35. Iola limestone in Wilson County.

Neospirifer, Hustedia, and Composita, horn corals, and fragments of crinoid stems and ramose and fenestrate bryozoans. In places, much of the member is made up of medium-light-gray (~~N6~~), very fine-crystalline, irregularly shaped fragments of limestone in a matrix of grayish-yellow (~~5Y8/4~~), very fine-crystalline Osagia-bearing limestone. The fragments range in size from 1/8 inch to 2 inches, and many have serrated ends. Local concentrations of clay and very fine-grained dolomite, identified by staining with Alizarine Red S, occur in the matrix material. Fenestrate bryozoans, crinoid columnals, and other fossil fragments are abundant in this matrix. In several exposures, the upper few inches of the member weathers to small flakes of algal(?) limestone; in a few others the upper part is oolitic.

The sandy facies of the Raytown consists of very pale yellowish-brown (~~10YR7/2~~), sandy limestone that contains very fine angular quartz grains and much fine-grained muscovite mica. A thin fossiliferous limestone bed containing many small unidentified brachiopods occurs in the upper 3 inches of the sandy limestone. Outcrops of dark-yellowish-orange (~~10YR6/6~~) sandstone of the underlying Cottage Grove sandstone member of the Chanute shale occur in secs. 14 and 15, T. 29 S., R. 16 E., at the same altitude as nearly contiguous pale-yellowish-brown (~~10YR6/2~~), fossiliferous, sandy limestone of the Iola.

An exposure of light-gray (~~N7~~) limestone a few hundred feet west of Barnhill Bridge (sec. 6, T. 29 S., R. 16 E.), at the approximate stratigraphic position of the Raytown, apparently represents a debris reef that developed during Raytown time. The limestone is thin bedded, argillaceous, and weathers to vertically jointed, uneven, arched surfaces (see Fig. ~~35, B~~ 19, A). The exposed arched beds are about 20 feet across and are composed of the remains of bryozoans, crinoids, productids and other brachiopods, sparse mollusks, and many unidentifiable shell fragments in a fine-grained clastic limestone matrix. These beds are possibly the uppermost part of a bioherm and may be draped over a central, as yet unexposed, bryozoan core. Thin, very calcareous shale beds are interbedded with the arched limestone; laterally, the shales are less calcareous, and the unit is a clay shale with intercalated zones of fossil fragments. Inasmuch as a thin, continuous, medium-gray (~~N5~~) limestone bed lies horizontally above both the bioherm and the adjacent shale (see Fig. ~~35, B~~ 19, A), the effects of differential compaction are seemingly negligible, and the vertical dimension of the bioherm is assumed to be small.

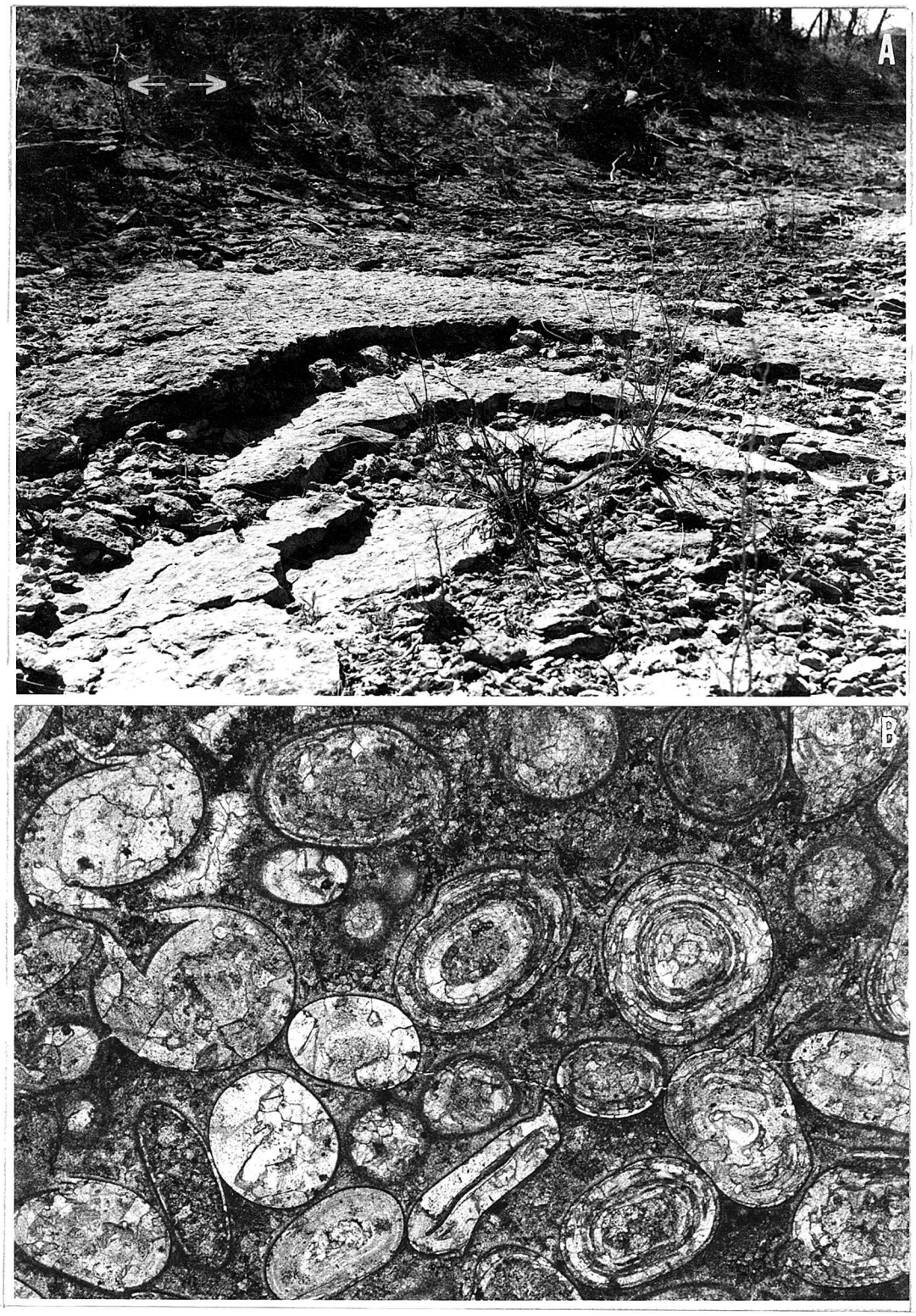



FIGURE 19.--Iola and Drum Limestones. (A) Debris reef in the Raytown Limestone Member of the Iola Limestone west of Barnhill Bridge in W½ sec. 6, T 29 S, R 16 E. Note that thin limestone bed (arrow) above reef top is not curved. (B) Thin section of oolitic Drum Limestone showing concentrically ringed oolites. Sec. 24, T 30 S, R 16 E. Crossed nicols (X 20).

Muncie Creek shale member.--The Muncie Creek shale member was named by Newell (see Moore, 1936, p. 114) after a stream in southern Wyandotte County, east of Muncie (Newell, 1935, p. 52). In sec. 12, T. 11 S., R. 24 E., near the type locality, the Muncie Creek member consists of 3 feet of shale that is mostly black and platy, but that is gray near the top and bottom (Jewett and Newell, 1935, p. 196).

Where well exposed in Wilson County, as beneath the Mill Street Bridge at Neodesha, or at the Dunbar Strip mine (SW¼ sec. 21, T. 29 S., R. 17 E), or at the top of the bank above Chetopa Creek (center sec. 29, T. 29 S., R. 17 E.), the Muncie Creek member is 1½ to 5 feet thick and has a grayish-black (~~N2~~) platy shale in the lower part (see ~~Fig. 35, A~~ 18, B). The upper 1½ to 2½ feet of the Muncie Creek consists generally of ~~silty~~ silty to non-silty yellowish-gray (~~5Y7/2~~) to pale yellowish-orange (~~10YR8/6~~) shale that is locally very silty at the base. In a few places it is calcareous in the uppermost few inches where it is very fossiliferous, and grades upward into the limestone of the Raytown member. The lower 1¼ to 2½ feet of the member is composed predominantly of grayish-black (~~N2~~) very fissile, platy shale that breaks into paper-thin ~~laminae~~ plates upon weathering. The black shale commonly contains small (¼-inch to 1-inch diameter), flattish, oval, phosphatic concretions that are brownish gray (~~5YR4/1~~) to olive gray (~~5Y4/1~~). The concretions occur in layers about halfway between the top and bottom of the black shale. They contain radioactive material (Runnels and others, 1953, p. 97, 99), but in amounts too small (.007 percent) to be of economic importance. About 2 to 6 inches of light-gray (~~N7~~) slightly silty shale locally underlies the platy shale.

Paola limestone member.--The Paola limestone member was named by Newell (see Moore, 1936, p. 114) from the county seat of Miami County, Kans., where it consists of 1½ feet of dark-bluish-gray, dense, brittle, blocky limestone with "worm-borings" at the top and numerous "marklets" (Newell, 1935, p. 125).

In Wilson County the Paola is generally about 1 foot thick (see Fig. 18, A, B) but locally thins to less than ½ foot and thickens to nearly 2½ feet. ~~(see fig. 34; fig. 35, A)~~. Commonly it is a medium-gray ~~(N5)~~, hard, very fine-crystalline fossiliferous limestone in which the most abundant fossils are crinoid stems and brachiopod fragments. In the southwestern part of the outcrop area, the upper part contains Cryptozoon, but farther north and east Cryptozoon are rare, and fusulinids are abundant in the upper part. Fenestrate bryozoans and horn corals are prominent locally. The Paola weathers grayish orange ~~(10YR7/4)~~, is vertically jointed, and where it surrounds erosional remnants of the Cottage Grove sandstone member of the Chanute shale, it is sandy. In a few places, where it apparently fills scours cut into the underlying siltstone of the Chanute shale, the Paola thickens and the lower part is ~~very~~ silty and flaggy.

Stratigraphic and structural implications.-- The abundant sand grains that are present in the limestone members of the Iola presumably came from sandstone beds at the top of the underlying Chanute Shale. The present distribution of sand in the Iola seemingly indicates that parts of the Chanute were exposed to erosion both east and south of Altoona, and the outcrops of sandstone of the Chanute that are surrounded by sandy limestone of the Iola apparently represent erosional remnants that stood 10 feet or more above the sea floor. The clayey, fossiliferous, locally algal or oolitic limestone of the Raytown away from the sandy limestone areas suggests that the environment of deposition was carbonate-rich but was generally modified by abundant influxes of clay, and was locally shallow, supersaline, and wave agitated. The arched beds of limestone debris and fossils on the northern flank of the Fredonia anticline near Barnhill Bridge suggest draping and compaction of a local accumulation of fossil debris around and upon a solid, as yet unexposed, calcareous framework (bioherm). The presence of a horizontal (unarched) limestone bed a few feet above the arched beds suggests that the ~~thickness of~~ amount of compaction above the bioherm is small.

The organic-rich black shale with phosphatic nodules and overlying calcareous gray shale of the Muncie Creek member suggest that deposition prior to Raytown time was in quiet, shallow, phosphate-rich, stagnant waters ~~of lagoons~~, and that as the water deepened, ~~and~~ an influx of clay-size debris ended the period of deposition. The local presence of gray shale at the base of the Muncie Creek suggests that the ~~lagoonal~~ shallow-water environment was preceded by a short period of deeper water.

The Paola limestone member is similar lithologically to the Haskell limestone member of the Stranger formation and the Leavenworth limestone member of the Oread limestone and presumably reflects a similar rapid cycle of transgression and regression. Abundant algae in the upper part near Neodesha indicate hypersaline shallowing waters in late Paola time in that area. Abundant fusulinids and few algae in the upper part east of Altoona suggest that a deep-water phase of deposition lasted longer east of Altoona than near Neodesha and that the regressive phase was of short duration. Bryozoan, coral, crinoid and brachiopod remains in the lower part of the member indicate a marine environment well suited to invertebrate life in early Paola time.

## Chanute shale

Naming, distribution, and thickness.--Haworth and Kirk (1894, p. 109) applied the name Chanute to shale that underlies the town of Chanute, about 5 miles east of Wilson County. At the type locality, the Chanute consists of about 100 feet of shale, sandstone, and thin coal beds. Northward along its outcrop belt in eastern Kansas, the Chanute thins to about 10 feet (Moore, 1936, p. 111), but it thickens southward, so that its average thickness in Kansas is probably about 50 feet.

In Wilson County, the Chanute crops out in the southeastern one-sixth of the county (~~see fig. 7~~ Plate 1), where it ranges from 40 to about 90 feet in thickness (~~see fig. 36~~ Plate 4). Subsurface records indicate that it averages about 75 feet in thickness, is more than 100 feet thick in small areas north and east of Altoona, and is only about 25 feet thick along a general northeast~~ward~~-trending line that extends from a point about midway between Altoona and Benedict past the north edge of Vilas and eastward to the Neosho County line.

~~Figure 36. Map and sections showing correlation of coal beds and other stratigraphic units in the Chanute shale in Wilson County.~~

The Chanute shale is unconformable with the overlying Iola limestone. Light-gray, platy siltstone immediately underlies the Iola limestone at some places, reddish-weathering, thick-bedded sandstone underlies it in others, yellowish-gray, silty sandstone approaches very near to the contact in others, and gray shale occurs at the contact in at least two places. The variety of rocks in contact with the overlying Iola limestone apparently reflects folding and erosional truncation prior to deposition of the Iola (Plate 4). ~~(see fig. 37).~~

The Chanute lies conformably on the Drum limestone in the few places where the contact is exposed. The relatively constant thickness of the unnamed lower shale unit of the Chanute shale, where measured, suggests that this lower shale unit was deposited evenly throughout Wilson County. However, the Cottage Grove sandstone member apparently occupies the position of this lower shale unit and that of the Drum limestone in the subsurface in some areas, suggesting that a prominent erosional unconformity occurs within the Chanute.

Lithologic character.--The Chanute shale is divided generally into an upper coarse clastic unit, the Cottage Grove sandstone member, and a lower unnamed shale member. In Wilson County, the Chanute ranges from almost 100 percent shale to about 70 percent sandstone and siltstone (Plate 4, ~~see fig. 36,~~ secs. 5, 8, 9, 16). The sequence of stratigraphic units described below was not directly observed in the field; it was constructed from many isolated small outcrops and measured sections. Lateral changes in facies may be more important than is indicated.

Cottage Grove sandstone member.--The Cottage Grove sandstone member was named by Newell (see Moore, 1936, p. 111) for exposures in Cottage Grove Township, Allen County, Kans., which adjoins the northeast corner of Wilson County. In both the type area and in Wilson County silty, arenaceous beds of the Cottage Grove member occupy the upper half of the Chanute shale.

As many as 8 thin coal beds occur in 3 groups in the Cottage Grove sandstone member. The two upper groups separate a whitish, platy, sandy siltstone from an overlying reddish-weathering, thick-bedded sandstone and an underlying yellowish-gray, thin-bedded, silty sandstone.

The group of coal beds beneath the reddish-weathering sandstone consists of 2 to 3 coal beds separated by claystone partings (see fig. 20, A). The aggregate thickness of coal is generally less than a foot and the coal has been mined in few places. The coal beds between the platy, sandy siltstone and the yellowish-gray, silty sandstone have been mined in a half-dozen places in the Dry Creek Mining District, and extensively at the Dunbar strip mine and adjacent area in the Chetopa Mining District (see Plate 4), where they total as much as 24 inches of coal. The coal contains twigs and branches of dark-yellowish-brown silicified wood in the lower part in the Chetopa Mining District, but not in the Dry Creek Mining District. This coal group consists generally of 2 or 3 separated beds (see fig. 20, B). A coal bed, termed the Thayer coal (Newell, 1935, p. 49; Moore, 1936, p. 110-111; Whitla, 1940, p. 18-19; Schoewe, 1944, p. 87), occurs at the base of the yellowish-gray, silty sandstone. This coal has been mined extensively a few miles east of Wilson County, and has furnished coal for a few small drift mines in the southeastern part of the Chetopa Mining District in Wilson County. The Thayer coal has an aggregate coal thickness of as much as 22 inches, and occurs generally as two thin beds separated by claystone (see fig. 20, C). Schoewe made a detailed study of the coal resources of the Thayer bed in eastern Kansas and recorded 78 known coal localities in Wilson County (Schoewe, 1944, p. 127-129). Twenty-four localities were mine operations, mostly for local use only; the others were road and creek exposures.

Figure 20 near here

Figure 37. Coal sections showing variations in number and thickness of coal beds in the Chanute shale in Wilson County.

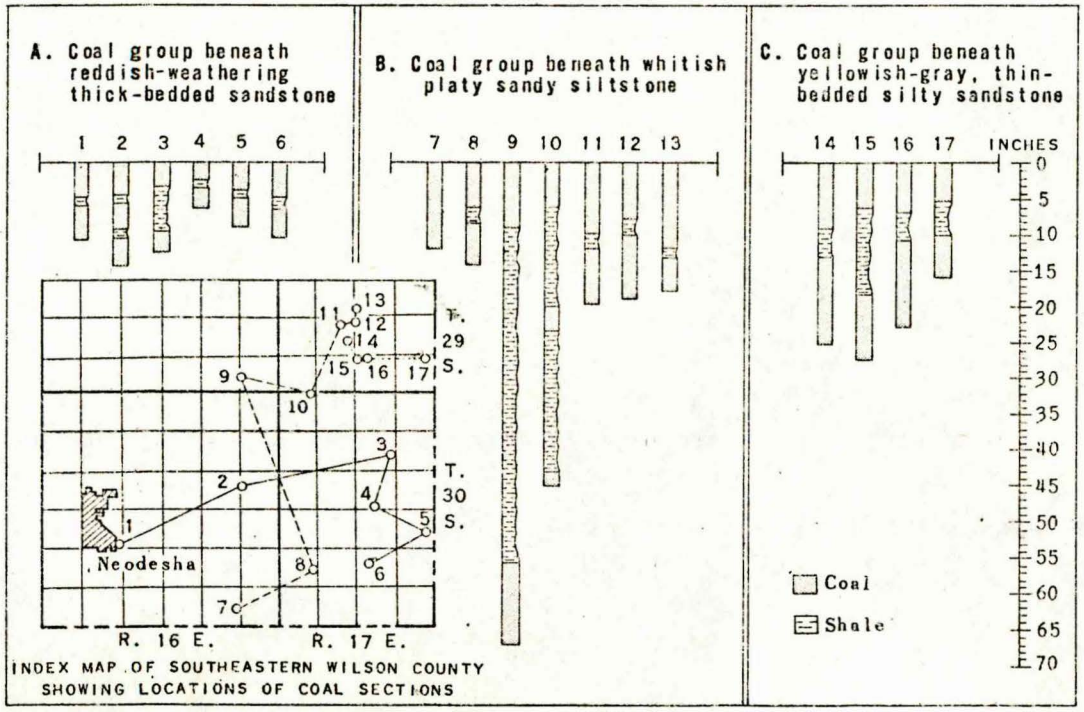



Figure 20.--Coal sections showing variations in number of coal beds in the Chanute Shale in Wilson County. (Data largely from Schoewe, 1944, p. 120.)

The upper sandstone unit of the Cottage Grove Sandstone Member is as much as 45 feet thick, but averages about 30 feet in thickness. It is cross bedded locally, but in many exposures its bedding is irregular or obscure. It is generally a grayish-orange (~~10YR 7/4~~) to grayish-red (~~10R 4/2~~) thin- to thick-bedded sandstone (~~Fig. 38, A~~)

Figure 38. Chanute Shale (Cottage Grove Sandstone Member) and Drum Limestone.

that is chiefly angular to subangular, fine-grained quartz. The sandstone locally contains a few angular to well-rounded gray shale fragments, a few light-colored limestone granules, and fragments of carbonaceous matter. Thickness variations of the underlying platy siltstone suggest that, at some localities, the upper sandstone unit unconformably overlies it.

The platy, sandy siltstone that underlies the upper sandstone unit ranges in thickness from about 30 feet in the northwestern part of the outcrop area to only 10 to 12 feet in the southeastern part of the area. At the Dunbar strip mine (SW¼ sec. 21, T. 29 S., R. 17 E.), the siltstone is 7 to 10 feet thick, very light gray ~~(N8)~~, and breaks readily into ¼- to 5/8-inch thick plane-surfaced plates (Fig. 18, A). The 10° ~~degree~~ northwest dip of the beds may represent initial dip of foreset beds on a delta front. Many well-preserved fern leaves and calamites stems occur amid abundant small carbonized plant fragments on the finely micaceous bedding planes. This unit contains ripple-marked bedding surfaces at a few localities, and is cross-bedded in others. The orientation of these features suggests currents moving from south to north. The coal that underlies the platy siltstone is associated with many large pieces of dark-colored silicified wood in the northern area of outcrop in the county.

should this be Triassic?
I think you are right

The lower part of the Cottage Grove sandstone member is a lenticular unit that is as much as 45 feet thick and is apparently restricted to a 3-mile wide strip along the eastern edge of the county (~~see fig. 30~~ Plate 4). It consists of yellowish-gray (~~5Y7/2~~), slightly micaceous, very fine-grained, silty sandstone that is generally thin- and even-bedded. The sand grains are well sorted, and thin sections show that they form a remarkably tight mesh of interlocking quartz and chert grains, many of which have attenuated shapes. The contacts between grains are undoubtedly the result of secondary solution and penetration, presumably without compensating outgrowth, because no well defined contact between an original grain surface and an outgrowth is apparent. Furthermore, quartz grains with undulatory extinction show no change in extinction near the grain boundary, as would be expected if outgrowth had occurred. Several of the quartz grains are in solution contact with grains of chert. Quartz composes more than half of the grains, and chert about one-third. The remainder of the grains are sodic plagioclase (andesine?) and flakes of muscovite. Limonitic clay, dispersed irregularly throughout the rock, forms about 5 percent of the sandstone. The Thayer coal occurs at the base of this yellowish-gray, thin-bedded sandstone and separates it from the underlying unnamed shale unit.

Unnamed shale unit.--Throughout southeastern Wilson County, the lower 15 to 40 feet of the Chanute shale consists of gray, unfossiliferous shale. The uppermost 2 inches to 5 feet of this shale is locally light olive gray (~~5Y6/1~~), plastic when wet, and may be an underclay. Elsewhere, this ~~uppermost~~ part of the Chanute shale is yellowish gray (~~5Y7/2~~), non-silty to very slightly silty, and breaks to small angular fragments.

A distinctive, thin, unfossiliferous, argillaceous limestone bed 4 to 14 inches thick occurs about 5 feet below the top of the unnamed shale unit in much of the area. It is pale yellowish orange (~~10YR8/6~~), and is seamed with veinlets of moderate yellowish-brown (~~10YR5/4~~) calcite about 1/50th-inch wide. The bed is represented locally by a layer of nodules or concretions. Upon weathering, it generally forms rounded shapes and becomes very soft and porous. It undoubtedly corresponds to the "marlite" bed in the Chanute shale reported by Newell to the north in Johnson and Miami Counties. Newell (1935, p. 50) described his "marlite" as a "spongy" rock that ranges from a ferruginous, argillaceous limestone to a calcareous shale. The shale that underlies the "marlite" bed is medium gray (~~N5~~) and unfossiliferous. In a few places it is dark yellowish gray (~~5Y6/2~~) to medium light gray (~~N6~~) and is slightly silty.

Stratigraphic and structural implications.--Chanute time apparently ended with local uplift along previously active areas of upwarp, as is indicated by the thinning and absence of the reddish-weathering sandstone and arching and truncation of the underlying platy siltstone prior to deposition of the Iola limestone. (= Plate 4) The reddish-weathering sandstone presumably indicates subaerial deposition by streams debouching onto a subsiding coastal plain. Dips of 10° degrees in the platy siltstone (Fig 18, A) may reflect initial dip of foreset beds on a delta front. Just prior to this period of deposition, land plant debris, now in the form of coal beds, accumulated in 2 or 3 individual stages. The layers of impure coal or carbonaceous claystone between the beds of coal show that these stages were separated by periods of clay accumulation and soil development.

The well-bedded, platy siltstone apparently formed in nearshore quiet waters into which silt-size debris and small plant fragments were fed at regular intervals in order to produce a sequence of plane-surfaced beds about one-half inch in average thickness. Coal-swamp conditions immediately preceded deposition of this unit. The coal beds underlying the siltstone suggests that two, and locally three, times coal swamps formed along the coastal plain and were drowned and covered with silty clay. Silicified fragments associated with the coal indicate that large twigs and branches in the carbonaceous debris were selectively silicified by percolating silica-charged waters. The thick deposit of thin-bedded sandstone in the small area between sec. 20, T. 30 S., R. 17 E., and sec. 29, T. 29 S., R. 17 E., suggests that local downwarping controlled the accumulation of the silts and sands. The presence of silt, sand and coal beds in Neosho County to the east indicate that the downwarp extended several miles eastward. The coal beds possibly represent the initiation of downwarping which began with the development of a shallow, vegetation-filled swamp. Downwarping apparently continued until arenaceous material had covered the drowned trees to a local thickness of more than 50 feet. Conditions conducive to coal accumulation were then again at optimum, and the coal-forming debris represented in beds of the overlying coal group accumulated.

The uniform even thickness of the slightly silty claystone that formed in earliest Chanute time indicates a general period of quiet, shallowing water, undisturbed by local structural uplift. A change from a clear-water environment to one filled with clay-size debris is presumed to have eliminated a previously abundant marine fauna from the area and to have led to the accumulation of a thick mud deposit. The dark-seamed "marlite" bed above this claystone suggests that an iron-rich, calcareous, argillaceous mud formed toward the end of early Chanute time during a short period of carbonate concentration. The filling of cracks in the clayey limestone with dark-colored calcite apparently occurred somewhat later during desiccation and diagenesis.

## Drum limestone

Naming, distribution, and thickness.--The Drum limestone was named by Adams for conspicuous exposures on Drum Creek, Montgomery County, about 12 miles south of Wilson County (Adams, Girty, and White, 1903, p. 37). In the vicinity of the type locality the Drum is subdivided into an upper oolitic, locally conglomeratic, limestone, the Corbin City member, and a lower hard, dense, blue-gray limestone, the Cement City member. As pointed out by Newell (1935, p. 44-45),

> "There is a great deal of variation in the Drum of the type region, for it ranges from eight feet of nonoolitic blue-gray limestone just north of Cherryvale to more than sixty feet of granular and oolitic limestone near Independence."

Corbin City, for which the upper limestone member was named, is about 2 miles south of Cherryvale in Montgomery County; the lower limestone member was named for Cement City, in Jackson County, Mo. (see Moore, 1936, p. 105-106).

In Wilson County, the Drum is exposed only in the southeastern part. It is partly oolitic, and apparently both members are represented, but because it is only about 18 inches thick and the outcrop is discontinuous and difficult to trace, the members could ~~only~~ be differentiated in a few places. The largest exposures are in stream beds.

Lithologic character.--In Wilson County the Drum is generally a single, hard, vertically jointed, medium-light-gray (~~N6~~), fossiliferous, algal limestone. The lithology and fauna of the limestone vary both vertically and laterally, and correlation between widely separated outcrops is uncertain. For example, in the southeastern part of T. 30 S., R. 16 E., the Drum is oolitic, and farther east in T. 30 S., R. 17 E., Osagia and Cryptozoon-like algae are ~~very~~ abundant.

The oolites, algae, and invertebrate fossil remains are generally concentrated in the upper half of the unit, and in some localities they fill scour channels or large desiccation cracks that apparently formed in the lower part of the limestone prior to accumulation of the upper part. The oolitic facies, with its concentrically banded, locally composite, and collapsed oolites (~~see~~ Fig. ~~39~~ 19, B), ~~[illegible]~~ was noted in a few small outcrops only. ~~[illegible]~~. The oolites are much larger at the top of the bed than in the lower part, and in many oolites the outer rings are broken and stripped back or folded, possibly as a result of partial desiccation (~~see~~ Fig. ~~39~~ 19, B). The fossils in the upper part of the Drum consist of the brachiopods Composita, Derbyia, Echinoconchus, Hustedia, Juresania, Marginifera, Neospirifer, and Punctospirifer; horn corals and Syringopora; ramose, fenestrate, and encrusting bryozoans; crinoid stem segments and calyxes; small bellerophontid and high-spire gastropods; Myalina and small pelecypods; and locally abundant Osagia and Cryptozoon-like algae.

The lower part of the Drum is brownish-gray (5YR4/1) to medium-gray (N5), sparingly fossiliferous limestone. Broken crinoid stems are the dominant fossils and, in conjunction with shell fragments of brachiopods, they occur in a fine-crystalline calcite matrix.

In the bed of Washington Branch, 3 miles east of Neodesha on State Highway 37, the Drum was two prominent joint systems that trend approximately N. 10° E. and N. 80° E., and a series of undulations that trend approximately N. 45° E. Similar undulations occur in a limestone unit exposed in tributaries to Dry Creek in secs. 19 and 30, T. 30 S., R. 17 E., but that bed appears to lie stratigraphically below the projected Drum outcrop, and is mapped as the underlying Dennis limestone. The Drum and the Dennis are similar in lithology and fauna in this area, and it is difficult to distinguish one from the other.

Stratigraphic and structural implications.--The lithology and fauna of the Drum Limestone record generally shallow marine waters inhabited by an abundant and varied bryozoan, brachiopod, and mollusk fauna interspersed with large and small alga. Abundant oolites, locally concentrated in pockets with shell fragments, suggest a depositional environment of local shoreline embayments in which oolites formed, and in which currents cut scour channels into which the oolites and shell fragments were concentrated. Withdrawal of the sea, or local uplift, may have resulted in desiccation toward the middle of the time represented by the Drum, and cracks thus formed also served as sites of oolite and fossil-fragment concentration. The elongated and collapsed oolites suggest that temporary exposure in late Drum time may have allowed many of the later oolites to become partly desiccated prior to final incorporation into the upper part of the Drum.

## Cherryvale shale

Naming, distribution, and thickness.--The term Cherryvale shale was first used by Haworth (1898a, p. 47) for a shale unit 120 feet thick that underlies the prominent escarpments along Drum Creek northwest of Cherryvale, Montgomery County, about 6 miles south of Wilson County. In Wilson County, the Cherryvale shale crops out in the Dry Creek-Washington Branch area and at the southeasternmost corner. It is 35 to 45 feet thick at the few localities where both top and base are exposed.

Lithologic character.--The best exposures of the Cherryvale shale in Wilson County are in the northern parts of sec. 25, T. 30 S., R. 16 E., and sec. 30, T. 30 S., R. 17 E., where it is about 40 feet thick. The upper 26 feet is yellowish-gray (5Y7/2), finely micaceous, thin-bedded, clayey siltstone and silty shale with several ¼-inch to ½-inch platy, unfossiliferous limestone beds in the lower 2 feet. Ironstone concretions occur in the upper 5 feet. A light-olive-gray (5Y6/1), hard, unfossiliferous limestone bed that is about 9 inches thick and is micaceous and silty in the upper few inches and argillaceous in the lower few inches occurs below the silty shale. The lower few inches of the limestone bed weathers dark yellowish orange (10YR6/6) and is separated from the upper part by a thin yellowish-gray (5Y7/2), micaceous shale bed. The lower 14 feet of the Cherryvale is dark yellowish-brown (10YR4/2) to medium-gray (N5), slightly silty, finely micaceous shale with a few beds of ironstone concretions. The lower 2 feet has current ripples locally.

The upper 2 to 4 feet of the Cherryvale in the southeastern corner of the county is well-bedded, non-silty, yellowish-gray shale. Below this are 1 or 2 beds, 2 to 6 inches thick, of hard, unfossiliferous, vertically-jointed limestone. The limestone is light gray where fresh and weathers yellowish-orange or brownish-orange. Light-grayish-orange, silty, micaceous shale underlies the limestone.

Stratigraphic and structural implications.--The argillaceous sediments of the Cherryvale in Wilson County suggest deposition in shallow water into which abundant clay- and silt-size material was supplied by erosion of a nearby land area for a relatively short time. The absence of marine fossils and the lithology of the strata suggest that the sea rapidly withdrew from this area after a moderate thickness of terrigenous mud and silt had accumulated in the area directly to the south. Subsequent erosion there carried the mud-size materials northward into local areas of downwarp that developed in Wilson County during Cherryvale time and served as catchment basins for the silts and clays. Thin beds of limestone that were deposited and later covered by more clay and silt suggest that calcium-carbonate concentration reached oversaturation near the middle of Cherryvale time.

## Dennis limestone

Naming, distribution, and thickness.--The oldest strata that crop out in Wilson County are tentatively correlated with the Dennis limestone. This limestone was named by Adams (Adams, Girty, and White, 1903, p. 36) for exposures near Dennis, in northwestern Labette County, about 7 miles southeast of Wilson County. Near Dennis, where the formation contains three members and is about 10 feet thick, it consists of an upper thick, gray or blue, thin-bedded or in part massive, oolitic limestone (Winterset limestone member) that is underlain by black fissile and gray or buff shale (Stark shale member) and thin, blue, dense, blocky limestone (Canville limestone member) (Moore, 1936, p. 91). In Wilson County, only the upper limestone crops out. It is exposed in six places in the bottom of Dry Creek and its tributaries, where it consists of 1½ feet of partly oolitic limestone that is here correlated with the Winterset limestone member. This member was named for exposures near the town of Winterset, Iowa (Tilton and Bain, 1897, p. 517-519) about 300 miles to the northeast. Equivalency of the limestone at Winterset with the limestone at Dennis was regarded as established in 1912, but correlation of the unit at Winterset with the upper limestone at Dennis was not reported until 1932 (see Wilmarth, 1938, p. 597).

Suggest original source of this info be cited rather than Wilmarth
GMC

Lithologic character.--In Wilson County, the Winterset consists of very fine-crystalline, fossiliferous, medium-light-gray (~~N6~~) limestone that weathers to thin, uneven-surfaced, yellowish-gray (~~5Y7/2~~) to grayish-orange (~~10YR7/4~~) blocks. It is generally a single, hard, vertically-jointed bed, and commonly contains many small Osagia or oolites in local concentrations, as well as crinoid fragments, productid spines, ramose and fenestrate bryozoans, abundant horn corals, Myalina and the brachiopods, Hustedia and Composita. A bed correlated with the Winterset is folded into a series of roughly parallel undulations in the SW¼NE¼ sec. 19 and in the NW¼NE¼ ~~of~~ sec. 30, T. 30 S., R. 17 E. (Fig. 29, B). The undulations trend N. 25° E.

Stratigraphic and structural implications.--Oolites and Osagia in the Winterset suggest a nearshore marine environment. The ir concentration into pockets and the presence of fossil debris of bryozoans, horn corals, crinoids, and brachiopods indicate an abundance of life, as well as active current and wave action. Minor post-depositional, compressional folding may have formed the parallel-trending undulations.

## Subsurface rocks

Exploratory wells drilled in Wilson County cut rocks of Pennsylvanian to Precambrian age. The rocks of Pennsylvanian age are largely limestone and shale in the upper part and sandstone and shale in the lower part. The rocks of Mississippian age are chiefly limestone, those of Cambrian and Ordovician age are largely dolomite, and those of Precambrian age are mainly reddish granite.

The subsurface rocks are known from samples and electric logs of a few wells, and from drillers' logs of more than 8,000 wells drilled for oil and gas in Wilson County. Ditch samples give the best lithologic data for recognition of subsurface formational units. Such samples are available for only about 45 wells in the county, and in most of these wells the samples were taken only occasionally. Electric and radioactivity logs are also aids in the differentiation of rocks in the subsurface, but records of this kind have been made on only about 60 wells in Wilson County, and many of them are incomplete. Typical electric and radioactivity logs and their correlations with lithologic units interpreted from the log or recorded by the driller are shown ~~in figure 39~~ on Plate 5. Strip logs plotted

Figure 39. Typical electric, radioactivity, and drillers' logs from Wilson County.

from drillers' records are useful in determining the general structural configuration, and the lithologic continuity or lenticularity of rock units. Logs of 39 wells, shown ~~in figure 40~~ on Plate 6, illustrate the lateral

Figure 40. East-west subsurface cross section across central Wilson County.

continuity of limestone beds and the lenticularity of sandstone units. The lateral continuity of such units as the Pawnee and Fort Scott limestones makes them excellent marker beds.

## Rocks of Pennsylvanian age

Formations at the top of the lower part of the Kansas City group are the youngest strata that both crop out at the surface and occur throughout the subsurface of Wilson County. Younger strata are encountered in wells only as permitted by the extent of their outcrop. Thus, formations of the Shawnee group are penetrated only in the northwestern corner of the county, those of the Douglas and Pedee groups are cut only in the western half of the county, and those of the Lansing group are encountered only in wells drilled west and north of a line extending generally from Neodesha to Altoona, and northeast from Altoona to about the middle of the east boundary of the county (see Plate 1).

The Haskell and Westphalia limestone members of the Stranger formation are recognized in cable-tool wells by most drillers. The Tonganoxie sandstone member is recorded in only a few wells. The Stanton limestone is generally the first unit carefully recorded in logs of wells drilled in the county, but its usefulness in determining structure is reduced because of its rapid lateral changes in thickness. It is generally recorded in logs as a single, massive unit as much as 50 feet thick. The Plattsburg limestone also varies greatly in thickness, and where the intervening Vilas shale is thin, as in the areas south of the Silver City dome, south of Fredonia, and west of Neodesha, the limestones of the Lansing group form a single unit 150 feet or more thick. The Plattsburg is recorded in logs as hard gray limestone, and in the logs of a few wells, the lower calcareous shale and basal thin limestone are indicated. The generalized well log on Plate 7 ~~in Figure 41~~ shows the typical lithologies and average thicknesses of

Figure 41. Generalized well log of important stratigraphic units and producing zones ~~units occurring~~ in the subsurface of Wilson County.

the more significant ~~useful~~ stratigraphic units in the subsurface of Wilson County. The figure also shows the relative positions of the producing zones and drillers' terms in common use in the county.

In drillers' logs the Lane-Bonner Springs shale is generally recorded as a light-colored shale in Wilson County. In the subsurface it ranges in thickness from less than 25 feet to more than 125 feet. A 10- to 30-foot limestone near the middle of the formation is recorded in the logs of several wells northwest of Fredonia and north of Altoona. This limestone may possibly be a southern extension of the Wyandotte limestone. A thin sandstone is recorded at the top of the shale in the logs of a few wells.

The Iola limestone ranges in thickness from 10 to 65 feet in the subsurface. Near New Albany, and throughout most of the northeastern part of the county, the thickness averages about 50 feet, but elsewhere it is generally recorded in well logs as about 10 feet. Near New Albany the thickness increases at the expense of the overlying shale, and the Iola apparently merges with the Plattsburg limestone. ~~(see fig. 40, wells 4 to 7)~~. The Iola is generally described in logs as a single, hard, limestone unit, but locally the middle black shale and thin limestone at the base are recorded also.

The Kansas City group in the subsurface of Wilson County is a shale and limestone sequence (see Plates 6, 7 ~~see figs. 40, 41~~). The upper one-third is a thick shale sequence (Chanute shale) that contains much sandstone. The Chanute shale ranges in thickness from 50 to 150 feet, and is about one-half sandstone. The upper sandstone unit, the Cottage Grove sandstone member ("New Albany sand"), averages less than 25 feet, ~~however.~~ In the northeastern corner of the county, however, the sandstone averages nearly 70 feet in thickness, and west of Neodesha it is as much as 140 feet thick. In T. 29 S., R. 16 E., the sandstone is divided into two parts by a shale unit as much as 60 feet thick. The sandstone below the shale may correlate with the Noxie sandstone member of the Chanute shale. In a few areas in Wilson County, three thin limestone beds ~~occur locally~~ are recorded 30, 60, and 80 feet below the top of the Chanute in the subsurface. In other areas, the entire Chanute shale thins in the subsurface, and the overlying Iola limestone nearly merges with the underlying Drum limestone. The shale of the Chanute is generally recorded in well logs as blue, white, or gray. Along a line extending southwestward from sec. 3, T. 28 S., R. 17 E., to sec. 10, T. 29 S., R. 15 E., and south to sec. 8, T. 30 S., R. 15 E., the Cottage Grove sandstone member extends to the base of the formation in the subsurface. In a few wells in this area the underlying Drum limestone is missing, and the unconformity extends through the Drum into the Cherryvale shale. The Drum is recorded in well logs as thin, hard limestone; the Cherryvale shale is generally described as dark-colored shale, about 30 feet thick.

The next 200 feet of strata in the subsurface is predominantly limestone and does not crop out in Wilson County. These strata are included in the Dennis limestone, Galesburg shale, Swope limestone, Ladore shale, and Hertha limestone (see Plate 7).[/] The shale

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[/] The naming and outcrop characteristics of these and other units that occur only in the subsurface of Wilson County are described in reports by Wilmarth (1938), Moore (1936, 1949), Jewett (1949, 1954), Lee (1940c), and Keroher and Kirby (1948).

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formations are not readily correlated from well to well and are of little value in subsurface studies. The most persistent shale unit (Galesburg) is near the middle of the limestone sequence, and in many places contains a lenticular sandstone body that produces small quantities of gas and oil locally. Most of the other shale units are in the lower one-half of the sequence. They cannot be readily correlated from well to well, either because of lateral changes in sedimentation, or because of incomplete well records.

A sequence of about 250 feet of shale with thin beds of limestone and sandstone separates the predominantly limestone unit just described and the Pawnee-Fort Scott limestone unit. The boundary between the Missourian and Des Moinesian series occurs in this sequence, but is recognized only locally in the subsurface. These rocks above the series boundary comprise the Pleasanton group and range in thickness from 25 to 125 feet. The boundary by definition is at the base of the Hepler sandstone ("Wayside sand"). The records of several wells in the northern part of the county show sandstone at this stratigraphic position. The records of other wells show one or more limestone beds 2 to 5 feet thick, but no sandstone in this ~~the~~ same stratigraphic position. One of these limestone beds probably correlates with the Checkerboard limestone that crops out to the east; the Hepler sandstone occurs slightly lower in the sequence. The shale above the sandstone or limestone beds is generally dark gray to black; below it is light gray to bluish-gray.

Two persistent limestones, the Lenapah and the Altamont, occur near the bottom of the upper one-third of the 250-foot sequence. The Lenapah is generally about 10 feet thick and locally is divided into two beds by about 5 feet of shale. The Lenapah is separated from the Altamont by about 10 feet of light-gray shale, the Nowata shale. The Nowata ranges from 5 to 35 feet in thickness and is locally sandy. The lower limestone unit, the Altamont, has an average thickness of about 15 feet. It is recorded in the logs of most wells and is locally divided into two separate beds. The Lenapah and Altamont limestones, form the upper part of the Marmaton group. The middle part of the group consists of about 100 feet of shale, the Bandera shale (see Plate 7 ~~fig. 41~~). Widespread sandstone beds ("Weiser sand") occur in the upper and lower parts of the Bandera. They are lenticular, 5 to 35 feet thick, and locally produce oil and gas. The color of the Bandera shale is recorded in well logs as light-gray or blue.

Underlying the Bandera shale is a readily-recognized, thick limestone unit, the Pawnee limestone. This is the "Pink lime" of many drillers and is the "40-foot lime" of others. It consists of 30 to 45 feet of brown, hard limestone. Locally, a 5-foot black shale bed near the top separates the Pawnee into two limestone beds 5 feet and 35 feet thick. The Labette shale, which averages about 30 feet thick and is black in the upper half and light colored in the lower half, underlies the Pawnee limestone. In a few places the Labette is sandy ("Peru sand") and contains gas.

The next lower unit in the subsurface is the Fort Scott limestone. This limestone, the "Oswego lime" of drillers, is one of the most important units for purposes of correlation in the subsurface of Wilson County because it is the last thick limestone unit above the oil- and gas-bearing sandstones of the Cherokee group. Lying as it does below the "Pink lime," it is recognized in most wells, and its depth is carefully recorded by drillers. The top of the "Oswego lime" was used to draw a subsurface structural contour map (~~fig. 53~~ Plate 8) which was used in constructing a profile of the top of the Fort Scott limestone along the line of the cross section ~~in figure 40.~~ on Plate 6. The top of the Fort Scott limestone on each well log was positioned on this profile in order to eliminate the effects of topography of the present land surface when wells were projected to the line of the cross section (~~see fig. 40~~ see Plate 6).

The Fort Scott limestone averages about 30 feet in thickness in Wilson County, but is as much as 75 feet thick in the southeastern part of the county. It generally consists of two limestone beds separated by black shale. The upper limestone bed is 15 to 25 feet thick and overlies 5 to 10 feet of black shale, which, in turn, overlies 5 to 10 feet of hard limestone. The upper limestone bed is generally called the "20-foot lime" by drillers, and the lower limestone bed is their "5-foot lime." The black shale bed beneath the "5-foot lime" commonly furnished the largest amount of gas, but each of the black shale beds was apparently a source of the "shale gas" for which the "Oswego lime" was noted during the early 1920's. A third limestone bed about 5 feet thick is recorded in the logs of many wells, and in the logs of a few wells, a fourth 5-foot limestone bed is recorded beneath another 5 feet of black shale.

The Cherokee group underlies the Fort Scott limestone. The group averages about 400 feet in thickness and ranges from 450 feet to as little as 200 feet (~~see fig. 40~~ Plate 6). The group is thinnest in areas of uplift and thickest immediately adjacent to such areas. The most productive petroleum-bearing zones in the county are in the lenticular sandstone beds that occur in this group. The tops of the more important petroleum-bearing sandstone beds lie approximately 25, 150, 250, and 350 feet below the top of the group (~~see fig. 41~~ Plate 7).

The shale of the Cherokee group is generally light colored in the upper 150 to 200 feet, but dark shale units are interbedded locally. The shale is dark colored to black in the middle 20 to 40 feet of the group, and is recorded in well logs as light colored or blue in the lower 100 to 200 feet.

A thin limestone bed which is recorded in the logs of many wells, 80 to 100 feet below the base of the Fort Scott limestone. ~~It is tentatively correlated with the Ardmore limestone of Missouri, and~~ serves to define the lower limit of a series of sandstone beds referred to as the "Squirrel sand" by drillers (see Plate 7). The three sandstone bodies of the "Squirrel sand" ~~which~~ range in thickness from 3 to 45 feet and are of restricted lateral extent. ~~occur near the top, middle, or bottom of this 80 to 100 feet of shale.~~

Sandstone beds below ~~the Ardmore limestone~~ the "Squirrel sand" are classed as "Bartlesville sand." Drillers refer to them as the "Upper Bartlesville sand" and "Lower Bartlesville sand," and many drillers include in this group the "Stray sand," the "Salt sand," and the "Burgess sand" as well. In this report, sandstone beds lying 100 to 200 feet below the base of the Fort Scott limestone are arbitrarily classed as "First Bartlesville sand," ~~because they are the first major group of sandstone beds below the Ardmore limestone.~~ The sandstone beds lying 200 to 300 feet below the Fort Scott are referred to as "Second Bartlesville sand," and those lying 300 or more feet below the Fort Scott are classed as "Third Bartlesville sand." Because of the thinning of the Cherokee group over structural highs, sandstones of the "Second Bartlesville sand" overlie Mississippian rocks in some wells. Elsewhere, those in the "Third Bartlesville sand" overlie rocks of Mississippian age. The most widespread and thickest productive sandstone bodies are those of the "First Bartlesville sand." In some areas the "Second Bartlesville sand" is most important; only very locally are sandstone bodies more than 300 feet below the Fort Scott limestone economically important. Coal, an important economic product of the Cherokee group at its outcrop southeast of Wilson County, was recorded in the logs of only a few wells.

## Rocks of Mississippian age

In many wells in Wilson County, 5 to 30 feet of chert fragments occur below the argillaceous and arenaceous rocks of the Cherokee group. These chert fragments lie upon or are part of marine cherty limestones of Mississippian age. The upper surface of these Mississippian rocks is an erosion surface upon which thick deposits of chert fragments, derived from weathering of the underlying cherty limestones, accumulated locally or were concentrated by stream and current action. This porous medium is the "Mississippi chat," or simply "chat" of the drillers, and is locally productive of oil and gas. Where rounded and concentrated by stream or wave action, the chert constitutes part of the "Burgess sand". The depth to the top of these rocks is as little as 1,000 feet along the eastern border of the county and along the axis of the Fredonia anticline. It is as much as 1,600 feet to their top near the southwestern corner of the county. The upper part of the Mississippian rocks has been tested by more than 600 wells in Wilson County (see Fig. 21).

Figure 21 near here

Figure 42. Map showing the locations of wells that have tested Mississippian and older strata in Wilson County.

Of these, about 100 were drilled entirely through the sequence. The Mississippian rocks are as much as 350 feet thick near the northwestern, northeastern, and southeastern corners of the county, and are only about 200 feet thick atop the Fredonia anticline (see Fig. 22).

Figure 22 near here

Figure 43. Isopachous map showing the thickness of the Mississippian strata in Wilson County.

The average thickness of these rocks in Wilson County is about 275 feet.

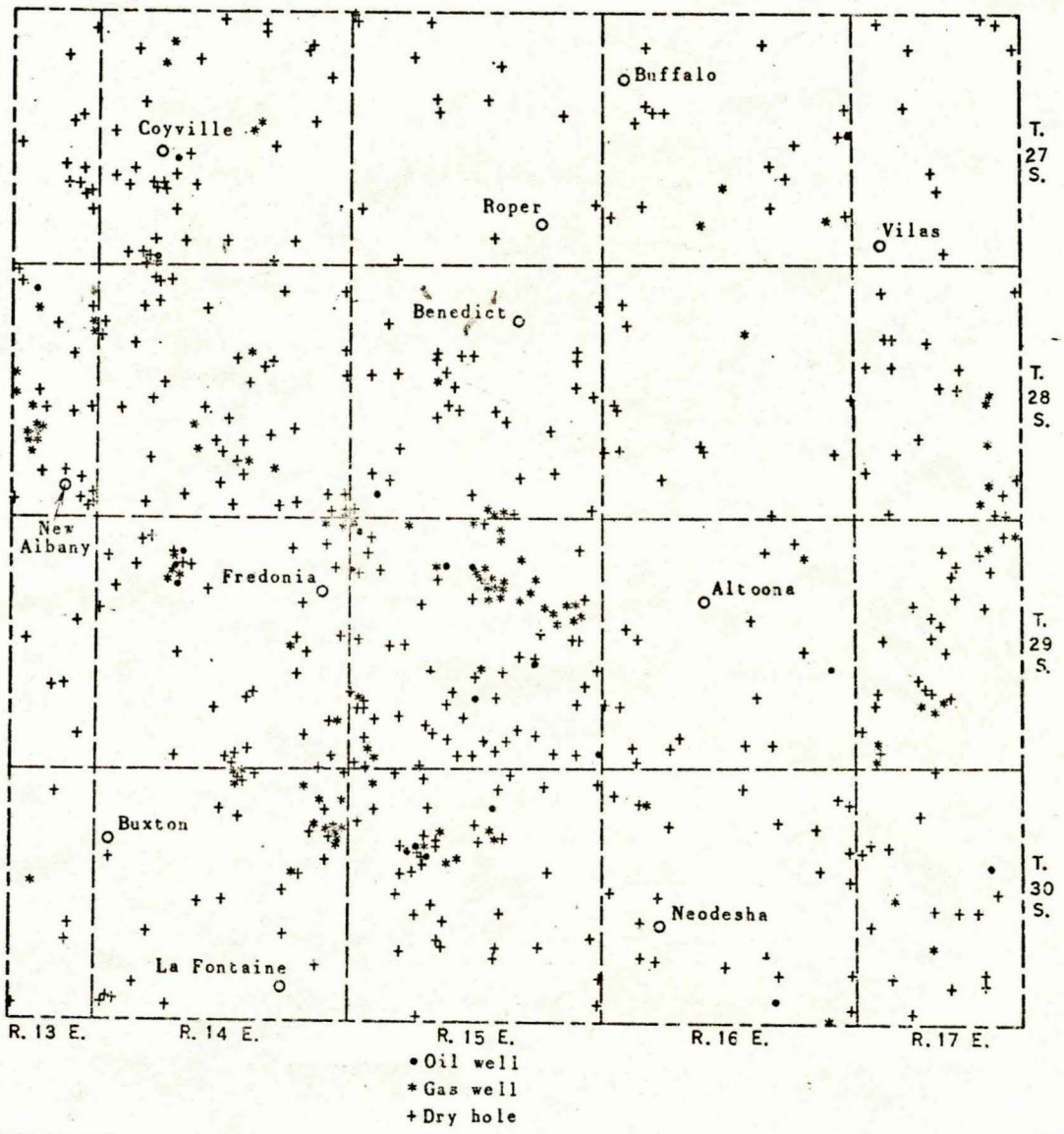



Figure 21.--Map showing locations of wells that have tested Mississippian and older strata in Wilson County.

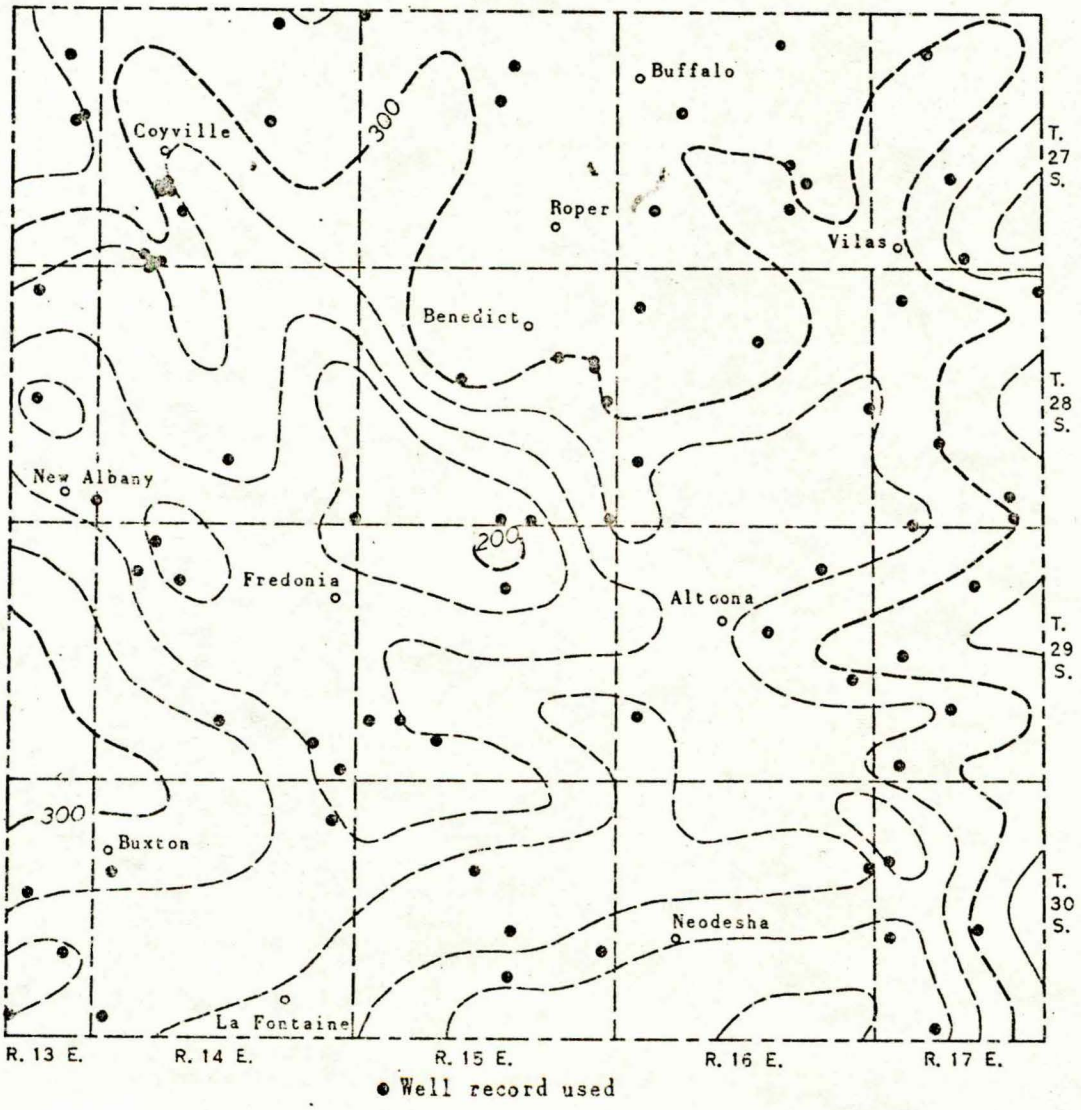



Figure 22.--Isopachous map showing the thickness of the Mississippian strata in Wilson County. Thickness interval 25 feet.

Thickness and lithologic variations in the strata of Mississippian age in the subsurface of Wilson County were described by Lee (1939, 1940c, and in Moore and others, 1951), who studied cuttings of rocks of Mississippian age from 9 wells in this county. ~~(Lee, 1940c, pl. 1)~~. Three of the wells, the Edwards No. 1 well in sec. 22, T. 30 S., R. 15 E., the Watt No. 5 well in sec. 34, T. 28 S., R. 17 E., and the Smith No. 3 well in sec. 10, T. 29 S., R. 15 E., were included in cross sections by Lee and are shown in Figure ~~44~~ 23. The Smith No. 3 well is located atop the Fredonia anticline; the other two are off the anticline and are therefore probably more representative of the Mississippian strata throughout the county.

~~Figure 44. Diagrams of three selected test wells showing correlation of formations of Mississippian age in Wilson County.~~

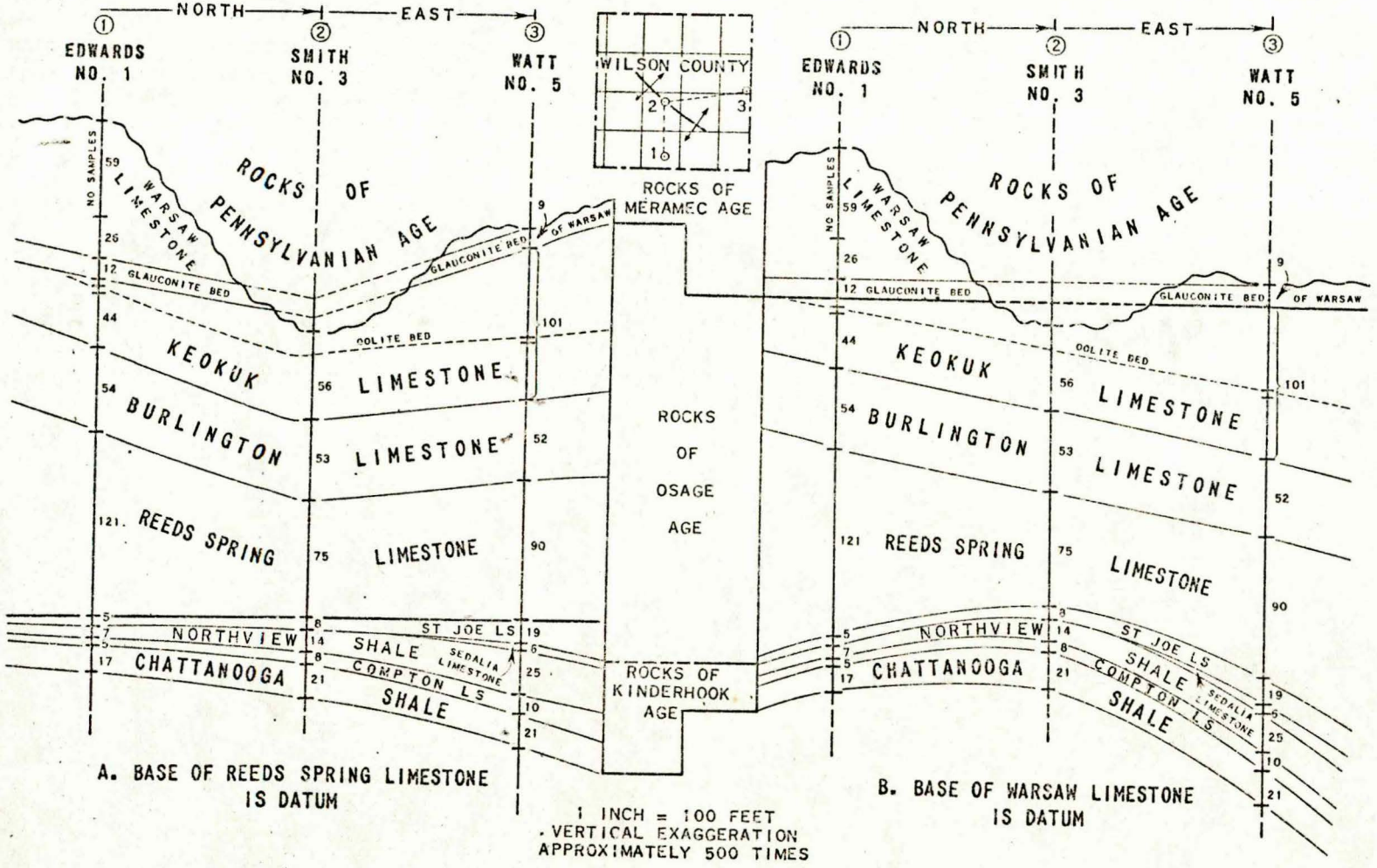



Figure 23.--Diagrams of three selected test wells showing correlation of formations of Mississippian age in Wilson County. (Data from Lee, 1939, 1940c, and Moore and others, 1951.)

Thickness variations in the Mississippian stratigraphic units in the wells shown ~~in~~ on Figure ~~44~~ 23 provide a clue to the approximate times and amounts of structural uplift or downwarp that occurred during the Mississippian period in Wilson County. Thickness changes are apparent throughout Mississippian time, and the northeastward increase in thickness of the Chattanooga shale, Compton limestone, Northview shale, Sedalia limestone, and St. Joe limestone (~~see~~ Fig. ~~44~~ 23, A) coupled with constant (uniform) lithology, indicates that the deeper part of the sea was to the north and east. In the Reeds Spring formation, however, the thickness was greatest in the south and least atop the Fredonia anticline (Smith No. 3 well) suggesting slight downwarp to the south and uplift on the anticline during its deposition. The ~~constant~~ uniform thickness of the Burlington indicates stable conditions, but the progressively greater thickness of the Keokuk suggests tilting to the northeast during its deposition or shortly thereafter (~~see~~ Fig. ~~44~~ 23, B). Whether the irregular upper surface of the Mississippian strata is depositional or erosional is not known, but Lee stated (in Moore ~~and others~~ et al., 1951, p. 108) that where the Warsaw does not grade downward into the Cowley formation, it is obscurely unconformable on rocks of Keokuk or Burlington age. Furthermore, the presence of the oolite bed at approximately the same distance above the base of the Keokuk in both the Edwards and Watt wells and the much greater thickness of Keokuk above the oolite in the Watt well suggests that the upper part was truncated by erosion. The presence of the glauconite bed at the base of the Warsaw limestone and the absence of additional Warsaw in the Smith and Watt wells (~~see~~ Fig. ~~44~~ 23) suggests that deposition of the

basal glauconitic bed and the remainder of the Warsaw was followed by ~~deep~~ erosion and concurrent uplift on the Fredonia anticline, thus ~~greatly~~ reducing the thickness of strata of Mississippian age on the anticline, while preserving it elsewhere. The presence of thick deposits of subround chert clasts in several wells suggests that lag gravels accumulated locally during the period of erosion and formed conglomerate(?) beds on the flanks of the uplifts; the gravels were presumably stripped off in areas of active uplift.

The lithologies of the Mississippian strata in the county range from cherty, dolomitic limestone to non-cherty limestone and from calcareous, green shale to carbonaceous, black shale. The Chattanooga shale is here included with the Mississippian rocks, although part of it is ~~it may be in part be~~ thought to be of Devonian age. The Mississippian rocks were described in detail by Lee (1940c), and many of the following descriptions of these rocks in the subsurface of Wilson County draw heavily on his work. Not only were samples studied by Lee but also the insoluble residues of the samples. Insolubles residues are particularly valuable in studying Mississippian and older strata because, as ~~discovered and~~ stated by McQueen (1931, p. 102, 129), residues from different formations are characteristically different, and for each formation are the same over large distances.

The uppermost Mississippian unit in the county is the Warsaw limestone. It is missing in some parts of the county, and in others is possibly as thick as 100 feet (~~see~~ fig. 23 ~~11~~). The Warsaw is composed mainly of semigranular limestone inter-laminated with sugary dolomite and relatively large amounts of distinctive, microfossiliferous chert. Chert in insoluble residues of the Warsaw is always gray, but some is dense and opaque, and some is semitranslucent. Insoluble residues from many of the dolomite beds are porous masses that contain abundant sponge spicules. At the base of the Warsaw is a characteristic silty glauconitic bed about 12 feet thick that rests on an irregular erosion surface at the top of Keokuk and older rocks (Lee, 1940c, p. 65-73).

Strata correlated with the Keokuk Limestone range in thickness from less than 50 to more than 100 feet in Wilson County. In the southern part of the county, erosion of 60 feet of limestone above a gray, fairly extensive oolite bed apparently accounts for the difference in thickness. The Keokuk Limestone is largely dolomite and dolomitic limestone with an oolitic limestone bed near the top of the lower half. The strata above the oolite bed are more dolomitic than those below and contain abundant chert. The chert in some zones is white or gray and even-textured, and in insoluble residues is almost everywhere accompanied by pitted siliceous limestone or by soft, porous siliceous rock ("cotton rock") composed of white, opaque, incompletely cemented microscopic particles of silica (Lee, 1940c, p. 17). Below the oolite bed the Keokuk consists of calcareous gray dolomite alternating with buff-gray semigranular crinoidal limestone that is less siliceous than the dolomite. The dolomite is extremely siliceous and contains large quantities of opaque white "cotton rock" and calcareous pitted, porous, opaque, white chert.

Underlying the Keokuk in each of the wells shown in Figure 23 is about 50 feet of light-colored, semigranular, crinoidal limestone, the Burlington limestone. The uniform thickness of this limestone, 52 to 54 feet, seemingly indicates widespread even deposition upon a plane surface, and rules out active structural movement or prominent erosion preceding or following its accumulation. Interbedded with the crinoidal limestone are many relatively thin beds of gray dolomite and limestone that are grained with minute dolomite crystals. Locally, chert is abundant in the limestone and dolomite beds. The chert is characteristically even-textured, opaque, and gray, grayish-white, or bluish-white. Chert in dolomitic limestone beds usually has a grainy or stippled texture. Druzy quartz and minute pockets lined with fine quartz crystals are common constituents of the insoluble residues of the Burlington (Lee, 1940c, p. 58-59).

The Reeds Spring limestone underlies the Burlington and consists of 75 to 120 feet of gray or buff, semigranular, fine textured, locally dolomitic, cherty limestone. The chert of the insoluble residues is largely dark gray, dull, blocky, particolored, and of grainy texture. In the lower part of the formation spongy silica, as well as chert that is semitranslucent, flaky, and chalcedonic, is relatively abundant.

The thin St. Joe limestone conformably underlies the Reeds Spring limestone in Wilson County. It ranges in thickness from 5 to 19 feet in the three wells illustrated on figure 23. In well cuttings, the St. Joe is distinguished from the overlying formations by the small amount or complete absence of chert. It is semigranular in texture and is composed of crystalline fragments embedded in a firm limestone matrix. Where the St. Joe is thick, the upper part is crinoidal.

A thin wedge of Sedalia limestone extends into Wilson County from the east. In the Watt well (fig. 23) it underlies typical St. Joe limestone (Lee, 1940c, p. 38) and consists of 6 feet of gray, coarsely sucrosic dolomite. The part of the insoluble residue of the Sedalia that is characteristic of the unit consists of microscopically botryoidal aggregates or roundish granules of chert, which seem to be the result of siliceous growth around impurities (Lee, 1940c, p. 37).

The Northview shale ranges in thickness from about 5 to 25 feet in Wilson County. In drillers' logs it is recorded as gray, green, or blue shale. In cuttings from many wells it is slightly calcareous or dolomitic. Insoluble residues are typically green, porous, silt aggregates (Lee, 1940c, p. 30).

The Compton limestone consists of 5 to 15 feet of hard limestone. Lee (1940c, p. 29-30) reported that in well cuttings it is typically a fine-textured, slightly greenish-gray, non-cherty limestone with waxy luster. The insoluble residues from the Compton are meager and consist of white, irregularly shaped, fragile, and spongy siliceous aggregates.

The Chattanooga shale of Mississippian and possibly Devonian age in Wilson County is recorded in drillers' logs as 5 to 25 feet of black shale underlying the Compton limestone. In the logs of several wells, about 5 feet of sandstone ("Misener sand") is shown at the base of the black shale. According to Lee (1940c, p. 21), the Chattanooga shale is separated from the underlying beds by an angular unconformity, whereas only an obscure disconformity separates it from the approximately parallel overlying deposits of definite Mississippian age. Locally, it contains abundant spores identified as Sporangites huronensis (Lee, 1940c, p. 22).

## Pre-Mississippian rocks

About 100 wells in Wilson County reached strata of Ordovician and Cambrian age (see Fig. 24). Eight of these wells penetrated through or nearly through the sequence. Four of the wells entered Precambrian granite, and one bottomed in hard gray rock below sandstone correlated with the Lamotte sandstone of Cambrian age. Studies of samples from two of the wells (the Neodesha Deep Test in sec. 19, T. 30 S., R. 16 E., and the Smith No. 3 well in sec. 10, T. 29 S., R. 15 E.) indicate the lithology of these rocks (see Haworth, 1908, p. 60-64, and Stryker, 1925, p. 1212-1214). Study of insoluble residues and correlation with similar studies at the outcrop were made on samples from the Smith No. 3 well and were reported on by Keroher and Kirby (1948, p. 64, 66-67) and Lee (in Moore and others, 1951, p. 120-121). Correlation of these two wells with drillers' logs of two other deep tests in the county show thickness changes in the pre-Mississippian units (see Fig. 25).

Figure 45. Map showing locations of wells in which "Arbuckle" and older rocks have been tested in Wilson County.

Figure 46. Stratigraphic relations of "Arbuckle" and older rocks in Wilson County.

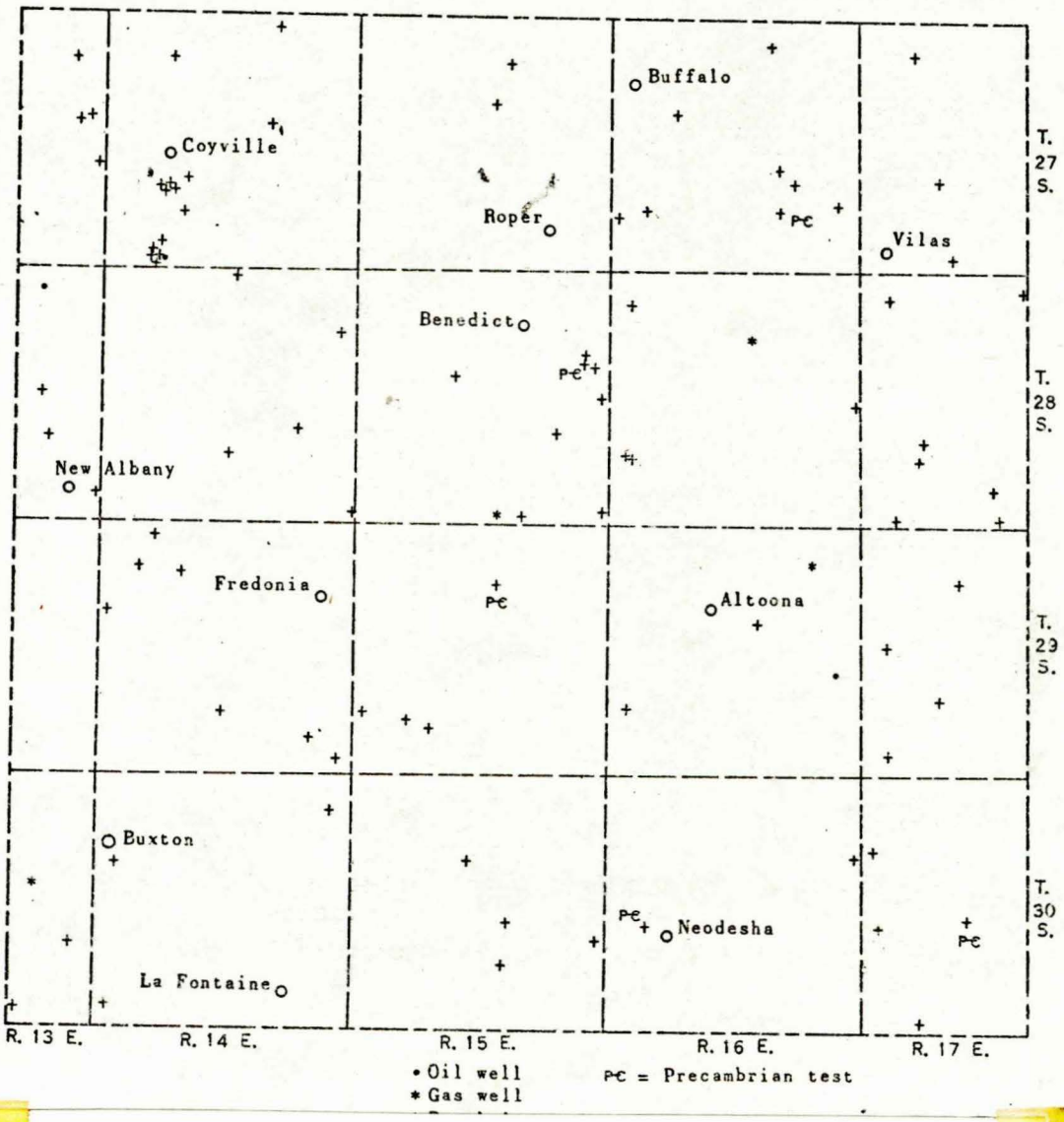



Figure 24.--Map showing locations of wells that have tested "Arbuckle" and older rocks in Wilson County.

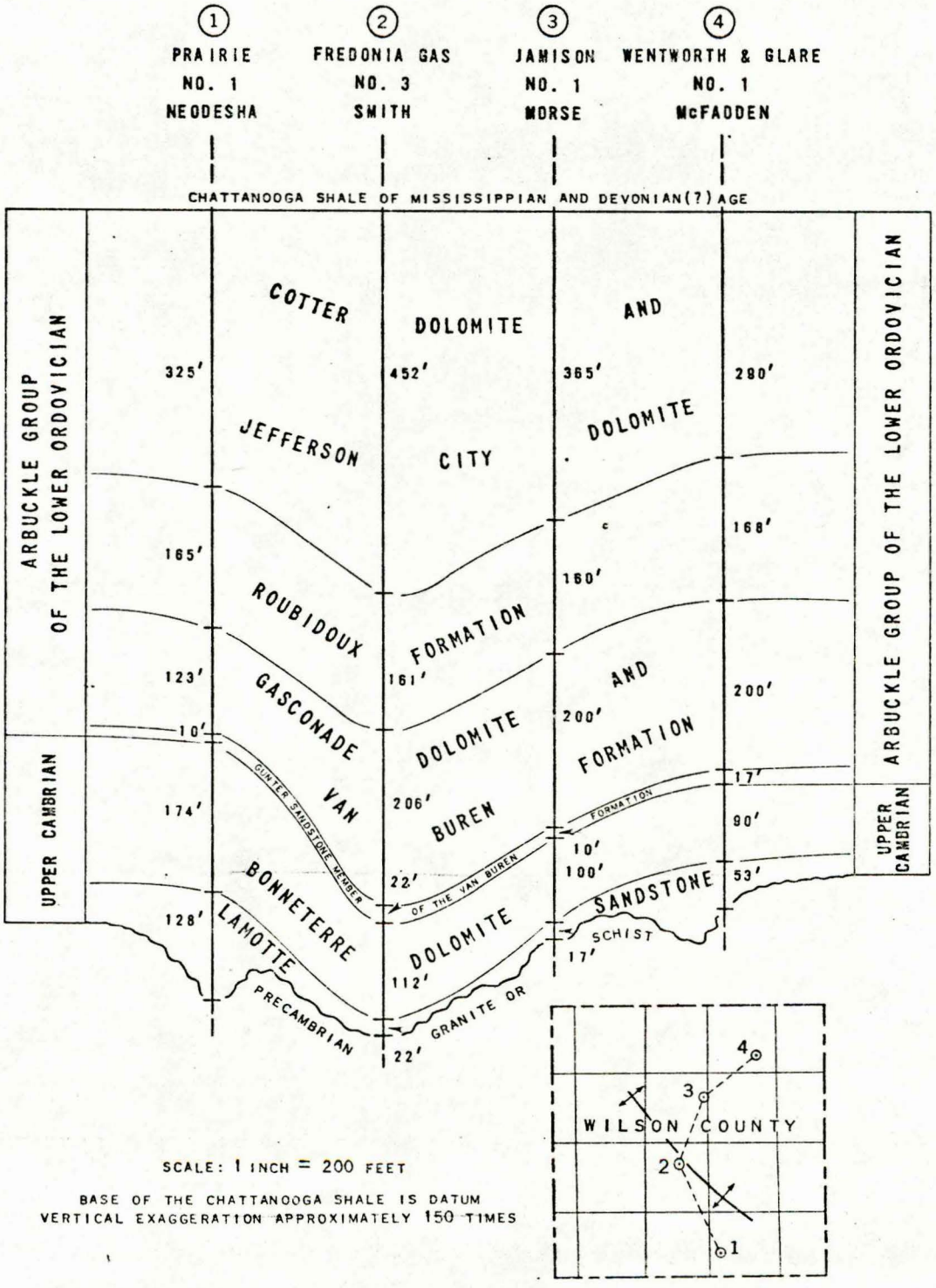



Figure 25.--Stratigraphic relations of "Arbuckle" and older rocks in Wilson County. (Data from Haworth, 1908; Keroher and Kirby, 1948; Moore and others, 1951; and drillers' logs.)

Strata below the Chattanooga shale are of Early Ordovician and Late Cambrian age and are correlated with the Cotter and Jefferson City dolomites, the Roubidoux formation, the Gasconade dolomite, the Van Buren formation, the Bonneterre dolomite, and the Lamotte sandstone. The Cotter and Jefferson City dolomites range in thickness from about 290 feet in the McFadden well to 452 feet in the Smith well (see Fig. ~~46~~ 25). The greater thickness of this sequence over the Fredonia anticline suggests that downwarping in Early Ordovician time may have preceded uplift of the structure in Mississippian and later time. The thickness of the Roubidoux formation ranges from about 160 to ~~180~~ 170 feet, of the Gasconade-Van Buren sequence from 123 to more than 200 feet, and of the Bonneterre dolomite from about [redacted] 90 to 175 feet. The increase in thickness of the Bonneterre dolomite in the [redacted] Neodesha well is almost offset by a compensating increase in thickness of the Gasconade dolomite and Van Buren formation in the other three wells (see Fig. ~~46~~ 25). These differences in thickness are seemingly attributable to facies changes or reversals in structural movement in southeastern Wilson County inasmuch as the overlying Roubidoux formation and the Gunter sandstone member of the Van Buren formation are of ~~constant~~ uniform thickness and presumably were deposited upon relatively plane surfaces.

The Cotter and Jefferson City dolomites are generally grouped into a single unit in subsurface studies in eastern Kansas because they are not separable on lithologic criteria in well cuttings. According to Lee (in Moore et al., 1951, p. 119), they consist mainly of coarsely granular, cherty dolomite. The upper part of the sequence includes much oolitic chert which is brown but becomes lighter colored and less abundant downward. Near the base, white, tripolitic chert is abundant. In the Smith well (Fig. 25) this sequence is very cherty, except for three 20-foot non-cherty units about 40 feet below the top, near the center, and 50 feet above the base.

The Roubidoux formation consists mainly of non-cherty, coarsely crystalline, sandy dolomite, but cherty dolomite occurs in the upper one-third of the formation in some wells. In the Smith well, for example, cherty dolomite occurs 35 to 55 feet below the top of the formation. The principal constituent of the insoluble residue is clean white quartz sand. The sand grains are mostly fine-grained and sub-angular, but the larger grains are generally well-rounded and pitted, frosted, or polished. Some of these larger grains, however, are angular and show evidence of secondary enlargement; some are doubly terminated crystals. The chert of the Roubidoux is white and dense, or bluish and translucent. Large, brown, translucent, glassy oolites are common. The Roubidoux is characteristically very sandy at both its top and base.

The Gasconade dolomite and Van Buren formation are not differentiated in the subsurface in eastern Kansas because of lack of consistent criteria for separating them by insoluble residues. The sequence consists mainly of coarse, granular, white to light-gray dolomite that is locally cherty in the upper and lower parts. It can be divided roughly into two units on the basis of the included chert, but the equivalence of these two units with the formations mapped at the outcrop in Missouri has not been established. In the Smith well (Fig. ~~46~~ 25) chert occurs in a 50-foot cherty dolomite in the upper 70 feet of the sequence. The chert in this upper part is gray to dark bluish gray, dense, and glassy. About 50 feet above the base is 15 feet of cherty dolomite in which the chert is white, dense, smooth, partly porcellaneous, and quartzose. The dolomite at the base of the Van Buren is sandy and is known as the Gunter sandstone member. Insoluble material in the member ranges from 10 to more than 50 percent of the sample. The sand grains are generally well rounded with frosted or polished surfaces. Bright, angular, grains, both coarse and fine, that result from secondary quartz enlargement are common. Keroher and Kirby (1948, p. 40, 44, 65) pointed out that relatively unweathered feldspar in the Gunter in the Smith No. 3 well in Wilson County probably came from Precambrian rocks upon which the Gunter lies in Cowley, Sumner, and Sedgwick Counties 50 to 75 miles to the west ~~(Keroher and Kirby, 1948, p. 69)~~.

The Gasconade-Van Buren sequence is readily distinguished from the underlying Bonneterre in the Smith well by both lithology and insoluble residue. The residue of the Gunter member is coarse-grained, rounded or secondarily enlarged sand, and that of the Bonneterre is fine-grained, silty sand.

The Bonneterre dolomite is the oldest carbonate-rich rock in the subsurface of Wilson County. In eastern Kansas it is a conspicuously glauconitic, non-cherty dolomite that is dark gray to brown and finely crystalline (Lee, in Moore et al., 1951, p. 122). Locally it includes beds of sandy and silty dolomite and dolomitic shale near the top. Both the upper and lower 30 feet of dolomite in the Bonneterre in the Smith well are very sandy. The insoluble residues of the Bonneterre are much finer in the upper part than in the lower. Aggregates of silt-size grains of quartz associated with very fine-grained quartz sand and fine glauconite grains are abundant in the upper part. The aggregates are brown and porous and have a spongy texture. In the lower part, the sand grains are coarse, angular, and occur both free and in loosely cemented clusters associated with large glauconite grains (Keroher and Kirby, 1948, p. 28).

The Bonneterre grades downward into the Lamotte sandstone of Late Cambrian age. The Lamotte unconformably overlies a Precambrian surface of moderate relief (see Fig. 25), and ranges in thickness from less than 25 to more than 125 feet in Wilson County. The grains in the Lamotte are largely quartz, are angular to subround, and are poorly sorted, ranging from coarse to fine.

Five wells in Wilson County bottomed in rock believed to be Precambrian in age. The rock was apparently granite in three of the wells; in the two others it presumably was metamorphic rock. The five wells are as follows (see Fig. 24):

Wentworth and Glare No. 1 McFadden, NW¼NW¼SW¼ sec. 26, T. 27 S., R. 16 E., total depth 3,352 ft.

Jamison No. 1 Morse, SE¼NE¼SW¼ sec. 13, T. 28 S., R. 15 E., total depth 2,732 ft.

Fredonia Gas No. 3 Smith, SE¼SE¼NW¼ sec. 10, T. 29 S., R. 15 E., total depth 2,246 ft.

Prairie No. 1 Neodesha, SW¼SE¼NE¼ sec. 19, T. 30 S., R. 16 E., total depth 2,412 ft.

Finley and Henderson No. 1 Birk, SE¼SE¼NW¼ sec. 21, T. 30 S., R. 17 E., total depth 2,310 ft.

The top of the granite was recorded at about 2,313 feet in the McFadden No. 1 well, but most likely the sand recorded between 2,313 and 2,366 is Lamotte, and the red rock recorded from 2,366 to 3,310 feet is the granite. No data are given for the interval from 3,310 to the total depth of 3,352 feet.

The Morse No. 1 well drilled sandy lime and sand from 2,240 to 2,367 feet, and then went into rock reported as schist. No record is given between 2,370 and 2,615 feet at which depth red rock was recorded, and then more sand. The well may have been in granite from 2,615 to the total depth of 2,732 feet.

Samples from the Smith No. 3 well were studied by Lee and others. Lee reported granite cuttings from 2,212 feet to the total depth of 2,246 feet (personal communication, September 1952). Samples from the No. 1 Neodesha ~~Deep Test~~ were studied by Haworth, who reported (1908, p. 62-64) sandstone with much angular quartz and feldspar from 2,182 to the total depth of 2,412 feet. He did not interpret the cuttings between these depths as representing granite basement because the grains were rounded. However, the very abundant angular grains of quartz and pink feldspar suggests that the cuttings may have come from weathered granite at 2,182 feet, and that the well was in granite from that depth to the bottom.

The Birk No. 1 well may have bottomed in metamorphic or basic igneous rock of Precambrian age. The log shows a change from light colored sandstone, apparently the Lamotte sandstone of Cambrian age, to gray, hard rock at 2,298 feet, and only another 12 feet was drilled.

The pink granite encountered in these wells is probably the "later" granite of Farquhar (1957, p. 60, 61, 81-88), who stated that much of the "later" granite is salmon pink, hypidiomorphic and granular, and varies considerably in grain size. An average mode as given by Farquhar (1957, p. 83) is:

| Mineral | Percent |
|---|---|
| Quartz | 25-30 |
| Orthoclase and microcline | 40-50 |
| Plagioclase (c. $Ab_{75}An_{25}$) | 20-25 |
| Muscovite | 2-3 |
| Biotite | 1-2 |
| Accessory minerals* | 1 |

*Include magnetite, zircon, sphene, hornblende, tourmaline, and apatite.

This description fits well the cuttings from the Smith well.

## Intrusive rocks

Intrusive rocks of peridotite composition do not crop out in Wilson County but are so near the surface at the Silver City dome (sec. 5, T. 27 S., R. 15 E.) that their metamorphic effects are seen in the outcropping rocks as color changes, silification, and cavities in limestone. The peridotite is exposed about half a mile north of Wilson County in the western half of sec. 32, T. 26 S., R. 15 E. (Wagner, 1954) where it crops out as weathered, very micaceous, grayish-yellow ~~(5Y 8/4)~~ clay.

Thin section studies by E. W. Heinrich (unpublished report for K. K. Landes, Feb. 1948), Paul Franks (unpublished report for W. W. Hambleton, June 1953), Charles Milton (written communication, July 1956), and by the author indicate that the intrusive rock is a fine- to medium-grained peridotite. The peridotite was composed originally of olivine, biotite, diopsidic-augite and relatively abundant sphene, but most of the olivine has been altered to serpentine and phlogopite, the biotite to phlogopite and vermiculite, and the diopsidic-augite to green chlorite. Weathering resulted in the formation of mixed-layer clay minerals, limonite, and magnesite(?). The only metamorphic effects in the outcropping rocks in Wilson County are an increase of porosity and slight silicification in the South Bend Limestone Member of the Stanton Limestone in roadcuts along the north line of the NE¼ sec. 6, T. 27 S., R. 15 E. The porosity increase is apparently the result of alteration of limonitic oolites to a more soluble form of iron, and subsequent removal of the oolites and enlargement of the cavities thus formed. Chemical analyses by the State Geological Survey of Kansas show a 13 percent increase in silica and magnesia and a compensating loss in calcium and water.

Unusual rocks in several wells in northern Wilson County are interpreted as sills of ~~igneous material~~ peridotite intruded into the sedimentary sequence (~~see~~ fig. ~~47~~ 26). Logs of the Hase, Bentley and Young

~~Figure 47. Correlated drillers' logs in the area of the Silver City dome, showing igneous intrusions.~~

wells of ~~Figure 47~~ 26 recorded hard black rock or mica rock at several ~~footages~~ depths; the Puckett and Honor Lodge wells, located about a mile south of the Silver City dome, have no such rocks, and show the normal stratigraphic section of the area. The log of the Hase No. 1 well (~~NW. cor.~~ NW NW NW sec. 6, T. 27 S., R. 15 E.) recorded black rock and black mica rock from about 915 feet to about 1,105 feet depth; the log of the Bentley No. 1 well (~~SE. cor. NW¼NW¼~~ SEc NW NW sec. 6, T. 27 S., R. 15 E.) recorded mica rock from about 910 to 1,060 feet and from 1,142 to 1,155 feet; the log of the Young No. 1 well (~~SE. cor. NE¼NE¼~~ SEc NE NE sec. 5, T. 27 S., R. 15 E.) shows mica rock from 298 to 350 feet, 620 to 644 feet, 805 to 820 feet, and 1,038 to 1,056 feet (~~see~~ fig. ~~47~~ 26). The log of the Young well recorded granite(?) from 350 to 370 feet, and black rock from 820 to 830 feet. These anomalous rocks may represent altered and unaltered igneous rock similar to the very micaceous grayish-yellow clay that crops out less than a mile to the north or similar to the dark blackish-green micaceous rock cut in core-drill holes at shallow depths in the same area.

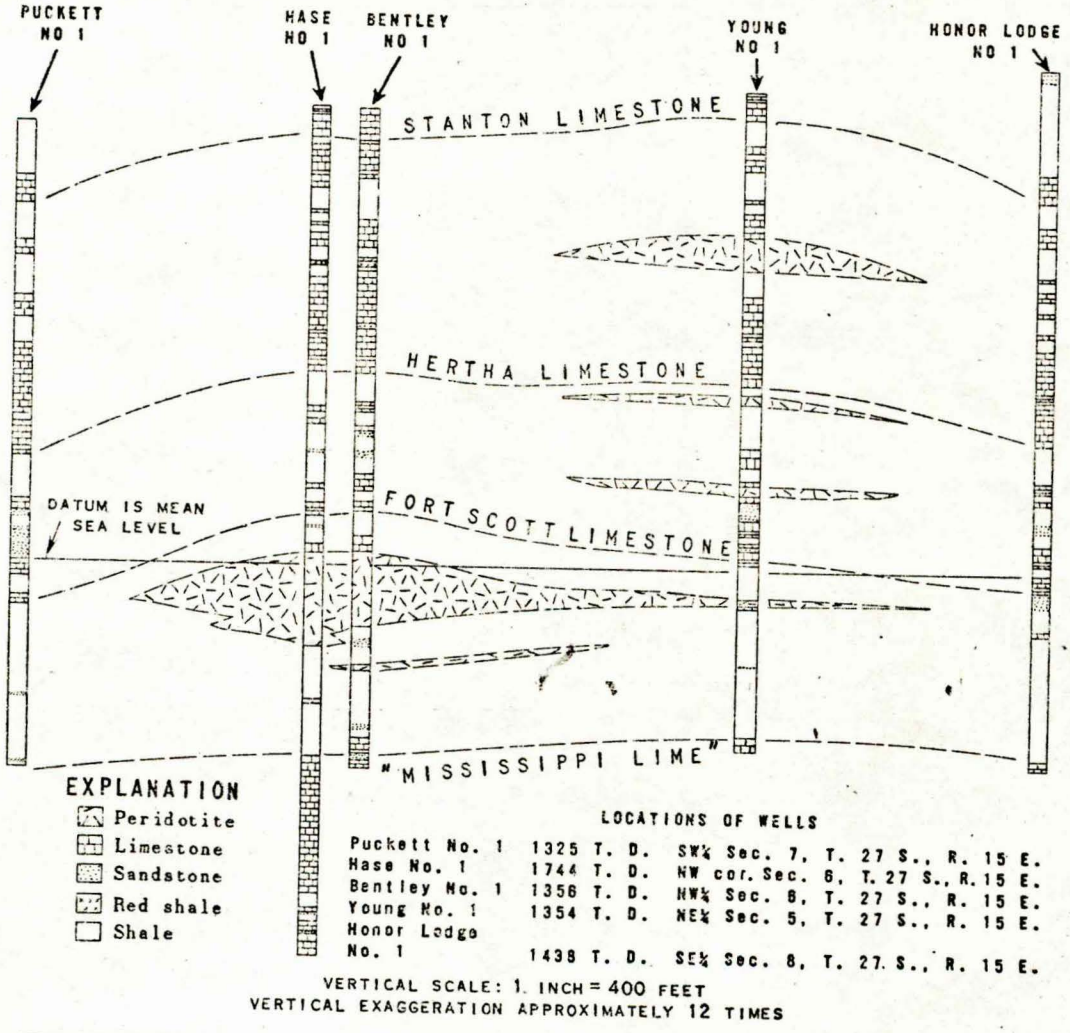



Figure 26.--Correlated drillers' logs in the area of the Silver City dome, showing igneous intrusions. (Datum is mean sea level.)

Just north of Wilson County, rocks of the Douglas group are apparently faulted along a line of steep dips and as much as 65 feet of intrusive peridotite occurs between the Stranger formation and the Stanton limestone (Wagner, 1954). In ~~the~~ Wilson county, however, the doming effect is principally in rocks of the Kansas City and Cherokee groups (~~see~~ Fig. ~~47~~ 26). Thin intrusions occur locally in strata of the Lansing, Pleasanton, and Marmaton groups. Most of the arching of the Silver City dome is thus a result of igneous intrusion into Pennsylvanian strata, but ~~the~~ slight upward bowing of the top of the "Mississippi lime" suggests that some arching resulted either from uplift or from igneous intrusion into Mississippian rocks.

## Structural geology

### ~~Introductory statement~~

Wilson County lies in the northern part of the Cherokee basin of southeastern Kansas and northeastern Oklahoma. This structural basin is the northern part of an area of sedimentation that extended across eastern Oklahoma and into Kansas in Pennsylvanian time (Moore and Jewett, 1942, p. 487). The Cherokee basin is bounded on the west by the Nemaha uplift, on the east by the Ozark uplift, on the north by the Bourbon arch (~~see~~ fig. ~~48~~ 27), and is a northward extension of the McAlester basin of Oklahoma (Jewett, 1951, p. 126). It is also located on the Prairie Plains monocline, a large tectonic element that is chiefly post-Permian in age (~~see~~ ~~Jewett, 1951~~, p. 152).

Figure 48. Map showing major structural uplifts and basins of Early Pennsylvanian age in Kansas, and the position of Wilson County ~~in relation to this framework~~.

The strata in Wilson County strike approximately N. 20° E. and dip westward at an average of about 25 feet to the mile, but the prevailing attitude of the strata is modified locally by a flattening of the westward dip through horizontal ~~dip~~ to eastward (reverse) dip. Many of the oil and gas fields of the county are located on the structures formed by these local variations. The structures are commonly less than 5 miles long and 2½ miles wide.

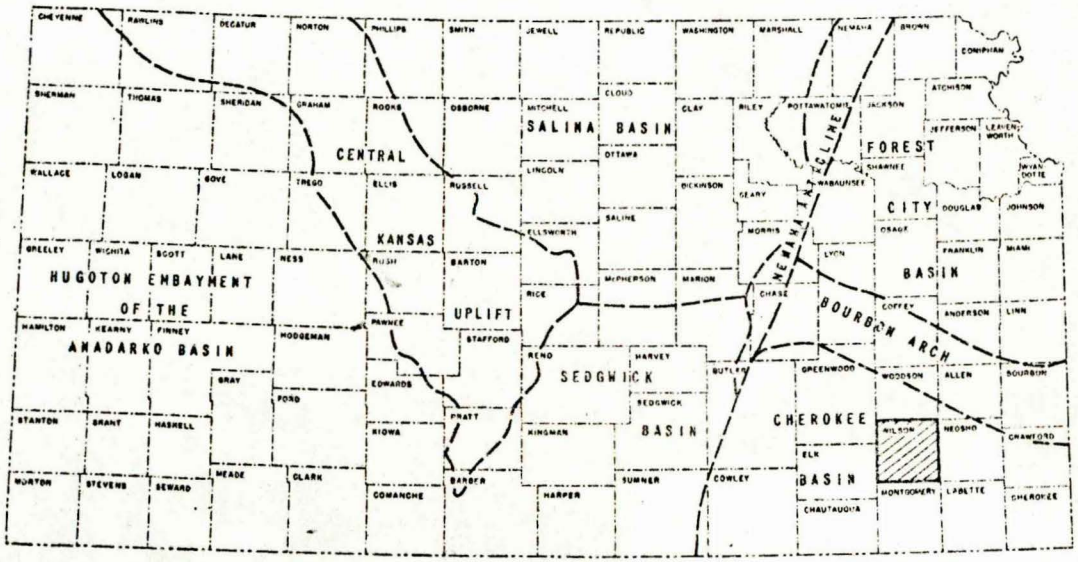



Figure 27.--Map showing major structural uplifts and basins of post-Mississippian age in Kansas, and the position of Wilson County in relation to this framework (modified after Jewett, 1951, p. 110).

## Surface indications of structure

Faults.--Six faults were observed in Wilson County; all are small and of little importance. They were seen only in creeks or roadcuts (see fig. 49), and because they could not be traced laterally, they are not shown on the geologic map. The greatest stratigraphic displacement on any of the faults is estimated to be about 25 feet. The faults displace the Tonganoxie sandstone member of the Stranger formation in roadcut exposures in the SE¼ sec. 9 and the NE¼ sec. 16, T. 27 S., R. 14 E.; the Iola limestone in a creek exposure in the NW¼ sec. 6, T. 29 S., R. 16 E.; the Stanton limestone in roadcut exposures in the SW¼ sec. 7 and NE¼ sec. 18, T. 29 S., R. 16 E.; and the Plattsburg limestone in a roadcut exposure in the NE¼ sec. 18, T. 29 S., R. 16 E. Five of the faults trend nearly north-south; the other trends nearly east-west. All are nearly vertical except the one that cuts the Plattsburg and dips about 12° to the west.

Figure 49. Normal faults in the Tonganoxie sandstone member of the Stranger formation in Wilson County.

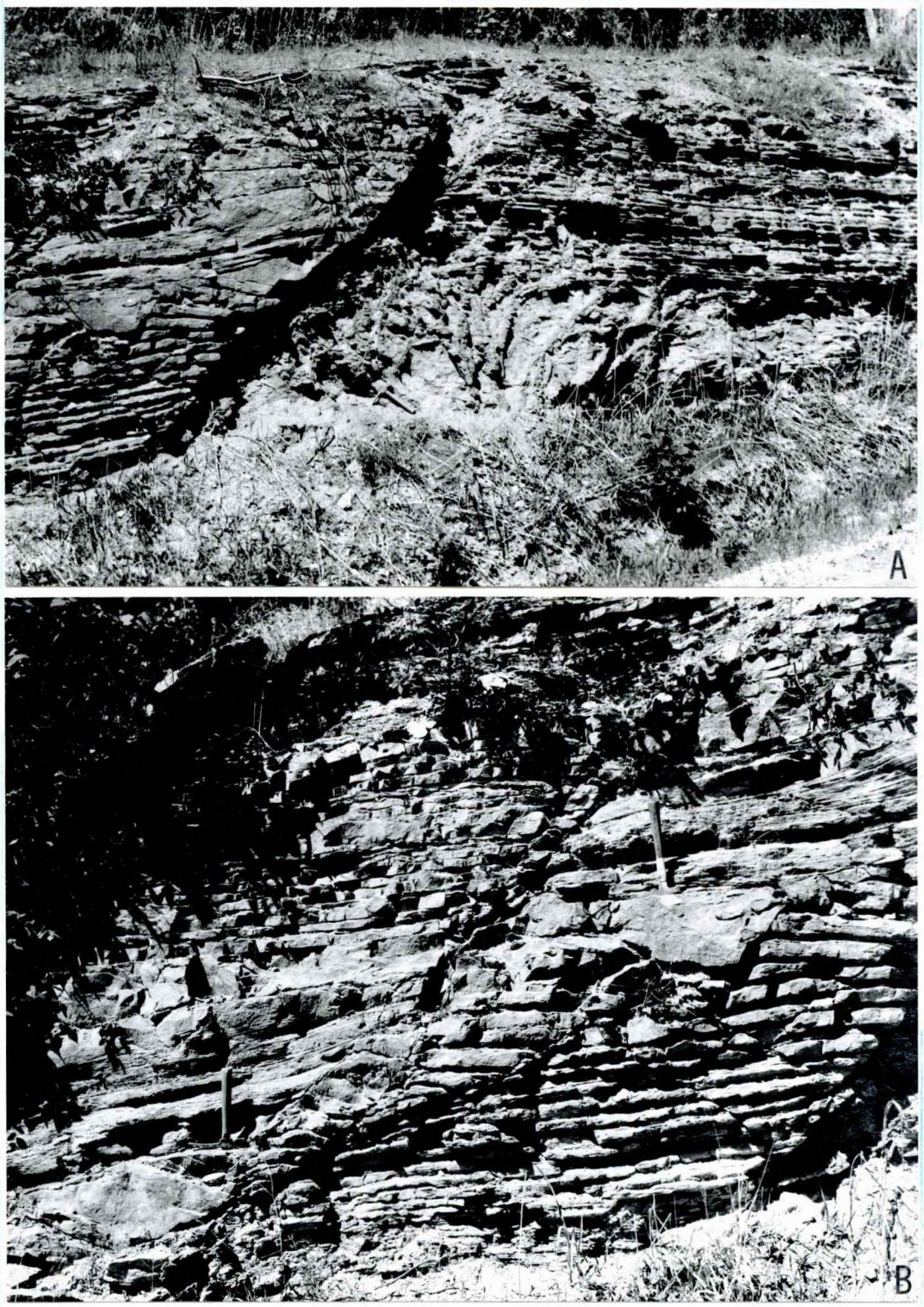



FIGURE 28.--Normal faults in the Tonganoxie Sandstone Member of the Stranger Formation. (A) Roadcut exposure in the NE¼ sec. 16, T 27 S, R 14 E. Strata at base of hanging wall correlate approximately with the uppermost strata in the footwall. (B) Detail of the hanging wall at the same exposure showing subsidiary normal faults. Heads of the two hammers are on the same stratigraphic plane.

Folds.--Exposed folds in Wilson County are of small magnitude and little importance and apparently have both structural and sedimentational origins. A series of parallel undulations in the Drum limestone are exposed in the bed of Washington Branch about 3 miles east of Neodesha on State Highway 37, and similar folds are exposed in the Dennis limestone in the beds of tributaries of Dry Creek in the NE¼ sec. 19 and NE¼ sec. 30, T. 30 S., R. 17 E. The undulations in the Drum limestone trend approximately N. 45° E., and those in the Dennis trend about N. 25° E. Those in the Drum have an amplitude of about 2 feet, and those in the Dennis have an amplitude of about 1½ feet. The horizontal distance from crest to crest of the undulations in the Drum is about 30 feet but ~~this~~ ranges from 7 to 35 feet. The distance between crests of the folds in the Dennis ~~averages 12 to 14~~ ranges from 6 to 20 feet, (Fig. 29, A). Figure 29 near here The undulations may represent slight compressional folding between uplifts to the northwest and southeast. Both limestones are very thin, and slight lateral flowage of the underlying and overlying shales during downwarping could have allowed such undulations to form.

The arching of beds of the Iola limestone just west of Barnhill Bridge in the NW¼ sec. 6, T. 29 S., R. 16 E. (~~see Fig. 25, B~~ Fig. 19, A) is interpreted as having resulted in part from compaction over a reef core, and in part from initial dip, but it may be the result of compressional folding. A thin limestone bed that overlies the arched beds has not been folded, and makes the depositional origin more likely.

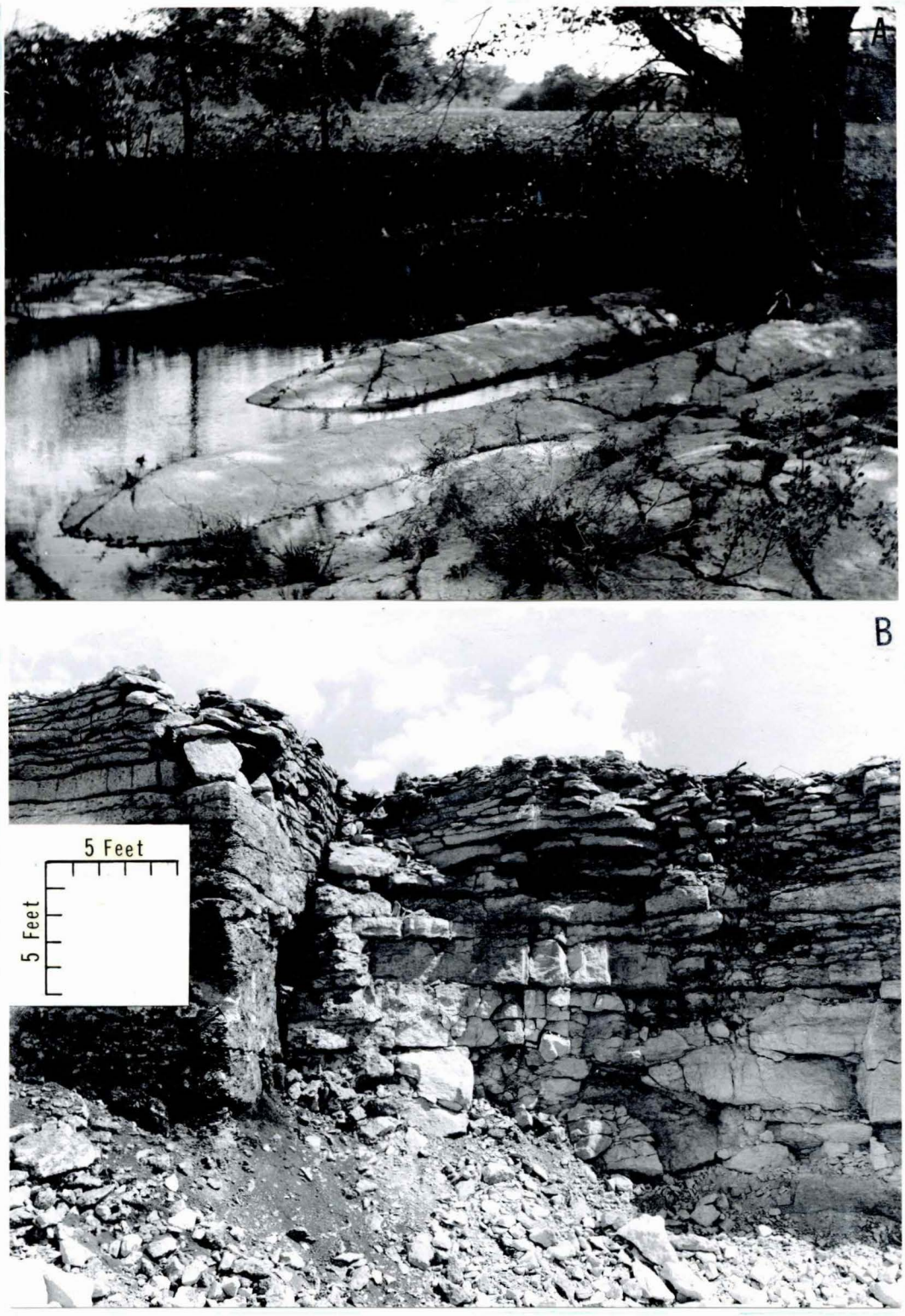



Figure 29.--Folds and joints in limestone strata in Wilson County. (A) Folds in the Dennis Limestone in a tributary to Dry Creek in the NE$\frac{1}{4}$ sec. 30, T 30 S, R 17 E. (B) Vertical joint system in the Stanton Limestone at the Wilson County State Lake quarry. SE$\frac{1}{4}$ sec. 17, T 27 S, R 16 E.

A few larger folds or areas of uplift were mapped in the county. The most readily recognized are the Silver City dome and the Fredonia anticline. The Silver City dome occurs at the north border of the county, but only the southern half of the structure is in the county. It can be seen best from a vantage point half a mile north of the county line just east of the ~~NE cor.~~ SE¼ SW¼ sec. 36, T. 26 S., R. 13 E. The Fredonia anticline is a less obvious feature whose apex is the site of a gas storage reservoir a few miles east of Fredonia. Several local upwarps that are apparent on the geologic map (Plate 1 ~~Fig. 7~~) are difficult to observe directly in the field. The nearly circular outcrop of Chanute shale about 3 miles northeast of Altoona, and the elongate exposure of the Chanute shale 5½ to 6 miles east of Altoona are ~~good~~ examples.

Joints.--Vertical joint systems are conspicuous in many of the hard limestone and sandstone beds in the county. The major trends and attitudes of the joints were observed in the field (see Fig. 50) (see Fig. 29, B),

Figure 50. Vertical joint system in the Stanton limestone at the Wilson County State Lake quarry.

but most of the trends shown on the geologic map were taken directly from aerial photographs. The density of the joint pattern on the geologic map thus reflects both the conspicuousness of the joint system in the rocks and the size and clearness of the outcrops of jointed rock on the photographs (see Fig. 51) (see Fig. 30). On photographs, the

Figure 30 near here

Figure 51. Joint system in the Stanton limestone as shown on aerial photographs.

joints are clearest in limestone units 15 to 30 feet thick; they are obscure but detectable in sandstone units.

The joints fall into two general groups that trend about N. 55° E. and N. 35° W., but in some areas other trends are superimposed upon these, and in other areas local deviations occur (see Fig. 7) (see Plate 1).

Figure 30.--Joint system in the Stanton Limestone as shown on aerial photographs. Sec. 19, T 28 S, R 16 E. Main trend is N55°E; secondary trend is N35°W. Barn (circled) gives approximate scale. Photograph courtesy of U.S. Department of Agriculture.

## Subsurface indications of structure

Records of wells drilled for oil and gas in Wilson County furnish much information on the character and position of stratigraphic units in the subsurface. Stryker (1925, ~~p. 1207-1214~~) utilized all available records of wells drilled in the county before 1925 and prepared an excellent short report on the subsurface geology of Wilson County. Included were a structural contour map of the upper surface of Mississippian rocks and two subsurface cross sections, one trending northeast and the other northwest, in which lithologic variations in the rocks were graphically shown. Information from many new wells was used in the preparation of a more detailed structural contour map of the upper surface of Mississippian rocks (Fig. ~~52~~ 31) which verifies the general picture presented by Stryker.

Figure 31 near here

Figure ~~52~~. Structure contour map on the top of rocks of Mississippian age in Wilson County.

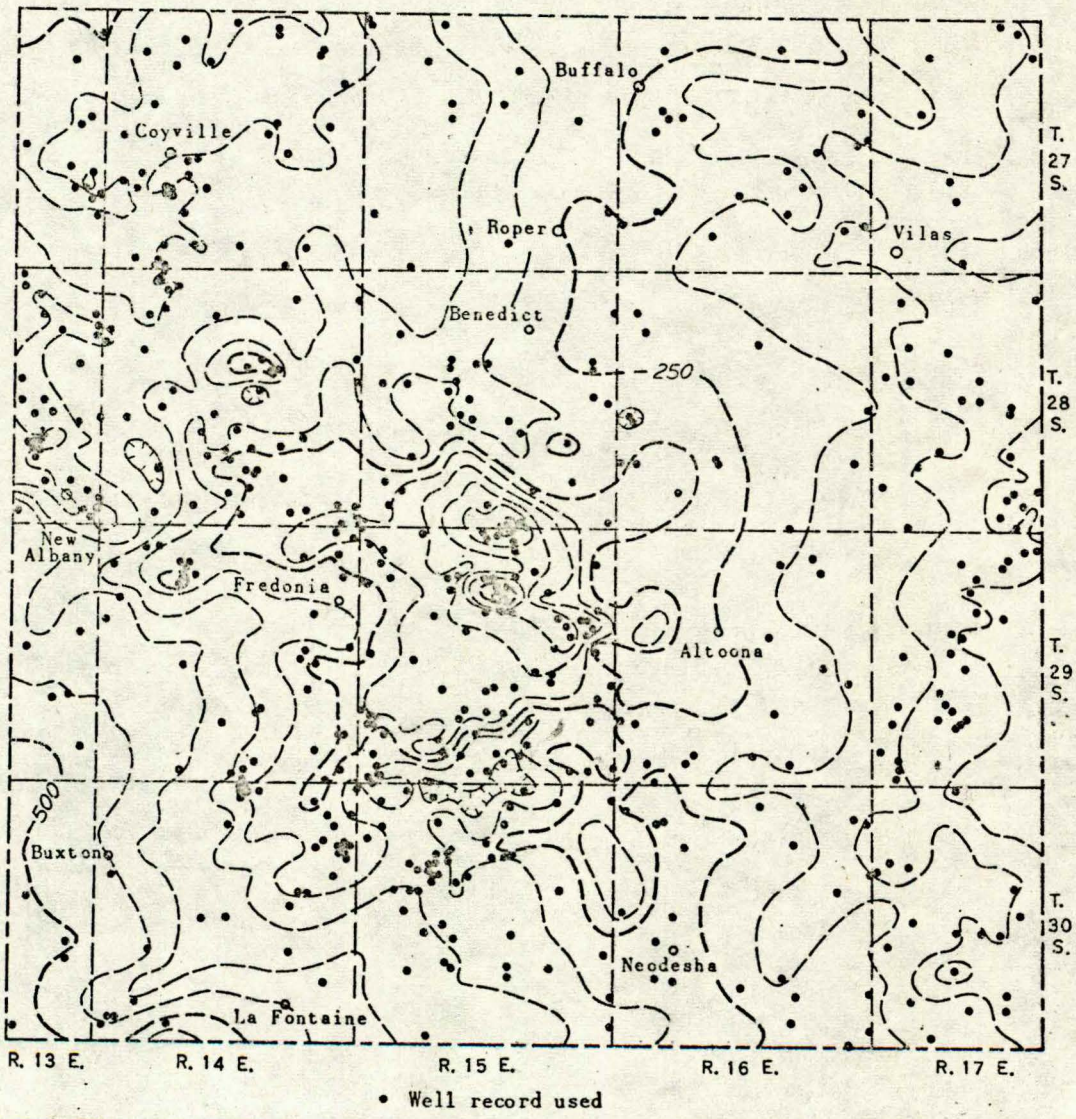



Figure 31.--Structure contour map on the top of rocks of Mississippian age in Wilson County. Contour interval 50 feet.

In the present study, the Fort Scott ("Oswego") limestone was the stratigraphic datum selected for detailed contouring because it is the most readily recognized Pennsylvanian unit in the subsurface of the county, and its depth is generally carefully recorded by drillers. The structural contours on the top of the Fort Scott limestone (see Plate 8 ~~fig. 53~~) show that strata in Wilson County strike about N. 25° E. and dip generally west-northwest at approximately 25 feet to the mile. The altitude of the top of the Fort Scott ranges from nearly 400 feet above sea level near the southeastern corner of the county to nearly 200 feet below sea level near the northwestern and southwestern corners. The structural relief at this horizon is nearly 600 feet across the county, but maximum local closure is only about 150 feet.

Figure 53. Map showing the structural configuration of the top of Fort Scott limestone and its relation to the occurrence of oil and gas.

Superimposed upon the regional dip are many reversals and deviations in strike and dip that impart an amoeba-like pattern to the structural picture (~~see fig. 53~~ Plate 8). The structural pattern is based on information from the logs of about 7,000 wells. Because many of the well records have neither precise locations nor elevations, many wells had to be located on the basis of surface geology or arbitrary placement near the centers of quarter sections, and elevations had to be taken from topographic maps. Most of the errors introduced by this procedure have probably been removed through generalization of an originally more detailed structural contour map. The well logs are seemingly fairly accurate because there is a close agreement in stratigraphy from well to well. The use of data from a large number of wells made possible the recognition and elimination of inaccurate or specious information.

Anomalies shown by the contours are the result of both structural movement and lateral variations in sedimentation and differential compaction. Some anomalies apparently indicate places where thick elongate sandstone bodies were only slightly reduced in thickness by compaction as compared to the reduction of the enclosing shale unit. Other small irregularities seem to indicate places where dome-shaped growths of limestone were surrounded and enclosed by muds that compacted much more than the limestone. The small structures that formed in either of these ways are of comparatively small magnitude and local extent, and only slightly modify the regional structural trend. They are very important, however, because they are loci for ~~many~~ accumulations of oil and gas. The complexity of the structure contours in the eastern part of the county is due in large part to local variations in ~~these~~ sandstone and limestone thickness ~~accumulations~~ and in part to local structural movement. A greater density of well information furnished closer control on positioning of the contours in the eastern part of the county.

Comparison of structural contours drawn on the top of the Fort Scott limestone (~~fig. 53~~ Plate 8), on the top of rocks of Mississippian age (Fig. ~~52~~ 31), and on the top of rocks of Ordovician age (Fig. 32)

Figure 32 near here

~~Figure 54. Structure contour map on the top of rocks of Ordovician age in Wilson County.~~

shows an increase in closure on several of the upwarps. The increase in closure seemingly indicates more or less progressive uplift in those areas after Early Mississippian time. An increase in complexity of the contour lines is largely due to more complete information for the younger strata, but indicates also the effects of local, short-lived, structural movement and differential compaction in post-Ordovician time. The structural contour map of the top of rocks of Ordovician age shows that the most prominent structures are along the trend of the Fredonia anticline, and on an offshoot of the anticline in the northwestern part of T. 29 S., R. 14 E. (~~see~~ Fig. ~~54~~ 32). This offshoot is also prominent on the structural contour maps of the Mississippian rocks and Fort Scott limestone. The isopachous map of Mississippian strata (Fig. ~~49~~ 22) shows a thinning of the rocks of Mississippian age over this structure, further ~~proof~~ evidence of the long history of upward movement.

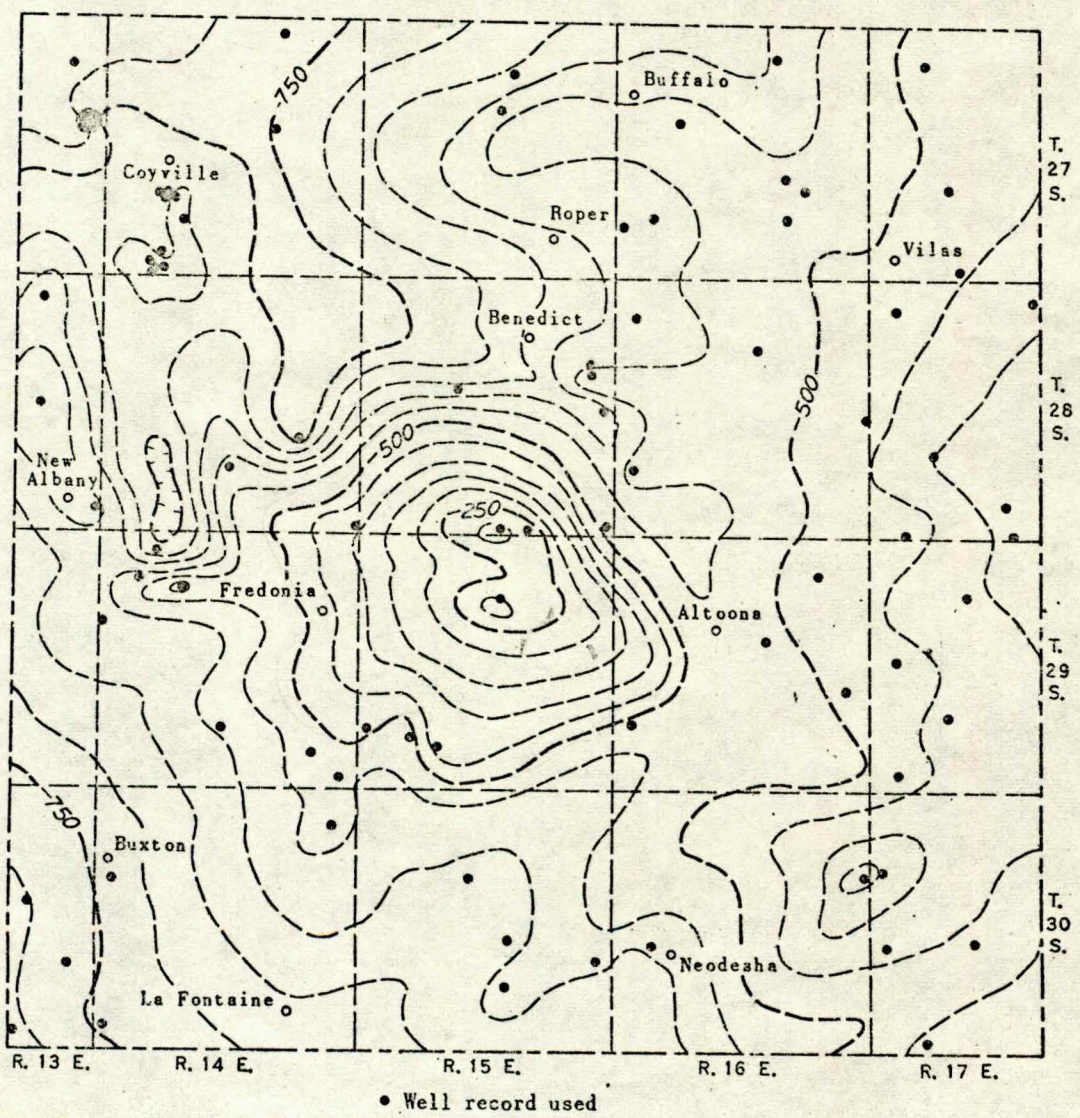



Figure 32.--Structure contour map on the top of rocks of Ordovician age in Wilson County. Contour interval 50 feet.

Subsurface structures or lithologic changes are also located by geophysical work. A ground magnetometer survey made by Hambleton and Merriam in the area of igneous intrusion in southern Woodson County and northern Wilson County showed several areas of greater than normal magnetic intensity (Hambleton and Merriam, 1955; p. 113-128; Merriam and Hambleton, 1959, p. 165-167). In the Wilson County part of the survey most of the magnetic anomalies trend generally north-south (see Fig. 33). The domal area underlain by the igneous

Figure 33 near here

Figure 55. Vertical intensity magnetic map of part of northern Wilson County.

intrusions shown on Figure 26 coincides best with an area of negative anomaly (see shaded area on Fig. 33), but the outcrop pattern and known subsurface positions of the intrusive agree neither in shape nor position with the geophysical data. Furthermore, the elongate configuration of the magnetic anomaly is at right angles to the structural shape of the Silver City dome as shown by structure contours. A relation to this structure is therefore doubtful. Inasmuch as the structure contour map shows no fold in the vicinity of Roper of the magnitude indicated by the magnetic contours in that area, and since none of the trends of the magnetic anomalies in the mapped area agree with geologic structures, the magnetic effects must be related to other geologic features. Application of the "steepest gradient" method of approximating the depth of a magnetic anomaly (Vacquier et al., 1951, p. 3-5, 20-21, 29) suggests that the rock body responsible for this anomaly is ½ to 1 mile deep, and the anomaly therefore probably reflects lithologic changes, or possibly structure, in Precambrian basement rock.

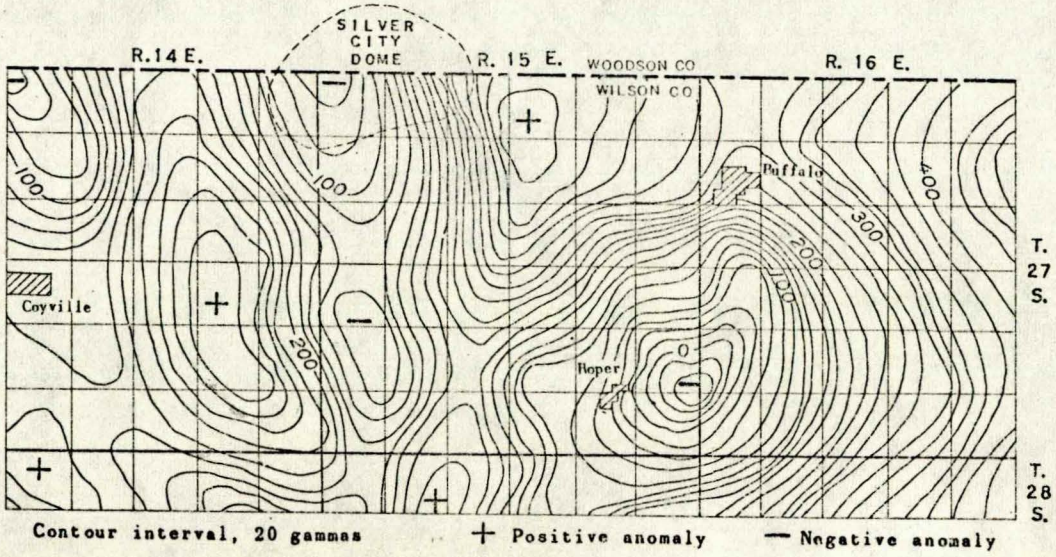



Figure 33.--Vertical intensity magnetic map of part of northern Wilson County. (From Hambleton and Merriam, 1955.)

## Major structural features

Fredonia anticline.--The Fredonia anticline is the most prominent structural feature entirely within Wilson County. This structure, which was first described by Stryker (1925, p. 1208), trends approximately N. 55° W. across the middle of the county and a few miles east of Fredonia has a closure at the top of the Fort Scott limestone of more than 100 feet. It is a composite elongate structure with a length of 6 to 10 miles and a width of 3 to 6 miles (see Plate 8, Figs. ~~see fig. 52,~~ 31 ~~53~~ and 32 ~~54~~).

The Fredonia anticline apparently has undergone uplift throughout Mississippian and later geologic time, as recorded by variations in the thickness of the sedimentary sequence on and adjacent to the anticline. For example, in the Smith No. 3 well (sec. 10, T. 29 S., R. 15 E.) on the axial part of the anticline, six formations of Mississippian age are only 215 feet thick, whereas in the Watt No. 5 well (sec. 34, T. 28 S., R. 17 E.), about 12 miles east of the anticline, these formations are 297 feet thick. Lower to Middle Pennsylvanian strata in these wells thicken from 995 feet in the Smith well to 1,225 feet in the Watt well. The thinning of sediments over the anticline seemingly resulted from upward movement of nearly 350 feet during Pennsylvanian and Mississippian time. Depressed areas ("peripheral sags"), made apparent by changes in thickness of the Mississippian strata (~~see~~ fig. ~~43~~ 32), are roughly parallel to the anticlinal axis, but are interrupted by structural offshoots from the main domal upwarp.

Silver City dome.--The Silver City dome is a prominent topographic and structural feature at the northern border of Wilson County. It is an eroded dome whose rim is held up by the Tonganoxie Sandstone Member of the Stranger Formation and whose floor is cut through the Weston Shale to the Stanton Limestone (~~see fig. 7~~ Plate 1). Structural closure on the dome is approximately 175 feet. The Silver City dome originated differently than the Fredonia anticline, being caused largely by igneous intrusion (~~see~~ Fig. ~~47~~ 26). Mica peridotite, probably of Cretaceous age, intruded the area and accounts for all but about 40 feet of the uplift. The remaining uplift may reflect igneous intrusion into the underlying Mississippian strata, but it seems more likely that it is due to upward structural movement in Pennsylvanian time, because the folding appears to be progressively less in younger strata. Removal of igneous material from the logs of the wells drilled on the Silver City dome and use of the base of the Stanton Limestone as a datum resulted in good correlation of stratigraphic units and shows that the upward curvature on the correlated beds extends only to about the middle of the Kansas City Group (~~see~~ Fig. ~~56~~ 34). At the time of deposition of the Hertha Limestone, ~~at which time~~ upward

Figure 34 near here

~~Figure 56. Correlated drillers' logs in the area of the Silver City dome, omitting igneous material.~~

movement apparently ceased.

The Silver City dome lies at the junction of two anticlinal trends directed N. 55° W. and N. 60° E. The N. 60° E. trend is in line with the Rose dome, another area of igneous intrusion about 5 miles to the northeast, and suggests that the two domes are genetically related.

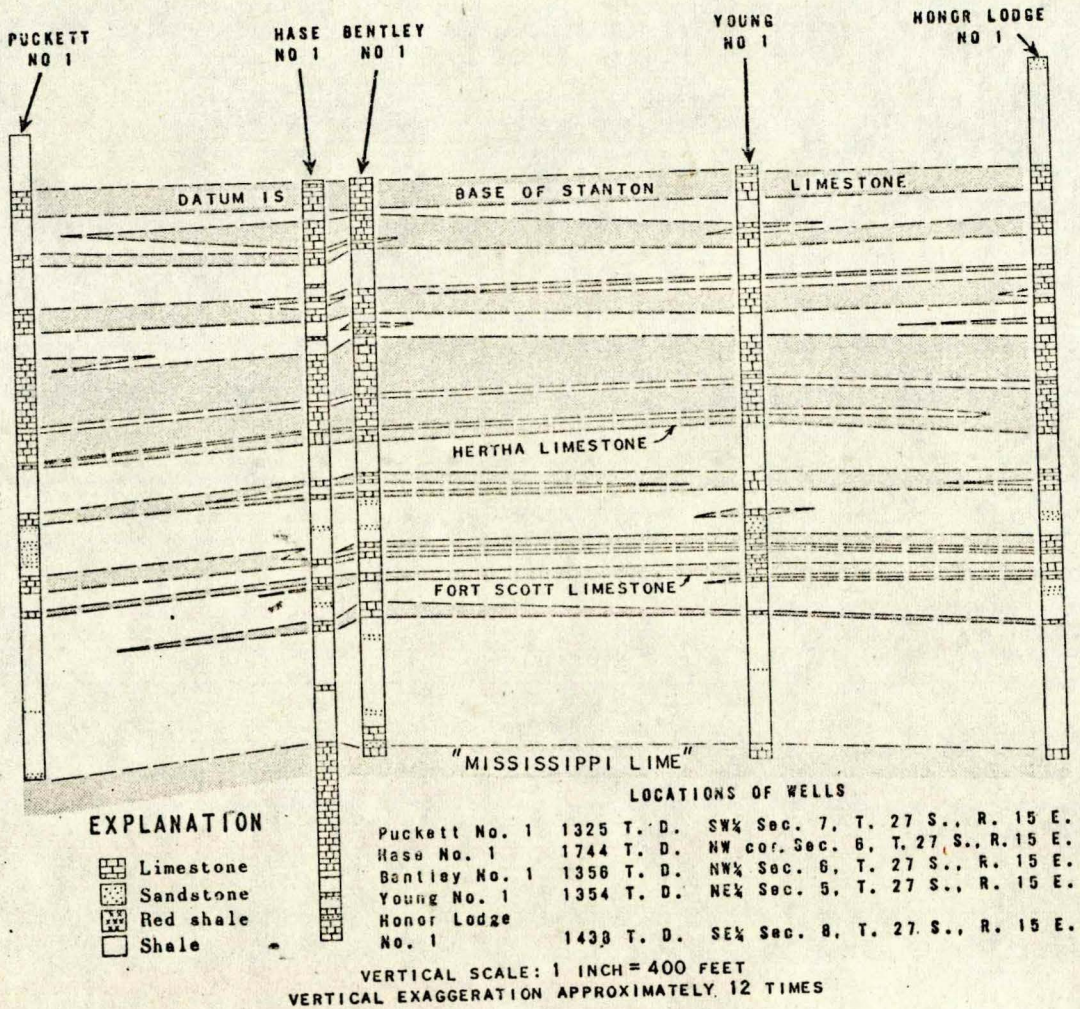



Figure 34.--Correlated drillers' logs in the area of the Silver City dome, omitting igneous material. (Datum is base of Stanton Limestone.)

## Geologic history

The geologic history that follows attempts briefly to put into proper sequence the many structural movements and depositional environments reflected in the rocks underlying Wilson County. During late Precambrian time (more than 500 million years ago), Wilson County was covered by a sea in which clayey and silty muds were deposited. These muds accumulated to a great thickness before granite magma forced its way into them and metamorphosed them to slate and schist. At the time of or shortly after this intrusion, the area was probably raised above sea level, ~~and~~ mountains were formed, and erosion began.

~~Cambrian through Mississippian.~~ For possibly the next 50 million years Wilson County was above the sea, and erosion during Early and Middle Cambrian time removed most of the sedimentary rocks and exposed the granite. The mountains were worn down until the hills were only about 100 feet high and the valleys were only 50 to 100 feet deep.

In Late Cambrian time the sea transgressed upon this land surface, and the quartz and feldspar from the weathered granite accumulated to form a blanket of sand about 25 feet thick (Lamotte). As the sea continued to transgress, the shore moved farther ~~away~~ from Wilson County, ~~the land (area) furnished~~ less and less ~~debris~~, and ~~the~~ calcium and magnesium carbonate in the sea formed a thick dolomite deposit (Bonneteerre). The Cambrian period ended with a slight withdrawal of the sea, but Wilson County remained submerged.

In Early Ordovician time much coarse sand was carried into the shallow sea that covered Wilson County, and about 20 feet of coarse-grained, dolomite-cemented sand (Gunter) formed. Transgression of the sea deepened the water over Wilson County, and for the next 25 to 50 million years dolomite accumulated on the sea floor (Van Buren, Gasconade, Roubidoux, Jefferson City, and Cotter formations). During periods of high-silica concentration, sinuous, gel-like, siliceous bodies formed and were enclosed in the dolomite. Periodic lowering of sea level allowed oolites to form and accumulate, and active currents many times transported quartz sand grains into Wilson County. Toward the end of Early Ordovician time the sea again partially withdrew, and oolites formed in abundance and were enclosed in calcium- and magnesium-carbonate precipitates. The remainder of Ordovician, all of Silurian, and most of Devonian time is not represented by rocks in Wilson County, and presumably the sea withdrew completely and left the county as a land area undergoing erosion for nearly 200 million years. As erosion progressed, the land surface bowed down as much as 150 feet in a few small areas, and a greater thickness of Lower Ordovician dolomite was preserved.

Near the end of Devonian time the near-level surface that had been cut was covered by a shallow encroaching sea. Streams from the adjacent land brought sand into the area and deposited it in local accumulations along the shoreline, while fine terrigenous muds containing very abundant organic humus and many spores (Chattanooga shale) collected along the shoreline and in estuaries. Wind, tidal, and current action was at a minimum and, although the land-derived materials were widely distributed, very little agitation of the water accompanied their accumulation. The deepest part of the sea probably lay to the north and east during Late Devonian time, and the black shale accumulated to a slightly greater thickness in that direction.

The sea continued to transgress upon the land for the next 15 to 20 million years, and during much of Mississippian time deposits of dolomitic limestone accumulated. At the beginning of Mississippian time, little magnesium was available in the sea water, and a deposit of almost pure calcium carbonate formed (Compton limestone). An influx of argillaceous material during a period of greater current action brought an abundance of mud into Wilson County (Northview shale), and later an increase in silica content of the water led to the formation of botryoidal, siliceous aggregates which became enclosed in limestone (Sedalia limestone). This environment extended westward almost to only to about the middle of the county. At times, crinoids abounded, and their remains formed thin limestone beds (St. Joe limestone). The magnesium and silica content of the water increased, and during much of the remainder of Early Mississippian time, cherty dolomitic limestone accumulated. Irregularly shaped masses of colloidal silica gel formed and assumed characteristic features from each different environment. Some of the resulting chert contained terrigenous debris, some was pure and cryptocrystalline, some was granular. Small masses of porous silica formed concurrently with chert toward the end of Early Mississippian time both before and after a shallowing of the sea had resulted in the formation and concentration of abundant oolites into a thin bed (part of Keokuk limestone).

A short period of structural uplift on the Fredonia anticline near the middle of Early Mississippian time led to a lesser thickness of limestone (Reeds Spring) in the area of uplift. At the end of Early Mississippian time general uplift to the south resulted in erosion, and the upper limestone was beveled to a relatively flat surface.

Late Mississippian time began with a slow transgression of the sea upon a deeply weathered land surface. Wave action was at a minimum, and in the presence of bacteria and organic acids the clay was largely transformed into glauconite. However, short periods of wave action removed the fine material between the glauconite grains and rounded and concentrated the grains into a bed. Transgression of the sea continued, and many sponges and other invertebrate animals abounded. Their remains are now enclosed in a thick, cherty limestone (Warsaw). Deposition of limestone may have continued for some time, but uplift and erosion in Early Pennsylvanian time removed any later deposits and cut completely through the rocks deposited in Late Mississippian time leaving only remnants in Wilson County.

~~Pennsylvanian.~~ The erosion that started in Late Mississippian time continued for about 20 million years until part of Middle Pennsylvanian time had elapsed and a surface of low to moderate relief had formed. On this surface were concentrations of chert fragments that resulted either from accumulation in situ of Mississippian cherty limestone or as abraded chert in stream and beach gravel. In the 5 million years remaining in Middle Pennsylvanian time (Desmoinesian ~~series~~ Series) the sea moved across Wilson County and back 15 or more times. Vegetation grew on the exposed mud flats after the regressions and the accumulated plant debris later formed coal beds. When the sea transgressed, sand bars formed along the shore, and the vegetation was drowned by back-bay brackish water and was covered by lagoonal muds. During further transgression the sand in the bar was transported forward across the lagoon, and strong winds locally blew the sand into high dunes. Where streams entered the sea, the valleys were filled with sand. Continued transgression moved the shoreline farther distant, the water deepened, and the predominant material reaching the county was clay and silt.

~~[As the sea regressed across the county, sand again formed bars and dunes, and covered the limestone.]~~ As the shoreline retreated back across the area, the water in local ~~local~~ back-bay lagoons supported a calcareous marine plant and lagoonal fauna, and ~~deposited~~ thin limestone beds formed intermittently as ~~[until]~~ silt and clay filled the lagoon. Then vegetation grew and accumulated until ~~and~~ a reversal of water movement initiated the cycle again. The sea in the first 5 to 10 oscillations did not have an environment suitable to limestone deposition, or water sufficiently deep to bring in a fusulinid fauna, but in the last 5 to 10 oscillations, the marine environment had many minor fluctuations which led to the accumulation of several fossiliferous limestones and interbedded very fissile, black, organic shales.

A long period of erosion separates Middle Pennsylvanian time from Late Pennsylvanian time, and an unknown thickness of strata was removed and the material redistributed. Sand locally filled the small topographic depressions left at the end of that time, but in most of Wilson County the materials furnished to the transgressing sea were of clay and silt size. During the 5 to 10 million years of Late Pennsylvanian time (Missourian and Virgilian Series) recorded in Wilson County the sea transgressed and regressed across the county many times. Lengths of time encompassed by cycles varied, and during some transgressions the sea was deep and calcareous for long periods, and thick limestones formed. At other times the county lay in a near-shore or shoreline environment for long periods, and thick deposits of sand, accompanied by coal or unfossiliferous shale, formed. Upward movement on the Fredonia anticline and adjacent small structures locally modified the general sequence of deposition throughout this and the earlier part of Pennsylvanian time and led to small areas of thin limestone and shale accumulations and adjacent areas of thick accumulations. Different water depths and distances from land brought about living conditions suitable for the abundant entry into the area by many kinds of marine animal and plant assemblages, and at times provided environments suitable to the formation of mud cracks and oolites, and to the accumulation of thick deposits of these and other calcareous materials, such as unabraded limestone fragments, fossil fragments, crystalline limestone, and vuggy limestone. This calcareous debris combined with the fauna and flora to form distinctively different limestone units. The last marine sedimentation recorded in Wilson County is the relatively clear, shallow-water, calcareous deposition represented by the Plattsmouth Limestone Member of the Oread Limestone.

No record of sedimentation is preserved in Wilson County for the more than 200 million years included in Permian, Triassic, Jurassic Cretaceous, and most of Tertiary time. In Cretaceous time, ~~[illegible]~~ peridotite magma intruded Pennsylvanian strata in sheetlike bodies at several levels at the northern border of the county.

In late Tertiary time a stream that headed in the Flint Hills area to the northwest of Wilson County flowed eastward to the longitude of Wilson County and then turned southward and flowed across Wilson County along a strike valley west of the Stanton Limestone. There, thick accumulations of chert gravel were left upon the upper surface of the Stanton. Almost concurrently, another stream that originated somewhat farther south flowed eastward and southward into the northwestern part of Wilson County and left remnants of chert gravel high on the Oread escarpment.

Early in Pleistocene time the easternmost of the two south-flowing streams was diverted out of the Wilson County area to a position east of the Stanton escarpment by upward movement on the Fredonia anticline and headward erosion of a stream that lay to the east (the present Neosho River). Meanwhile, the other south-flowing stream was also diverted southeastward along the north flank of the rising Fredonia anticline and a third major stream entered the western part of Wilson County south of the axis of the Fredonia anticline. At times of maximum flow in the Pleistocene Epoch the two southeastward-flowing streams in the county area cut downward ~~2 or 4 times~~ and left chert-gravel remnants on the bedrock of the older valley floors. Uplift on the Fredonia anticline shifted the streams progressively away from the anticlinal axis, and each succeeding chert gravel deposit formed at a relatively lower level farther north on the north flank and farther south on the south flank than the preceding deposit. The remnants of these deposits contain an increasing amount of locally derived material with decreasing antiquity, which suggests that local relief changed from a near level plain in early Pleistocene time to about 200 feet in late Pleistocene time. During Recent time relatively steep-sided canyons continued to be cut in areas of outcrop of thick limestone deposits; where argillaceous strata of low resistance to erosion were crossed, the wide valleys with broad floodplains seen today formed along the river courses.

## Economic geology

The mineral resources of Wilson County include oil and gas, coal, cement, brick and tile, crushed rock, agricultural lime, and sand and gravel. The value of Wilson County's mineral production in 1958 exceeded $7 million. Of this total, cement was valued at greater than $5 million; brick and tile were estimated at $700,000; oil and gas accounted for more than $600,000; crushed stone and agricultural lime amounted to almost $600,000; sand and gravel was valued at about $4,000; and coal was not reported. Most of these data were published by Schoewe (1959), but his figure for clay in the Wilson County total (Schoewe, 1959, p. 250) was for raw clay, not for the finished product. The brick and tile figure used herein was estimated from average daily production and sales prices for brick and tile plants active in Wilson County.

## Fuels resources

The fuels resources of Wilson County are principally oil and gas, but coal has been mined in quantity in the southeastern part of the county. Oil and gas production has been mainly from the eastern half of the county. The value of the fuels produced to June 1959 is estimated at more than 10 million dollars. This figure may be considerably below the actual value, because early production figures for gas are practically nonexistent, and the projection of cost data for both oil and gas is necessarily based upon tenuous evidence (see text Table 2). Oil and gas production data since 1948 are shown in Table 3, and are an indication of the value of the petroleum industry in Wilson County.

Table 1. Statistical summary of fuels resources activities in Wilson County, 1893-1959.

Table 2. Oil and gas production by field in Wilson County, 1948-1958.

SEE TABLES LIST.

Table 2--Statistics of fuels resources activities in Wilson County, 1893-1959

| Year | Oil production, bbl | Gas production, M cu ft | Value of petroleum products, dollars | No. of oil wells producing Jan. 1 | No. of gas wells producing Jan. 1 | Cumulative oil production (recorded), bbl | No. of oil wells drilled | No. of gas wells drilled | No. of repressuring or disposal wells drilled | No. of dry holes drilled | No. of unreported wells estimated drilled | Total wells drilled |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1893 | 10,000 | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1894 | 20,000 | ------- | ------- | ---- | ---- | --------- | 34 | 8 | -- | 61 | -- | 103 |
| 1895 | 21,000 | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1896 | 63,000 | ------- | ------- | ---- | ---- | --------- | 32 | 6 | -- | 35 | -- | 73 |
| 1897 | 44,000 | ------- | ------- | 54 | ---- | --------- | 2 | 2 | -- | 1 | -- | 5 |
| 1898 | 40,000 | ------- | ------- | 64 | ---- | --------- | ---- | 3 | -- | --- | -- | ---- |
| 1899 | 38,000 | ------- | ------- | 65 | ---- | --------- | 4 | 3 | -- | 7 | -- | 14 |
| 1900 | 38,000 | ------- | ------- | 78 | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1901 | 38,000 | ------- | ------- | 100 | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1902 | 104,210 | ------- | ------- | 162 | --- | --------- | 22 | -- | -- | 12 | -- | ---- |
| 1903 | 50,000 | ------- | ------- | 227 | --- | --------- | 250* | -- | -- | --- | -- | ---- |
| 1904 | 100,000 | ------- | ------- | ---- | --- | --------- | 100 | 70 | -- | 41 | -- | 211 |
| 1905 | 85,000 | ------- | ------- | ---- | --- | --------- | 36 | 24 | -- | 16 | -- | 76 |
| 1906 | 80,000 | ------- | ------- | ---- | --- | --------- | 7 | 48 | -- | 26 | -- | 81 |
| 1907 | 70,000 | ------- | ------- | ---- | --- | --------- | ---- | 47 | -- | 10 | -- | 57 |
| 1908 | 50,000 | ------- | ------- | ---- | --- | --------- | ---- | 66 | -- | 21 | -- | 87 |
| 1909 | 33,000 | ------- | ------- | 198 | --- | --------- | ---- | 89 | -- | 24 | -- | 113 |
| 1910 | 30,000 | ------- | ------- | 196 | --- | --------- | 1 | 80 | -- | 27 | -- | 108 |
| 1911 | 30,000 | ------- | ------- | 193 | --- | --------- | 2 | 65 | -- | 27 | -- | 94 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1912 | 43,000 | ------- | ------- | 170 | ---- | --------- | 18 | 86 | -- | 52 | -- | 156 |
| 1913 | 53,000 | ------- | ------- | 169 | ---- | --------- | 40 | 54 | -- | 45 | -- | 139 |
| 1914 | 80,000 | ------- | ------- | 198 | ---- | --------- | 27 | 12 | -- | 20 | -- | 59 |
| 1915 | 70,000 | ------- | ------- | 177 | ---- | --------- | 6 | 13 | -- | 4 | -- | 23 |
| 1916 | 76,000 | ------- | ------- | 162 | ---- | --------- | 63 | 3 | -- | 2 | -- | 68 |
| 1917 | 208,000 | ------- | ------- | 225 | ---- | --------- | 137 | 21 | -- | 22 | -- | 180 |
| 1918 | 290,000 | ------- | ------- | ---- | ---- | --------- | 251 | 22 | -- | 28 | -- | 301 |
| 1919 | 220,000 | ------- | ------- | ---- | ---- | --------- | 158 | 12 | -- | 33 | -- | 203 |
| 1920 | 350,000 | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1921 | 305,000 | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1922 | 147,000 | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1923 | 110,000 | ------- | ------- | ---- | ---- | --------- | 17 | 11 | -- | 17 | -- | 45 |
| 1924 | 99,000 | ------- | ------- | ---- | ---- | --------- | 58 | 15 | -- | 44 | -- | 117 |
| 1925 | 126,000 | ------- | ------- | ---- | ---- | --------- | 23 | 20 | -- | 62 | -- | 105 |
| 1926 | 93,686 | ------- | ------- | ---- | ---- | --------- | 34 | 21 | -- | 52 | -- | 107 |
| 1927 | 83,959 | ------- | ------- | ---- | ---- | --------- | 20 | 9 | -- | 7 | -- | 36 |
| 1928 | 74,000 | ------- | ------- | ---- | ---- | --------- | 59 | 11 | -- | 20 | -- | 90 |
| 1929 | 61,134 | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1930 | 56,098 | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1931 | 57,848 | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1932 | 51,097 | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1933 | 60,000 | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1934 | 62,000 | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1935 | 89,317 | ------- | ------- | ---- | 800* | --------- | ---- | -- | -- | --- | -- | ---- |
| [illegible] | [illegible] | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1937 | 145,000 | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | |
| 1938 | 135,000 | ------- | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1939 | 130,000 | 734,880 | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1940 | 122,000 | 687,886 | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1941 | 106,247 | 517,605 | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1942 | 86,157 | 463,954 | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1943 | 55,714 | 417,748 | ------- | ---- | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1944 | 75,745 | ------- | ------- | 126* | ---- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1945 | 79,088 | ------- | ------- | 308* | --- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1946 | 90,356 | ------- | ------- | 371* | --- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1947 | 77,281 | ------- | ------- | 188* | --- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1948 | 69,976 | ------- | ------- | 176* | --- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1949 | 64,944 | 148,722 | ------- | 157* | --- | --------- | ---- | -- | -- | --- | -- | ---- |
| 1950 | 71,005 | 532,369 | ------- | 146* | 171 | 5,206,901 | ---- | -- | -- | --- | -- | 112* |
| 1951 | 68,974 | 110,845 | ------- | ---- | 49 | 5,275,875 | ---- | -- | -- | --- | -- | 100* |
| 1952 | 67,271 | 185,316 | ------- | 32* | 15* | 5,343,146 | ---- | -- | -- | --- | -- | ---- |
| 1953 | 70,438 | 191,642 | ------- | 109* | 46* | 5,413,584 | 4 | -- | -- | 46* | -- | 50* |
| 1954 | 186,514 | 175,517 | 545,276 | 431 | 69* | 5,600,098 | 192* | 2 | -- | 96* | -- | 290* |
| 1955 | 187,047 | 242,776 | 554,178 | 465 | 72* | 5,787,145 | 116* | -- | 10 | 54* | -- | 182* |
| 1956 | 172,836 | 280,135 | 518,213 | 492 | 60* | 5,959,981 | 54* | -- | 40 | 32* | -- | 126* |
| 1957 | 188,935 | 205,668 | 602,653 | 537 | 59 | 6,148,916 | 45* | 2 | 10 | 27* | -- | 84* |
| 1958 | 194,251 | 265,265 | ------- | 623 | 34 | 6,343,167 | 10 | -- | -- | 1 | 91 | 102 |
| 1959 | 206,834 | 125,486 | ------- | 679 | 28 | 6,550,001 | 30 | -- | 19 | -- | 77 | 126 |

Data mainly from Annual Reports of the U.S. Geological Survey; Kansas Geological Survey Mineral Resources Circulars; Moore and Haynes, 1917; Moore and Boughton, 1921; Jewett, 1949; Ver Wiebe and others, 1948-1955; Goebel and others, 1956-1960.

-Denotes no data available.

*Denotes declared estimate.

Table 3. Oil and gas production by field in Wilson County, 1949-1958

| | 1949 | | 1950 | | 1951 | | 1952 | | 1953 | | 1954 | | 1955 | | 1956 | | 1957 | | 1958 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oil prod. bbls | Gas prod. M cu ft | Oil prod. bbls | Gas prod. M cu ft | Oil prod. bbls | Gas prod. M cu ft | Oil prod. bbls | Gas prod. M cu ft | Oil prod. bbls | Gas prod. M cu ft | Oil prod. bbls | Gas prod. M cu ft | Oil prod. bbls | Gas prod. M cu ft | Oil prod. bbls | Gas prod. M cu ft | Oil prod. bbls | Gas prod. M cu ft | Oil prod. bbls | Gas prod. M cu ft |
| Altoona | 2424 | ---- | 3121 | ---- | 1935 | ---- | 1840 | ---- | 5470 | ---- | 15847 | ---- | 18809 | ---- | 31651 | ---- | 27017 | ---- | 37647 | ---- |
| Altoona East | 3869 | ---- | 3671 | ---- | 3521 | ---- | 3635 | ---- | 11184 | ---- | 8810 | ---- | 7360 | ---- | 5960 | ---- | 5512 | ---- | 4818 | ---- |
| Altoona-Earlton | ---- | ---- | ---- | 115468 | ---- | 47494 | ---- | ---- | ---- | 90318 | ---- | 92698 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Benedict | 1453 | ---- | 922 | ---- | 623 | ---- | 518 | ---- | 472 | ---- | 25265 | ---- | 22191 | ---- | 13050 | ---- | 9409 | ---- | 7454 | ---- |
| Buffalo | 3770 | ---- | 4263 | 307000 | 7151 | ---- | 6475 | ---- | 17773 | ---- | 51603 | ---- | 46415 | ---- | 36556 | ---- | 35901 | ---- | 24869 | ---- |
| Buxton | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 1207 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Coyville | 110 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Coyville West ("Harvey") | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 1804 | ---- | 681 | ---- | 1145 | ---- | 949 | ---- | 810 | ---- |
| Fall River | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 196 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Fredonia | 4284 | ---- | 5406 | ---- | 5299 | ---- | 4628 | ---- | 4204 | ---- | 12720 | ---- | 10370 | ---- | 8060 | ---- | 7101 | ---- | 6653 | ---- |
| Humboldt-Chanute | 1278 | ---- | 1253 | ---- | 2079 | ---- | 3116 | ---- | 2037 | ---- | 2842 | ---- | 2832 | ---- | 1965 | ---- | 1806 | ---- | 1619 | ---- |
| Neodesha | 36327 | ---- | 40234 | 90384 | 36258 | 54845 | 32932 | ---- | 13069 | 41483 | 49805 | 27523 | 61127 | ---- | 69983 | ---- | 97417 | ---- | 106339 | ---- |
| Neodesha East | ---- | ---- | 328 | ---- | 835 | ---- | 744 | ---- | 506 | ---- | 618 | ---- | 238 | ---- | 677 | ---- | 572 | ---- | 149 | ---- |
| "Stryker" | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 1402 | ---- | 223 | ---- | 75 | ---- | ---- | ---- | ---- | ---- |
| Vilas | 7146 | ---- | 6210 | ---- | 5912 | ---- | 6316 | ---- | 5628 | ---- | 6164 | ---- | 6128 | ---- | 3041 | ---- | 2236 | ---- | 1759 | ---- |
| "Wiggins" | 4253 | ---- | 5597 | ---- | 5361 | ---- | 7067 | ---- | 8650 | ---- | 8533 | ---- | 9425 | ---- | * | ---- | * | ---- | * | ---- |
| Miscellaneous | 30 | 148722 | ---- | 19517 | ---- | 8506 | ---- | 185316 | 238 | 59841 | 905 | 55296 | 1260 | 242776 | 671 | 280135 | 1015 | 205668 | 2134 | 265265 |

From Ver Wiebe and others, 1950-1955; and Goebel and others, 1956-1959.

* Combined with Altoona.

More than 10,000 wells are estimated to have been drilled for oil and gas in Wilson County. Most of them were drilled with cable-tool rigs similar to that shown at the top of figure ~~57~~ 35. In the last few

Figure 35 reaches here

~~Figure 57. Cable-tool and rotary rigs in Wilson County, Kans.~~

years portable rotary rigs (fig. ~~57~~ 35, B) have become more common place. Records of about 8,000 wells were collected and used in the preparation of this report. The locations and types of major production of most of these wells are shown on ~~figure 58~~ Plate 9. Of those shown, approximately

~~Figure 58. Petroleum Resources map of Wilson County.~~

one-fourth are oil wells, one-half are gas wells, and one-fourth are dry holes. The ratio of dry holes to producers is about 1 to 3. Pipelines that carry crude oil, petroleum products, and gas across the county are shown also, as well as gas storage reservoirs, and areas of secondary recovery projects.

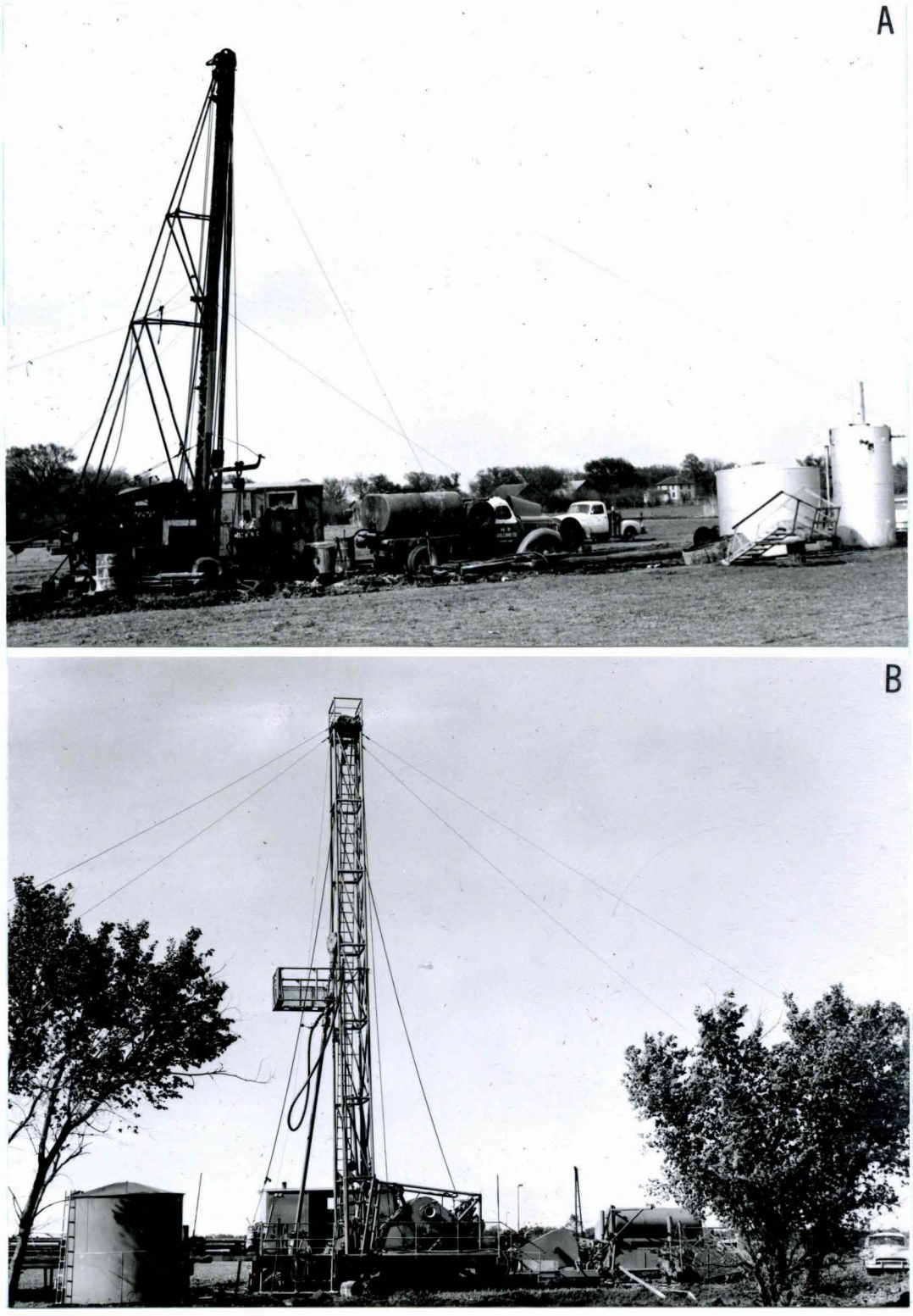



FIGURE 35.--Cable-tool and rotary rigs in Wilson County. (A) Cable-tool rig drilling on Holland lease in SW$\frac{1}{4}$ sec. 34, T 30 S, R 16 E. (B) Rotary rig drilling on Martin lease in SW$\frac{1}{4}$ sec. 10, T 29 S, R 17 E.

History of petroleum development in Wilson County

In a sense, the discovery of oil and gas in Wilson County began the history of Midcontinent oil, because it was from the Neodesha discoveries that the southeast Kansas field, and ultimately the great Midcontinent field itself, developed. Although oil had been found in Miami County many years earlier, the discovery and subsequent development and production in Wilson County signaled the beginning of an era of continuous discovery and production equalled in few other areas of this country.

The history of petroleum development in Wilson County began, according to F. W. Blackmar (1912, p. 923), with the suggestion by George W. Chase in 1888 that oil and gas were to be found there. Chase endeavored to interest the citizens of Neodesha in prospecting for petroleum, but no known action was taken by the local group. In the latter part of 1892, W. M. Mills of Osawatomie, Kans., secured a franchise from the Neodesha City Council to supply its people with natural gas (Morgan, 1902, p. 887), and he made several unsuccessful attempts to lease land within the town limits of Neodesha. Finally, in mid-October of 1892, a lease was signed with T. J. Norman, giving Mills the right to drill on the Norman property in the eastern part of Neodesha on the banks of the Verdigris River (Allen, 1959). With little delay, Mills, on October 28, spotted the location (Smiley, 1931a, p. 99), and drilling operations began November 6, 1892, near the southeast corner of sec. 20, T. 30 S., R. 16 E. On November 25 the drillers, C. L. Bloom and R. P. Bryson, drilled through a gas sand into an oil sand, and on November 28, 22 feet into the sand at a depth of 835 feet, the hole began to fill with oil. The fact that oil had entered the hole was not publicized; the well was capped, and another attempt to find gas was made in the SE¼NE¼SW¼ sec. 19, T. 30 S., R. 16 E., on the J. K. DeMoss farm on the south bank of a bend of the Fall River about 1 mile west of the No. 1 Norman well. This well also began to fill with oil, and on January 12, 1893, it too was capped, and Mills left immediately for the East, where he succeeded in interesting the Pittsburgh firm of J. M. Guffey and J. H. Galey in the enterprise (Haworth, 1908, p. 29). They came to Neodesha and began securing

leases in the name Guffey, Galey, and Mills and announced that the wells contained considerable oil sand. The search for gas had now become a search for both oil and gas, and on June 12, 1893, the third well, which proved to be a good gas well, was completed. This, the first gas well in Wilson County, was drilled on the J. J. Haag farm in the NE¼ sec. 14, T. 30 S., R. 15 E., about 3 miles northwest of Neodesha on the banks of the Fall River (Morgan, 1902, p. 887, 888).

Almost a year had elapsed, and neither of the wells drilled by Mr. Mills had been shot or production obtained. On August 5, 1893, however, the No. 1 DeMoss was shot with a strong charge of dynamite, and two months later (October 4, 1893), the discovery well, the No. 1 Norman, was shot. Thirty quarts of nitroglycerin, the explosive usually employed in the eastern oil fields, was set off at depths of 805 and 817 feet in the Norman well (Smiley, 1931b, p. 99) which started flowing at 371 barrels a day. Production soon dropped to 12 barrels a day, however (Smiley, 1931a, p. 15), and settled down to about 5 barrels. The amount gradually dwindled to about half a barrel a day, and this amount was still being produced 25 years later, in 1917, when water broke through the casing and the well had to be plugged and abandoned (Smiley, 1931b, p. 100). The No. 1 DeMoss was put on the pump February 28, 1894, thus becoming the first oil well pumped in the Midcontinent field (Smiley, 1931b, p. 99). During the summer of 1893, drilling proceeded slowly and resulted in 2 gas wells and 13 oil wells, all near Neodesha (Morgan, 1902, p. 888).

The years 1894 and 1895 saw the exit of Mr. Mills, the expansion of work by the Guffey and Galey interests, and the entry of the Forest Oil Company into the picture. On February 3, 1894, Mills sold his interest to Guffey and Galey for $4,000 (Smiley, 1931b, p. 99) and returned to Osawatomie. In the meantime, Guffey and Galey had been actively leasing, and by the middle of 1894 they had acquired about 700,000 acres of leases in the vicinity of Neodesha, had completed 5 wells, 4 of which were shot lightly, and had fitted them for pumping. They pumped an average of 12 barrels a day each, the crude being stored in two large steel tanks with a total capacity of 70,000 barrels (Morgan, 1902, ~~p. 887-890~~, and Weeks, 1894, p. 511). By the end of 1894, 34 oil wells with initial productions of 10 to 35 barrels per day were in operation (Weeks, 1895, p. 375). In addition, 8 gas wells and 61 dry holes had been drilled, making the year's total 103 wells (Bright, 1956, p. 445). Additional storage tanks were added, and in 1895 Guffey and Galey found themselves with 150,000 barrels of oil in storage, an actual production of 800 barrels daily in the Neodesha pool, and 21 wildcat producers widely scattered elsewhere, good for perhaps 1,000 barrels more (Smiley, 1931b, p. 100). At about this time the Forest Oil Company, a subsidiary of the Standard Oil Company (~~U. S. Geol. Survey, 17th Ann. Rept. pt. III~~ (Weeks, 1896, p. 699; ~~Min. Res. of U. S., 1893~~; and Haworth, 1908, p. 207), set up their Kansas Division and on October 30, 1895, bought out the interests of Guffey and Galey (Weeks, 1896, p. 699) for $225,000 cash. The deal included 65 oil wells, 12 gas wells, and 212,341 acres of leases. Thirty-two more oil wells were completed in 1896 (Oliphant, 1897, p. 847), and by

January 1, 1897, two more large storage tanks had been erected at Neodesha and held about 250,000 or 300,000 barrels of crude oil (Morgan, 1902, p. 889). The need to furnish an outlet for this oil had become so acute by then that the Standard Oil Company decided to erect a refinery at Neodesha, the first refinery in the Midcontinent field. On February 15, 1897, construction began, and on May 11, 1897, the first batch of crude oil was charged to the stills which had a capacity of 500 barrels of crude per day (Smiley, 1931b, p. 100). The next several years proved this capacity to be inadequate to the supply, and in 1902, two more stills were added (Johnson, 1903, p. 334). The capacity was thus increased to 1,000 barrels, which was soon exceeded by the supply, and in 1904, the capacity was increased to 5,000 barrels (Douglas, 1910, p. 138, and Bright, 1956, p. 446).

Meanwhile, the Prairie Oil and Gas Company had been organized and incorporated under the laws of Kansas for the express purpose of taking over the Forest Oil Company's western holdings, and on January 1, 1901, the transaction was completed. More than 100 producing oil wells, a dozen gas wells, and the refinery with its pipelines and tanks thereby came under the ownership of the Prairie Oil and Gas Company.

Prices paid for crude oil, which averaged about 85 cents per barrel when Prairie took over, rose during the first few years to $1.38 per barrel in 1903. In the latter part of 1903, the Prairie Oil and Gas Company, for the purpose of grading oils, drew an arbitrary east-west line through the middle of Wilson and Neosho Counties, and classed all oils north of the line as heavy oils and those south of the line as light oils. Light oils, of gravity 32° ~~degrees~~ Baumé or higher, brought several cents more per barrel than heavy oils, and producers in the northern part of the county began to look elsewhere for production. Later, Prairie began buying strictly on a gravity basis, and graded all oils of 32° Bé and upward in one class, but graded those below 32° Bé in several classes on a sliding scale. In buying the heavier oils (less than 32° Bé), they deducted a few cents per barrel for each half degree Bé or fraction thereof. This grading action, combined with a drop in price in 1904, resulted in the premature abandonment of many oil fields in the northern part of the county, a condition which continued until the time of World War I.

Gas, on the other hand, began a period of expansion in about 1904, partly due to increasing use in manufacturing and partly due to the entry into this field of an energetic and competitive company. According to Bright (1956, p. 444):

> "In 1904 real gas development of the southeastern Kansas field was organized by the Kansas Natural Gas Company, a concern initiated by T. N. Barnsdall, of Pittsburgh, Pennsylvania, using $12,000,000 of eastern capital. By 1906, through consolidation of local holdings, excepting a few local companies, the Kansas Natural Gas Company controlled the output of the Kansas field, centering its supplies at Altoona, just north of Neodesha in Wilson County, and at Dearing, south of Independence in Montgomery County. Pipe lines were laid into the Joplin, Missouri mining district, and north to Topeka, Lawrence, Kansas City, Leavenworth, and Atchison. By 1906 a population of over 1,000,000 was being served by this company."

The search for gas between 1906 and 1913 resulted in the completion of 535 new producing gas wells, an average of 67 each year (Moore and Haynes, 1917, p. 203).

Interest in oil and gas decreased during the early part of the World War I period, but picked up in 1917, oil again becoming the prime target of the drillers. Increased activity continued for several years, but during the period 1914-1917 large discoveries were made farther west in Kansas, and the large companies concentrated more and more of their efforts in the areas of Greenwood, Butler, Harvey, and Sedgwick Counties. The days of the big companies in Wilson County passed, and the small operators, who had contributed continually from the beginning, but had been in the background almost out of sight, came to the fore, and have maintained the role of petroleum in the county's economy to the present.

## Oil production

Oil has been produced continually in Wilson County since August 1893 and has amounted to more than 6 million barrels (see Table 2). The bulk of the production has been from the lenticular sandstone units of the Cherokee group. These sandstones include the "Squirrel sand," the "First Bartlesville sand," and the "Second Bartlesville sand" (see Plate 7 ~~Fig. 41~~). Other oil production has come from a locally developed sandstone bed in the Vilas shale, from the "New Albany sand" of the Chanute shale, from the "Weiser sand" of the Bandera shale, from the "Peru sand" of the Labette shale, and from porous zones at the tops of rocks of Mississippian age and rocks of Ordovician age. As shown on Plate 9, ~~figure 58~~ oil production has come largely from the eastern part of the county. In some areas the pools are only partly controlled by structure, and form trends similar to but not as distinct as those reported on occur along by Bass (1936) in Greenwood and Butler Counties. Thickness studies in many wells indicate that the sand bodies in Wilson County have biconvex forms which may in part be depositional and in part be due to differential compaction.

Oil produced in Wilson County ranges in gravity from 18° A.P.I. in the "Second Bartlesville sand" to 39° A.P.I. in the "First Bartlesville sand." Strata of different ages generally contain oil of different gravity in the same area, and strata of the same age generally contain oil of different gravity in different areas. A sufficient number of gravity determinations are available on the "First Bartlesville sand" and the "Second Bartlesville sand" to allow generalizations to be drawn concerning the variations in gravity of the contained oil. The "First Bartlesville sand" contains the highest gravity oil, as high as 39° A.P.I. The gravity ranges down to 27° A.P.I. a few miles northeast of Altoona and a few miles northeast of Buffalo (~~see~~ Fig. 36 ~~59~~). A line limiting oil of gravity less than 30° trends irregularly north and east from near Altoona, as shown ~~in~~ on Figure 36 ~~59~~. Oil of gravity greater than 35° is concentrated in the general vicinity of Neodesha.

Figure 36 near here.

~~Figure 59. Gravity of oil in the "First Bartlesville sand" in Wilson County.~~

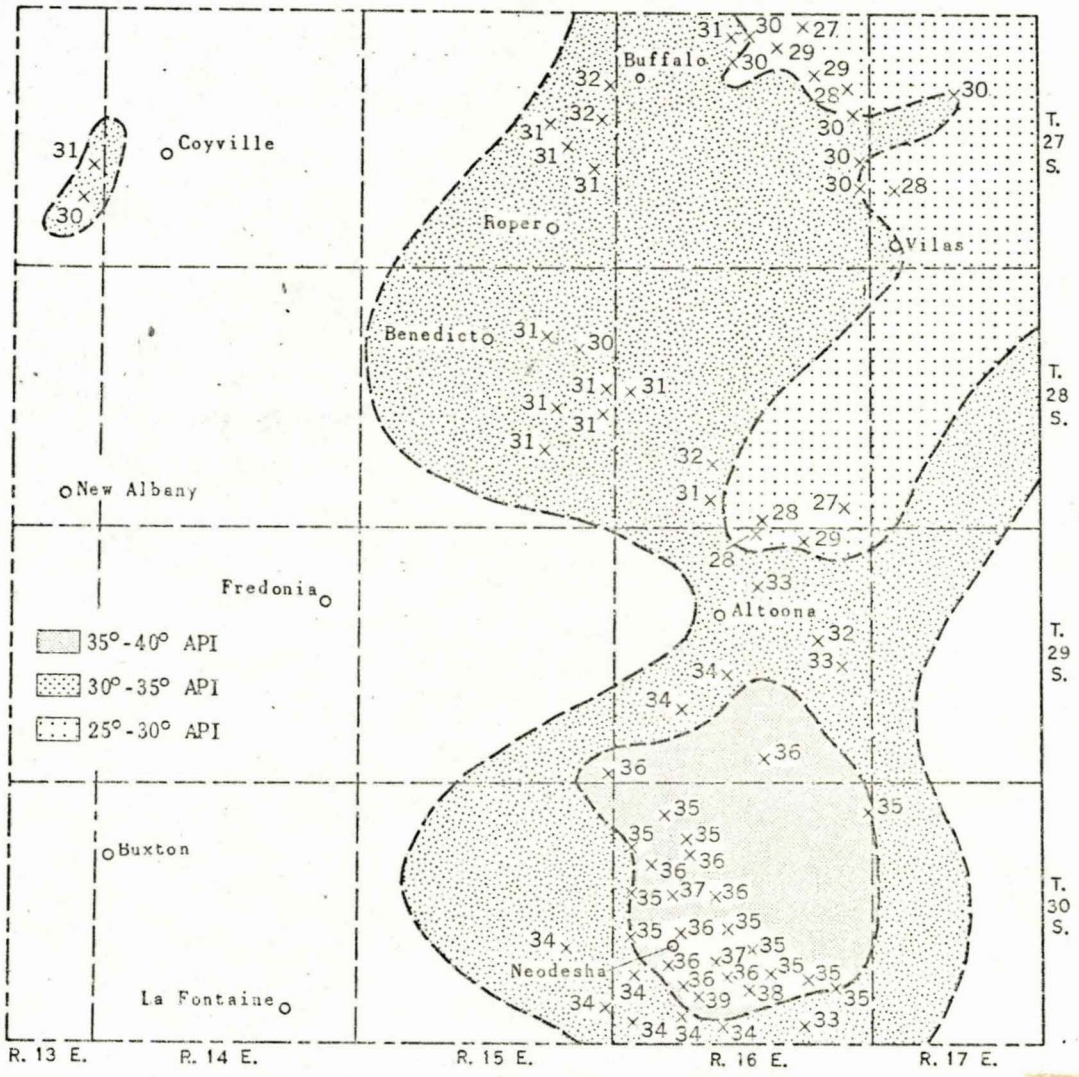



Figure 36.--Gravity of oil in the "First Bartlesville sand" in Wilson County.

Oil from the "Second Bartlesville sand" is much lower in gravity, ranging from 18° to 34° A.P.I. The higher gravity oil is found in the vicinity of Neodesha. The lower gravity oil occurs in the structurally highest areas, and the higher gravity oil generally occurs in structurally low areas (see Fig. 37). Oil gravity readings from the other producing units are not sufficiently numerous to warrant generalizations concerning their variations. A single determination for oil from the sandstone bed in the Vilas shale indicates a gravity of 30° A.P.I. Oil from the "Weiser sand" is generally of low gravity ranging from 23° to 27° A.P.I. Oil from the "Squirrel sand" ranges from 22° to 29° A.P.I. Oil from rocks of Mississippian age ranges in gravity from 19° to 31° A.P.I. The only record for "Arbuckle" oil showed a gravity of 22° Baumé.

Figure 37 near here

Figure 60. Gravity of oil in the "Second Bartlesville sand" in Wilson County.

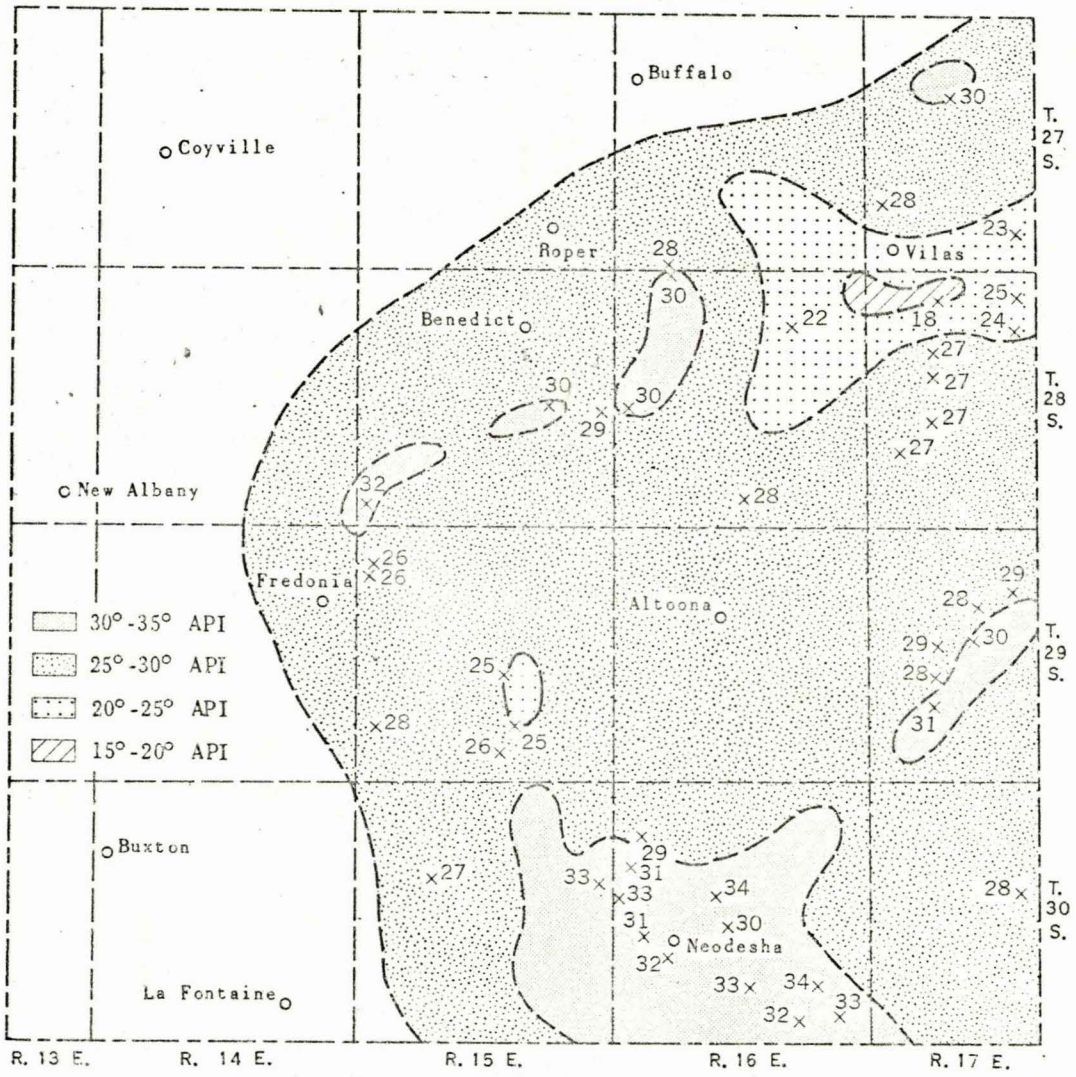



Figure 37.--Gravity of oil in the "Second Bartlesville sand" in Wilson County.

Other physical properties of oil from Wilson County, for which data are available, include specific gravity, thermal value, fractionation products, and viscosity. Calculations for specific gravity of the oils from the "Bartlesville sand" range from 0.835 to 0.924. The oil with the highest specific gravity came from the Benedict field as reported by Haworth (1908, p. 314) and Moore and Haynes (1917, p. 174, 177, 181). Oil from the Guilford field had a heating value of 19,510 B.t.u. per pound and 19.9 percent gasoline by volume at 200° C. A complete fractionation chart for this sample (lab. no. 14) is reported by Whitaker, Campbell, and Estes (1917, p. 181-187) and is shown in Table 4. A few data for four samples from the Neodesha field were reported by Haworth (1898, p. 51; 1908, p. 208).

Table 3. Properties of Wilson County crude petroleum from the Guilford pool.

Table 4.--Properties of crude petroleum from the Guilford Pool, sec. 23, T. 28 S., R. 15 E., Wilson County, Kansas

| Specific gravity @15°C | Baumé gravity @59°F | Viscosity @20°C | Flash point | Fire point | B.T.U. per lb | Sulfur wgt % | Paraffin wgt % | Unsaturated hydrocarbons vol % | Loss on distillation wgt % | Residue wgt % | Fractionation data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Water wgt % | Temperature | Vol % | Wgt % | Sp.gr. @15°C | Baumé @59°F | Refractive index @25°C | Flash point | Fire point | Gasoline vol % |
| .8662 | 31.6 | 3.29 | 5°C 41°F | 7°C 44°F | 19,510 | .10 | 1.06 | 26 | 1.7 | 63.9 | 0.8 | To 150°C (302°F) | 10.5 | 8.3 | .7118 | 66.7 | 1.4123 | Below 0°C 32°F | Below 0°C 32°F | 10.5 |
| | | | | | | | | | | | | 150-200°C (302-392°F) | 9.4 | 8.2 | .7773 | 50.1 | 1.4410 | 24°C 75°F | 27°C 81°F | 19.9 |
| | | | | | | | | | | | | 200-250°C (392-482°F) | 7.8 | 7.0 | .8064 | 43.6 | 1.4579 | 62°C 144°F | 69°C 156°F | ---- |
| | | | | | | | | | | | | 250-300°C (482-572°F) | 10.8 | 10.1 | .8346 | 37.7 | 1.4720 | 88°C 190°F | 96°C 205°F | ---- |

Data from Whitaker, Campbell and Estes, 1917, p. 181-187, sample No. 14.

Everett and Weinaug (1955, p. 197-221) tested certain physical properties of more than 450 samples of eastern Kansas crude oils. The figures for gravity, viscosity, and interfacial tension of the 10 samples from Wilson County are shown in Table 5. The A.P.I. gravity

Table 5 near here

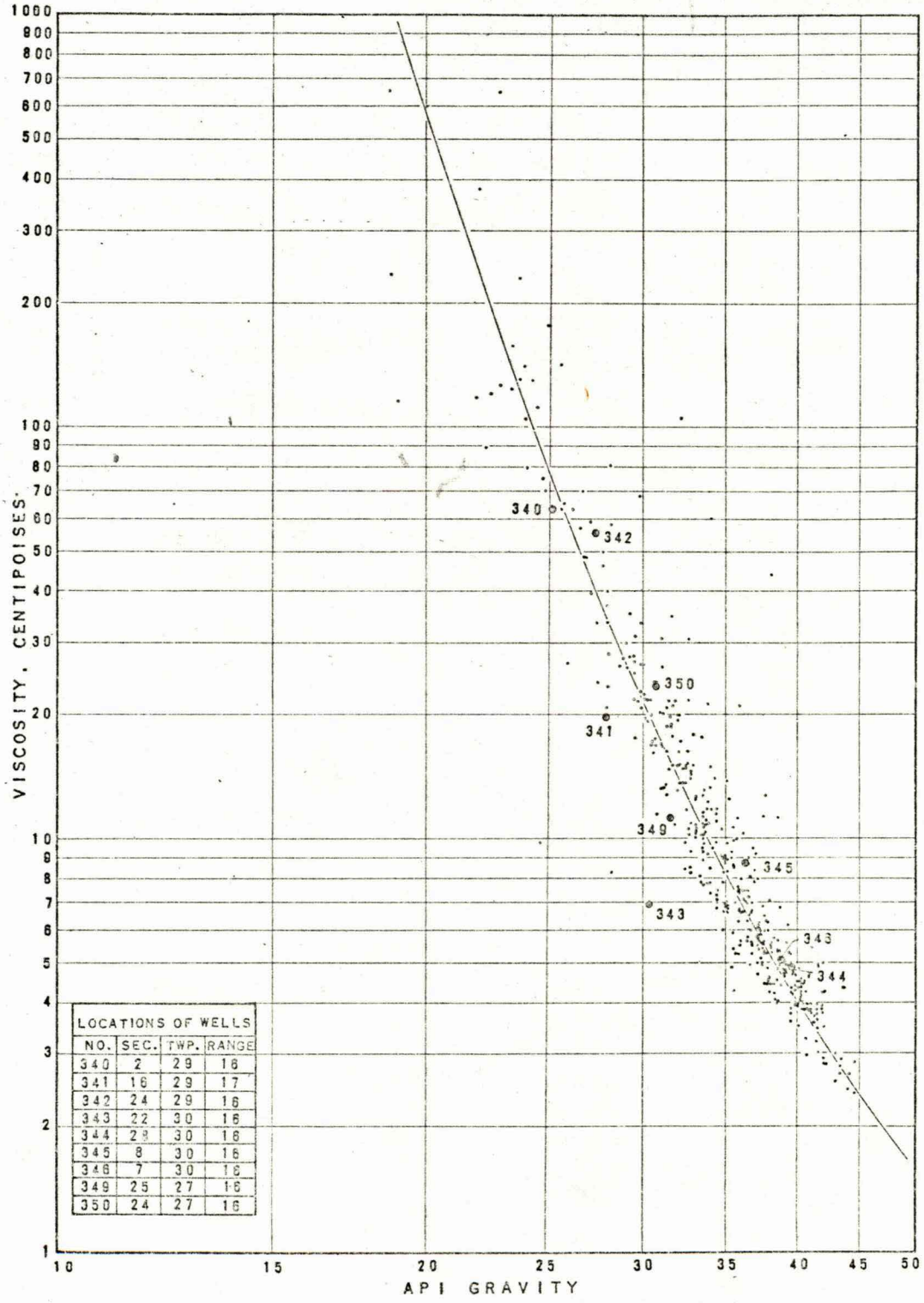
~~Table 4. Physical properties of Wilson County crude oils.~~

has been used to correlate other physical properties, as well as to indicate origin and similarity of crude oils. The gravity of the oil can be used to obtain an approximate value of the viscosity (generally within 10 centipoises) by finding the point of intersection of the A.P.I. gravity and the curve shown on Figure 38. The observation that

Figure 38 near here

~~Figure 61. Graph showing viscosity of "Bartlesville sand" crude oils from Wilson County in relation to other eastern Kansas oils.~~

plotting the gravity against the viscosity of samples obtained from similar formations resulted in no improvement in the correlation of formations led Everett and Weinaug (1955, p. 207) to believe that the general character of all oils in eastern Kansas is very similar. An attempt to correlate interfacial tension measurements with gravity of the oil indicated that there is no apparent correlation between these two physical properties either (Everett and Weinaug, 1955, p. 209). The viscosity of oils from the Altoona field is much higher than for other samples (see Table 5).




| LOCATIONS OF WELLS | | | |
|---|---|---|---|
| NO. | SEC. | TWP. | RANGE |
| 340 | 2 | 29 | 16 |
| 341 | 16 | 29 | 17 |
| 342 | 24 | 29 | 16 |
| 343 | 22 | 30 | 16 |
| 344 | 28 | 30 | 16 |
| 345 | 8 | 30 | 16 |
| 346 | 7 | 30 | 16 |
| 349 | 25 | 27 | 16 |
| 350 | 24 | 27 | 16 |

Figure 38.--Graph showing viscosity of "Bartlesville sand" crude oils from Wilson County in relation to other eastern Kansas oils (at 70° F. and atmospheric pressure). (Data mainly from Everett and Weinaug, 1955, p. 204.)

Table 5. Viscosity and other physical properties of crude oil from Wilson County, Kansas

| Sample No. | Field name | Well location sec Twp. S. Rge. E. | Depth to producing sand ft | Name of producing sand | A.P.I. gravity @ 60°F | Viscosity in centipoises @ 70°F | @ 100°F | @ 120°F | Interfacial tension @60°F dynes/cm |
|---|---|---|---|---|---|---|---|---|---|
| 340 | Altoona | 2-29-16 | 900 | Bartlesville | 25.3 | 63.51 | 29.18 | 19.83 | 33.50 |
| 341 | Neodesha | 16-29-17 | 950 | do | 27.9 | 19.84 | 10.95 | 8.06 | 26.38 |
| 342 | Altoona | 24-29-16 | 950 | do | 27.4 | 55.82 | 25.36 | 17.20 | 31.60 |
| 343 | Neodesha | 22-30-16 | 800 | do | 30.4 | 6.96 | 4.45 | 3.60 | 28.59 |
| 344 | do | 28-30-16 | 800 | do | 39.0 | 4.90 | 3.32 | 2.72 | 33.54 |
| 345 | do | 8-30-16 | 800 | do | 36.3 | 8.76 | 5.29 | 4.37 | 27.60 |
| 346 | do | 7-30-16 | 890-950 | do | 38.7 | 5.12 | 3.48 | 2.83 | 35.60 |
| 347 | Fredonia | 27-29-15 | 1050 | Burgess | ---- | ----- | ----- | ----- | 32.44 |
| 349 | Vilas | 25-27-16 | 900 | Bartlesville | 31.5 | 11.23 | 6.83 | 5.41 | 32.90 |
| 350 | Vilas | 24-27-16 | 1000 | do | 30.6 | 24.15 | 12.83 | 9.73 | 26.51 |

From Everett and Weinaug, 1955, p. 218

Recent data on distillation properties of crude oil from Wilson County were furnished by W. G. Mayhood (personal communication, May 1959). Samples from the "Weiser sand," the "Squirrel sand," the "First Bartlesville sand," and the "Second Bartlesville sand" were distilled, and the A.P.I. gravity, viscosity, and distillation temperatures were determined (see Table 6). These data make possible

Table 6 near here

~~Table 5. Physical properties of crude oil from Wilson County.~~

the comparison of Wilson County crude oils with stocks from elsewhere in the United States. This is done on the basis of the "Characterization Factor" of the oil, which is defined (Nelson, 1941, p. 77) as the specific gravity of the oil (at 60° F) divided into the cube root of the temperature (degrees Fahrenheit absolute). Characterization Factors calculated for Wilson County crudes are: "Weiser sand" 11.6, "Squirrel sand" 11.2, "First Bartlesville sand" 11.6, and "Second Bartlesville sand" 11.4. Typical Characterization Factors for various stocks are (Nelson, 1941, p. 77):

| | |
|---|---|
| Paraffin hydrocarbons | 12.7 |
| Pennsylvania stocks | 12.2-12.5 |
| Midcontinent stocks | 11.8-12.0 |
| Gulf Coast stocks | 11.0-11.5 |
| Cracked gasolines | 11.5-11.8 |
| Cracking plant feeds (combined) | 10.5-11.5 |
| Recycle stocks | 10.0-11.0 |
| Cracked residuums | 9.7-11.0 |
| Benzene | 9.8 |

By permission from "Petroleum Refinery Engineering", by Nelson, Copyright, 1941, McGraw-Hill Book Company, Inc.

Table 6.--Distillation data and other physical properties of crude oil from Wilson County, Kansas

| Sample No. | Location of well sec. Twp. S. Rge. E. | Distillation data | | | | | | | | Character-ization factor | A.P.I. gravity (uncorr.) | Water & sediment Vol. % | A.P.I. gravity (corr.) | Specific gravity | Viscosity S.S.U. 100°F | Sulfur wt % | Field name | Depth to producing sand, ft | Name of producing sand |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Initial °F | 10 ml °F | 50 ml °F | 90 ml °F | Max. E.P. °F | Recovery % | Loss % | Residue % | | | | | | | | | | |
| 1 | 26-29-16 | 140 | 256 | 582 | 696 | 696 | 96 | 1 | 3 | 11.6 | 35.5 | 4.0 | 36.6 | .842 | 45 | .25 | Neodesha | 490-500 | Weiser |
| 2 | 35-28-16 | 240 | 340 | 670 | --- | 720 | 85 | 1 | 14 | 11.2 | 30 | 0.5 | 30 | .876 | 86 | .37 | Altoona | 670-680 | Squirrel |
| 3 | 7-30-16 | 126 | 220 | 572 | 728 | 734 | 94 | 1 | 5 | 11.5 | 35.7 | Trace | 35.7 | .847 | 45 | .58 | Neodesha | 918-942 | Second Bartlesville |
| 4 | 26-28-15 | 180 | 280 | 640 | --- | 732 | 91 | 1 | 8 | 11.5 | 31.3 | 5.0 | 37.0 | .840 | 74 | .26 | Benedict | 950-960 | do |
| 5 | 7-30-16 | 250 | 364 | 650 | 720 | 732 | 93 | 1 | 6 | 11.4 | 29 | Trace | 29 | .882 | 90 | .29 | Neodesha | 1044-1056 | do |
| 6 | 27-30-16 | 110 | 210 | 550 | 708 | 708 | 96 | 1 | 3 | 11.6 | 38.3 | Trace | 38.3 | .833 | 42 | .21 | do | 758-778 | First Bartlesville |
| 7 | 28-30-16 | 130 | 220 | 530 | 712 | 734 | 98 | 1 | 1 | 11.7 | 37.2 | 4.0 | 38.3 | .833 | 41 | .24 | do | 795-810 | do |
| 8 | 29-30-16 | 118 | 220 | 554 | 750 | 760 | 94 | 1 | 5 | 11.8 | 38.6 | Trace | 38.6 | .831 | 40 | .20 | do | 795-815 | do |
| 9 | 29-30-16 | 130 | 240 | 558 | 746 | 752 | 96 | 1 | 3 | 11.6 | 35.9 | Trace | 35.9 | .845 | 42 | .21 | do | 800-820 | do |
| 10 | 8-30-16 | 168 | 290 | 610 | --- | 694 | 84 | 1 | 5 | 11.4 | 34.8 | 2.0 | 36.0 | .845 | 49 | .39 | do | 810-830 | do |

As thus designated, crude oils tested from the "Squirrel sand" and from the "Second Bartlesville sand" fall into the range of Gulf Coast stocks, and oils from the "Weiser sand" and from the "First Bartlesville sand" are nearer to Gulf Coast stocks than to Midcontinent stocks. The gravity and boiling points of these same crude oil samples when compared with graphed samples (see Fig. 62) Figure 39 near here indicates that Wilson County crudes fall in the mixed-base category, and that those from the "Weiser sand" and "First Bartlesville sand" have mainly paraffin-base affinities, whereas those from the "Squirrel sand" and "Second Bartlesville sand" have mainly asphalt-base affinities.

Figure 62. Comparison of A.P.I. gravity and boiling point of crude oils from Wilson County with national averages. After figure 80 in "Petroleum Refinery Engineering", by W.L. Nelson, New York, McGraw-Hill Book Company, 1941.

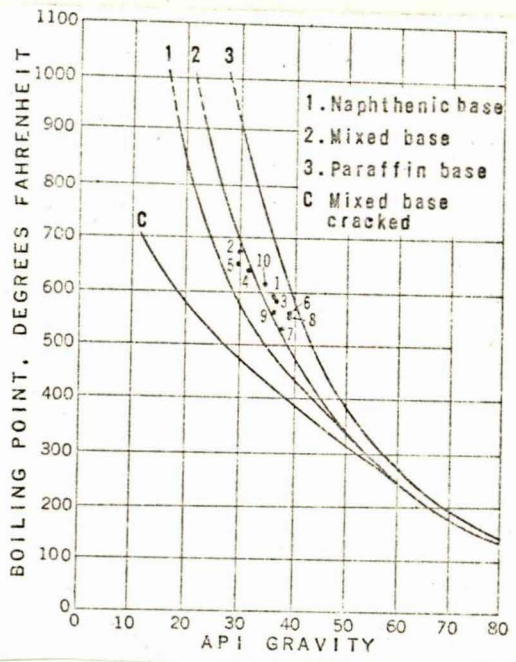



Figure 39.--Comparison of API gravity and boiling point of crude oils from Wilson County with national averages. Locations and other data for samples 1 to 10 are given in table 6. Chart after figure 20 in "Petroleum Refinery Engineering," by W. L. Nelson, New York, McGraw-Hill Book Company, 1941.

Production of oil is dependent to a large degree upon the permeability and porosity of the sandstone or other rocks in which the oil accumulated and from which it must be removed. Furthermore, in secondary recovery operations it is important to know the expectable rate of movement of fluid through the rock and the number of barrels of oil recoverable per acre. The permeability and porosity of the rocks are utilized in calculating these data and, because of the wide variation in permeability between the different strata, and even within any one stratum, tests must generally be run on samples taken in each well or area under consideration.

Of the sandstone units for which data are available (see Table 8), the "Second Bartlesville sand" had the highest maximum permeability (334.0 md), the "First Bartlesville sand" had the lowest minimum permeability (0.012 md), and the "Third Bartlesville sand" had the greatest average permeability (116.8 md). However, the latter figure was based upon only two readings. The "First Bartlesville sand" had the highest maximum porosity (23.0 percent), the "First Bartlesville sand" and the "Second Bartlesville sand" each had the same lowest minimum porosity (12.2 percent), and the "Second Bartlesville sand" had the greatest average porosity (17.8 percent). The average porosity of all the sandstone units tested was 17 percent. Tests on two samples of the "Mississippi lime" show it to have a much lower permeability and porosity than the sandstones (see Table 8).

Table 7. Permeability and porosity of strata in the subsurface of Wilson County, Kansas

| Producing zone tested | Permeability, md. | | | | Porosity, % | | | |
|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Ave. | No. readings | Min. | Max. | Ave. | No. readings |
| "Wayside sand" | 19.7 | 19.7 | 19.7 | 1 | 16.9 | 16.9 | 16.9 | 1 |
| "Weiser sand" | 3.1 | 37.3 | 16.3 | 6 | 15.7 | 18.9 | 17.3 | 8 |
| "Peru sand" | 5.9 | 5.9 | 5.9 | 1 | 15.2 | 15.2 | 15.2 | 1 |
| "Squirrel sand" | 1.6 | 34.9 | 21.0 | 7 | 16.1 | 19.7 | 17.5 | 8 |
| "First Bartlesville sand" | 0.012 | 275.0 | 37.0 | 66 | 12.2 | 23.0 | 16.9 | 70 |
| "Second Bartlesville sand" | 1.0 | 334.0 | 44.4 | 78 | 12.2 | 22.0 | 17.8 | 81 |
| "Third Bartlesville sand" | 59.9 | 173.7 | 116.8 | 2 | 15.6 | 19.4 | 17.5 | 2 |
| "Mississippi lime" | 0.3 | 0.8 | 0.6 | 2 | 5.2 | 11.4 | 7.9 | 3 |

Data largely from Oilfield Research Laboratories, Chanute, Kansas

Relation of oil accumulation to structure and stratigraphy.--Oil accumulation is related both to structure and to stratigraphy. Many of the oil pools are located near the tops of structural highs, but most of the pools appear to be slightly off-structure, generally to the west or northwest (see ~~fig. 53~~ Plate 8). This relationship probably reflects tilting of previously formed structures into which oil had already migrated and been trapped. As a result of such tilting, the former crests of the structural highs migrated westward. In reservoirs with strong gas pressure, readjustment to the new top of the high seemingly was almost complete; in others, the movement was slight. Oil on the flanks of structures of very low relief, such as in the vicinity of Neodesha, apparently readjusted only slightly.

Oil in distinct linear trends, such as those in R. 17 E., apparently occurs in shoestring-type sandstone bodies. The control is primarily stratigraphic, the oil being held in the body by the enclosing shale despite structural modifications; but generally, differential compaction below and above such bodies has produced a slight structural high in the overlying rocks. A nearly circular trend of oil production in the northeastern part of the county may be related to such bar-type sandstone accumulation in "First Bartlesville" time but not at other times. Thus, of much economic importance in oil exploration in Wilson County is knowledge of both the time and the place a shoreline of the Pennsylvanian sea remained relatively stationary for a considerable period because at such times thick sand bars were able to form in certain places, or erosion was able to cut deep channels into which sand could accumulate. In the outcropping and subsurface Pennsylvanian rocks of Wilson County, seven such periods of sand accumulation are represented, and although the effects are relatively local in this county, they may be of significance downdip to the west.

The stratigraphic record shows that in early Lawrence time (Ireland Sandstone Member), early Stranger time (Tonganoxie sandstone Member), and middle Chanute time (Cottage Grove Sandstone Member), part of the area of Wilson County was dry land and was being eroded. During these periods channels were cut into the underlying, newly deposited strata, were filled with sand-size debris, and were covered by shale. The thickest deposits of the Ireland Sandstone Member of the Lawrence Shale trend generally north-south along the west edge of the county. The deposits may, however, represent three separate valleys cut in east-west directions rather than a single north-south meandering channel. Several sheet-type sandstone bodies comprise the upper part of the Ireland, but are thin and relatively unimportant for oil accumulation in Wilson County.

of the Stranger Formation, a channel-filling sandstone,
The Tonganoxie sandstone member is fairly coarse-grained and channel-filling only in the west-central and possibly the northwestern parts of the county. Elsewhere the debris is poorly sorted and too fine-grained to make an effective reservoir. Similar variations probably occur in the subsurface to the west. In the Cottage Grove of the Chanute Shale,
sandstone member, the lower sand apparently filled a small structural basin that extended into the county from the east. Data from drillers logs suggest that deep channels were filled by 50 to 100 feet of sand of the Cottage Grove ("New Albany sand") both southeast of Vilas and southward from a few miles east of Fredonia to the Wilson-Montgomery county line. A fairly persistent blanket-type accumulation of "New Albany sand" seems to occur generally in the western part of the county north of New Albany, north and east of Fredonia, and east of Buxton and LaFontaine.

Preliminary study of other sands in the subsurface shows a sandstone trend in the Galesburg shale from Buxton northeast to Altoona. In the Bandera shale the "Weiser sand" is thick along an arcuate belt from about midway between Neodesha and Buxton, northeast to Altoona, and then southeast and south to the corner of the county. In the Cherokee group a trend of thickest "Squirrel sand" goes from Benedict westward a few miles, and then northeast to the north of Buffalo and into Woodson County. It then swings southeast into the northeastern part of Wilson County and southwest past Vilas a few miles before again swinging south toward the south line of the county. The "First Bartlesville sand" in the northeastern part of the county has a similar shape, but is more nearly circular. This trend is about a mile west of the "Squirrel sand" trend. Structural highs along the "First Bartlesville sand" trend have not been adequately tested. The "Second Bartlesville sand" and "Third Bartlesville sand" apparently accumulated more nearly as blanket-type deposits, but local elongate accumulations of the "Second Bartlesville sand" occur near the east line of the county.

Secondary recovery.--Lenticular, shoestring-type sandstone deposits lend themselves [~~well~~] to secondary recovery operations, and in Wilson County such operations have been in progress for more than 20 years. Permits for 23 water-flood projects and 1 salt water disposal project have been issued (as of January 1960) by the State Corporation Commission, the first [being] having been issued in April 1938. The locations are shown ~~in figure 58~~ on Plate 9. Sixteen of the water-flood projects have been in sandstone units of the "Bartlesville" zone, two have been in the "Squirrel sand," and one has been in the "Wayside sand" (~~see~~ Table 8).

Table 8 near here

~~Table 7. Water-flood and salt water-disposal projects in Wilson County.~~

Table 8.--Water-flood and salt-water disposal projects in Wilson County, Kansas

| Field or pool | Operator | Project | Location Sec., Twp. S., Rge. E. | Date of Application | Date of Approval | Type of project | Producing zone | Depth to zone | Fluid injected | Proposed amount of input, bbls | Proposed pressure, lbs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Altoona | Crest Oil and Gas Co. | Mullen | 21-29-16 | 9/4/59 | 11/24/59 | Water flood | First Bartlesville | 809-814 | Salt water | 20-50 | 30-300 |
| do | Howard W. Fleet | Stover | 3 2-28-17 | 11/15/58 | 1/20/59 | Salt water disposal | Second Bartlesville | 944-992 | do | 35-150 | Gravity |
| do | Virgil Gamble | Post & Watson | 34-28-16 | 7/17/57 | 8/5/57 | Water flood | Squirrel | 671-685 | do | 5-75 | 0-325 |
| do | Keas Pipeline Co. | Gibson Est., etc. | 35-28-16 & 1 & 2-29-16 | 11/15/57 | 1/10/58 | do | do | 650-680 | do | 0-100 | 0-375 |
| do | McLaughlin and Springer (Neff) | Davidson unit | 29,32, & 33-28-16 & 4-29-16 | 10/10/56 | 11/14/56 | do | First Bartlesville | 886-901 | do | 0-150 | 0-450 |
| Altoona East | Frank A. Harvey | Ben Martin | 9-29-17 | 8/21/56 | 9/19/56 | do | Second Bartlesville | 843-868 | do | 100-150 | 0-420 |
| Benedict | Shamrock Reconditioners | Morton | 24-28-15 | 8/25/59 | 10/29/59 | do | do | 945-958 | Fresh water & salt water | 0-75 | 0-470 |
| Buffalo | Fidelity Petroleum Co. | Long | 23 & 24-27-15 | 4/8/54 | 4/28/54 | do | First Bartlesville | 910-920 | Salt water | 0-25 | 0-500 |
| Buffalo NE | Aylward and Willis | Apt, Johnson, etc. | 34-26-16 & 2 & 3-27-16 | 9/8/54 | 9/29/54 | do | do | 961-984 | do | 30-70 | 0-500 |
| do | Ward Edinger | Apt, Martin, etc. | 33,34, & 35-26-16 & 2,3, & 4-27-16 | 3/20/58 | -------- | do | do | 960-985 | do | 60-70 | 0-500 |
| Buffville | Goering, Hedrick, et al. | Scudder, Louia, Maneval, & Coltrain | 34-29-16 | 6/25/57 | 8/19/57 | do | Weiser | 475-500 | do | 20-150 | 0-300 |
| do | do | do | 34-29-16 | 6/25/57 | 8/19/57 | do | First Bartlesville | 822-852 | do | 20-150 | 0-300 |
| Fredonia | Inland Oil Inc. | Porter Auten | 30 & 31-28-15 | 9/8/53 | 9/30/53 | do | Second Bartlesville | 1046-1056 | do | 25-200 | 0-35 |
| Neodesha | Nicholas Sage | Phillips & Redington | 26-30-16 | 9/28/59 | 12/2/59 | do | First Bartlesville | 750-795 | do | 25-200 | 100-800 |
| do | Noble Oil Co. (Nelson) | Clegg | 28-30-16 | 4/17/59 | 10/29/59 | do | do | 785-796 | Fresh water | 10-150 | 0-800 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Neodesha East | Willis, Davis, and Mitchell | Dickens & Sapp | 15-30-17 | 10/30/56 | 11/20/56 | do | Second Bartlesville | 930-940 | Salt water | 20-100 | 50-450 |
| Thayer | --- | Campbell & McDonald | 9-29-17 | -------- | 4/15/38 | do | do | 830-880 | do | ------ | ------ |
| do | --- | Johnson, Garten, & Twedell | 16-29-17 | -------- | 5/2/38 | do | do | 825-850 | do | ------ | ------ |
| do | Gillilan and Carr | Martin & McDonald | 9 & 16-29-17 | -------- | 1/10/42 | do | do | 825-850 | do | ------ | 450-550 |
| do | Keas Drilling Co. | Winter, Woods, Johnson, & Garten | 16,17, & 20-29-17 | 1/14/54 | 3/8/54 | do | do | 825-877 | do | 2-140 | 0-400 |
| do | Pingrey and Griffith | Woods | 17-29-17 | -------- | 4/20/42 | do | do | 830-870 | do | ------ | ------ |
| Vilas | Nolan Oil and Gas Co. and Pray Drilling Co. | Larsen, Butler, Hultin, & Helmick | 19-27-17 & 24-27-16 | 10/23/42 | 11/17/42 | do | First Bartlesville | 960-1020 | do | 10-200 | 0-250 |
| Volunteer | Thomas E. Berry | Van Camp | 27,28, & 34-29-15 | 1/-/56 | 7/-/56 | do | Second Bartlesville | 1162-1180 | do | 60-200 | 0-200 |
| Wiggans | Ensminger and Martin (Schermerhorn) | Wiggans, etc. | 8,17,20,29 & 30-28-17 | 7/31/57 | 8/26/57 | do | do | 950-980 | do | 0-200 | 0-500 |

From State Corporation Commission files, Wichita, Kans.

A detailed report on the Gillilan and Carr project in secs. 9 and 16, T. 29 S., R. 17 E. was included in a history of water-flooding of oil sands in Kansas by Grandone (1944, p. 141-144, and tables 1-7) and is typical of most such operations in the county. Before application of water-flooding, the area under lease had been virtually depleted of oil recoverable by primary methods. The cumulative production at the end of 3 years of secondary recovery operations was 507 barrels per acre. The first increase in the rate of oil production as a result of water injection occurred 7 months after the initiation of water-flooding. All wells were shot with nitroglycerin by using 1 quart per foot of sand in the input wells and total charges of 40 to 80 quarts in the sand section of producing wells. The sand averaged about 25 feet in thickness. Water was injected at pressures of 450 to 550 pounds per square inch measured at the well heads, and oil was produced by pumping (Grandone, 1944, p. 142-143). An extension of this water-flood was put into operation in March 1954 by the Keas Drilling Co. In the first 4 years of operation, about 145,000 barrels of oil were produced.

Oil refining.--Refining of oil in Wilson County began in 1897 when the storage of oil above ground, and the lack of transportation facilities, made necessary the installation of a refinery within reach of this growing producing area. Neodesha was then the hub of Mid-continent oil production and was a logical choice as the site of the first refinery in the Midcontinent region. Thus, on February 15, 1897, the Standard Oil Co. of Kansas began construction of a 500-barrels per day refinery at Neodesha (P. E. Moon, written communication, May 8, 1959). The refinery consisted of 2 crude stills, 1 steam still, 1 agitator, a pump house and tanks. The first crude was charged to the stills in May 1897 and was distilled by the "Batch Process" into refined oils, naphtha, and fuel oils. During 1897 and 1898 a very close relation was maintained between the refining company and the Forest Oil Co., the major producer, such that no more oil was produced than the refinery wished to handle (Haworth, 1899, p. 10). In 1898, 88,000 barrels of refined oil was marketed (Haworth, 1899, p. 10, 45). In 1899 the refinery reported a total consumption of 85,215 barrels (42 gallons each) of crude oil, from which the operators obtained 29,972 barrels (50 gallons each) of refined oil, and 5,880 barrels (50 gallons each) of naphtha and gasoline, with a residue of 33,000 barrels (42 gallons each) of fuel oil (Haworth, 1900, p. 38). By 1902 control of the production was impossible, pipelines were extended as far as Chanute and Humboldt, and the capacity of the refinery was doubled to 1,000 barrels per day (Haworth, 1903, p. 36; Oliphant, 1904, p. 557). In 1904 the capacity was increased to 2,500 barrels with 10 stills in operation

(Williams, 1904). There were then about 150 tanks in the tank farm, each with a capacity of 33,000 to 60,000 barrels of crude. In 1914 two more batteries of crude and coke stills and 40 Burton shell pressure stills were added, and in 1916, 20 Burton tube stills and another battery of crude stills were built (Moon, written communication, May 8, 1959). In 1916, 7,500 barrels of oil were refined (Moore and Haynes, 1917, p. 380). By 1919 the capacity had been increased to 12,000 barrels (Moore and Boughton, 1921, p. 32), and in the next 2 years two batteries of atmospheric pressure stills, 20 more Burton shell stills, and 40 Burton tube stills were built, and two batteries of coke stills were converted to continuous operation. These expansions were necessitated by better transportation of crude oil to the refinery from areas to the west and south. The first Holmes-Manley unit was built in 1927, and in 1932 a second unit as well as other thermal cracking facilities and a modern gas recovery plant were constructed.

In 1932 the refinery was purchased by the Standard Oil Company of Indiana and began utilizing crude oils from outside Kansas. By 1937 the gathering system had been greatly enlarged, refrigerated storage had been added for the light gasolines, and the cracking unit had been rebuilt to a two-furnace unit with soaking drums. In 1949 a naphtha reformer unit was added making the operation a three-furnace cracking unit. Expansion to a crude running capacity of 19,700 barrels per day was begun in January 1951, and crude runs were increased to that amount in February 1952. Pipeline capacity was increased to 17,000 barrels per day of oil, and new equipment included a stacked reactor-type Foster-Wheeler catalytic cracking unit with its own vapor recovery unit and alkylation unit. The cracking unit was designed to charge 9,000 barrels per day of gas oil and to operate at about 55 percent conversion. The alkylation unit had a capacity of approximately 1,100 barrels per day of aviation alkylate (P.E. Moon, written communication, May 8, 1959). In 1958 construction was completed on a 6,000 barrel Ultraformer and a 6,000 barrel Hydrofining unit (Schoewe, 1958, p. 211), and in 1959 the crude capacity of the Neodesha refinery was reported as 23,100 barrels per calendar day and 24,300 barrels per stream day (Oil and Gas Journal, ~~v. 57, no. 14, March 30,~~ 1959, p. 123).

Several smaller refineries operate in towns in adjacent counties, and because of the wide variation of the crude oils from Wilson County, much of its crude is refined in the smaller refineries. Refineries of the Chanute Refining Co. and the Mid-America Refining Co., Inc., at Chanute in Neosho County take the bulk of the Wilson County crude, but some oil in the southern part of the county is taken to the Cooperative Refinery Assn. refinery at Coffeyville, in Montgomery County. In 1958, the Mid-America Refining Co., Inc., added 15,000 barrels per day to its crude capacity and 400 barrels per day to its asphalt capacity at its Chanute refinery (Schoewe, 1959, p. 258).

## Gas production

Wilson County has been an active gas producing region since 1893, and in the past 65 years nearly 50 billion cubic feet of gas are estimated to have been obtained from reservoirs at depths ranging from 200 to 1,500 feet. Undoubtedly much gas was lost, and possibly only 35 billion cubic feet have been marketed. On the basis of average sale prices for different periods of production, the gas is estimated to have had a value of somewhat more than $1 million.

The presence of gas in considerable quantity in Wilson County was recognized at least as early as May 1874 when a strong flow of gas was struck at 120 feet by a party of well diggers drilling for stock water about 2 miles southeast of Benedict. An account of this event, written by J. S. Gilmore, is of considerable historical interest and is reproduced here (Wilson County Citizen, June 12, 1874):

"On Wednesday, May 27th, the usual quiet and repose of the village of Guilford was startled by a report scarcely excelled by a heavy cannon, and followed by a violent shaking of the earth, extending beyond the limits of the valley. The minds of the rural population were filled with doubts as to the cause of this sudden alarm, but on visiting the mill pond of Akin and Bros., where a party of well diggers were drilling for water, the cause of the shock became evident, and no fears of a repetition of the recent manifestations in North Carolina were entertained. The gentlemen engaged in drilling a stock well on the premises of the above, having reached a depth of 120 feet, all at once noticed the drill descend about six inches, evidently meeting with no obstruction, and at once a deep rumbling sound, like heavy thunder, came forth from the well, and drove the person who was tending the drill (at a depth of 27 feet, being at the bottom of an excavated well) to the surface, anticipating that a vein of water had been struck, which would at once fill the well to overflowing. Having reached the top, the drill was immediately withdrawn, but no water becoming visible, the drill was again lowered,

and a few strokes given, but the noise became so terrific that all operations were suspended. A slight odor was emitted from the well, and the conclusion that something inflammable was escaping, induced the gentlemen to test its burning qualities. A match was at once lighted on the edge of the well, and had hardly commenced to burn when the report and shock that has been described took place, and the adventurous well digger, with whiskers, eyebrows and hair missing, lay at some distance from the well, evidently meditating upon the peculiarity of combustibles. A solid column of flame shot up from the well at least 40 feet and continued to burn, attended with that same rumbling sound that at first indicated the presence of something escaping from the well. It continued to burn brightly until extinguished by several buckets of water thrown in the well. On visiting the spot the next morning the noise still continued, and another application of a match at a much greater distance from the well than at first, was attended with similar results. A column of flame would burst forth from the well from 30 to 40 feet in height and be followed by a shock that would be plainly felt at a distance of one hundred yards. An idea of the rapidity that the gas was generated may be obtained from the fact that every 15 minutes during the whole day, on lighting a paper and throwing it towards the surface of the well, a similar report and shock took place. At last it took fire at the mouth of the drill hole and burned brightly until extinguished by a heavy rain on Sunday night that followed. No water in any

quantity has appeared. The noise has ceased, and the usual quiet again 'reigns around'."

The presence of gas was not capitalized upon at that time, and another 20 years elapsed before wells were drilled for gas in the area.

The first commercial gas well drilled in Wilson County was located on the J. J. Haag farm in sec. 14, T. 30 S., R. 15 E., on the banks of the Fall River. The well was completed to a total depth of 980 feet on June 12, 1893, in four sandstone units that occurred in the position of the "First Bartlesville sand" and "Second Bartlesville sand" between 843 ~~feet~~ and 980 feet. All the sandstone beds contained gas, the third sandstone at 908 to 922 feet showed a little oil. By 1898 good fields had been established near Neodesha and Benedict, and by 1905 Wilson and Montgomery Counties had become the two richest gas fields in the Midcontinent area (Haworth, 1908, p. 213). Gas in both the Vilas and Fredonia fields had been developed by 1907, and wells ranging from 2 to 30 million cubic feet were being brought in near Vilas, and many ranging from 3 to 5 million cubic feet were completed just east of Fredonia (Haworth, 1908, p. 225-226). These wells were all "sand gas" wells drilled into the "Bartlesville sand" of the Cherokee group. "Shale gas" did not become a prime target for drilling until about 1921, when new "sand gas" wells had become relatively rare and when a simple and cheap device for separating the gas and salt water became generally available. "Shale gas" wells, although of smaller production than "sand gas" wells, were slower to decline. The promise of long life, low cost of operation, small percentage of dry holes, and the fact that as much as 70 percent of the open flow could be taken without injury to the well, made "shale gas" wells a good economic investment at that time (Charles and Page, 1929, p. 367).

Analyses of four samples of "shale gas" from Wilson County are given in Table 9. Several samples of town supply and "sand gas" wells

Table 8. Composition of natural gas from Wilson County.

in Wilson County were also analyzed (see Table 9). The average methane content of all samples analyzed was 91 percent; ethane averaged 3 percent. The total paraffins averaged 94 percent, and the heating value averaged 1,020 B.t.u. per thousand cubic feet.

Table 9.--Composition of natural gas from Wilson County, Kansas

| Sample No. | Location of sample | Date sampled | Methane $CH_4$ % | Ethane $C_2H_6$ % | Total paraffins $CH_4+C_2H_6$ % | Olefins $C_2H_4$ etc. % | Hydrogen $H_2$ % | Helium He % | Carbon Dioxide $CO_2$ % | Carbon Monoxide CO % | Nitrogen $N_2$ % | Oxygen $O_2$ % | Heating value, BTU | Specific gravity | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Near Chanute, Kans. | 10/23/05 | 98.00 | 0.00 | 98.00 | ---- | 0.00 | ----- | 0.00 | 0.00 | 1.88 | 0.12 | ---- | ----- | Composite from several wells |
| 9 | Wells 2 to 7 miles east, south, & northwest of Fredonia, Kans. | -------- | 82.25 | 0.00 | 82.25 | 0.12 | 0.00 | 0.616 | 0.61 | 0.00 | 16.40 | Trace | ---- | ----- | Fredonia town supply; depth 1080-1250 ft; rock pressure 300-440 lbs. |
| 10 | Neodesha, Kans. | 6/27/06 | ----- | ---- | ----- | ---- | ---- | 0.106 | ---- | ---- | ----- | ----- | ---- | ----- | Some air in sample |
| 16 | Wells in Eson District in SE Wilson Co. | -------- | 91.90 | 3.37 | 95.27 | 0.00 | 0.00 | 0.27 | 0.72 | 0.00 | 3.74 | Trace | ---- | ----- | Parsons town supply |
| 27 | New Albany, Kans. | 7/25/06 | 89.10 | 0.00 | 89.10 | 0.25 | 0.12 | 0.49 | 0.20 | 0.00 | 9.84 | 0.00 | ---- | ----- | ----- |
| 28 | Altoona, Kans. | 7/25/06 | 92.00 | 2.85 | 94.85 | 0.00 | 0.00 | 0.263 | 0.92 | 0.00 | 3.97 | 0.00 | ---- | ----- | ----- |
| 31 | Buffalo, Kans. | 7/28/06 | 96.20 | 0.78 | 96.98 | 0.00 | 0.18 | 0.27 | 0.00 | 0.11 | 2.46 | Trace | ---- | ----- | Sample from well inside of town |
| A | West Chanute Field, Wilson Co. | -------- | 94.3 | 4.2 | 98.5 | ---- | ---- | ---- | 0.7 | ---- | 0.3 | ----- | 1025 | .5683 | "Sand-gas" sample |
| B | do | -------- | 86.5 | 9.0 | 95.5 | ---- | ---- | ---- | 0.3 | ---- | 4.2 | ----- | 1031 | .6166 | "Shale-gas" sample |
| C | do | -------- | 89.7 | 6.0 | 95.7 | ---- | ---- | ---- | 0.5 | ---- | 3.8 | ----- | 1009 | .6025 | do |
| D | do | -------- | 93.3 | 4.7 | 98.0 | ---- | ---- | ---- | 0.6 | ---- | 1.4 | ----- | 1021 | .5870 | do |
| E | do | -------- | 89.7 | 6.2 | 95.9 | ---- | ---- | ---- | 0.6 | ---- | 3.5 | ----- | 1014 | .6030 | do |
| F | Neodesha, Kans. | -------- | 90.56 | ---- | ---- | 0.22 | ---- | ---- | 1.00 | 0.50 | 7.07 | 0.65 | ---- | ----- | ----- |

Data on samples 2, 9, 10, 16, 27, 28, & 31 from Haworth, 1908, p. 266-270; samples A, B, C, D, & E from Charles and Page, 1929, p. 371; sample F from Haworth, 1908, p. 229

During the development of the gas-producing area of Wilson County, gas occurrence was recorded on the well log as the well was drilled. Upon completion of the well, production was commonly obtained from one or more horizons above the major producing zone, as well as from that zone. In establishing the important gas-producing horizons in each area, the deepest producing zone was assumed to be the major producer; in many wells the nearest gas-bearing units up the hole contributed to the total gas flow. In preparing gas production maps, the area in which the stratigraphic unit being mapped was possibly a contributor is included within the bounding lines. This is particularly true of the area of production from the Fort Scott limestone ("Oswego lime").

A very close relationship exists between gas accumulation and structural configuration in Wilson County. Thus, within the limits of structural contouring based upon the data available, major gas production is in structurally high areas (see Plate 8 ~~see fig. 53~~). In the eastern part of the county four of every five sections have had substantial gas production, but all of the fields have now (1959) been depleted to the stage of production for local use only. Twenty-two horizons, the shallowest at about 200 feet and the deepest at about 1,500 feet, have been productive (see Plate 7 ~~see fig. 41~~).

Gas storage.--Gas was first stored in natural reservoirs in Wilson County in April 1942 near Buffalo by the Union Gas System. In August 1949 Union began storage in a second natural reservoir near Fredonia. The Buffalo unit includes about 560 acres, and in 1958 had an ultimate capacity of about 255,000,000 cubic feet of gas at 81 pounds gage pressure; at the Fredonia unit the area is about 750 acres with an ultimate capacity of about 380,000,000 cubic feet at 89 pounds pressure. Storage at Buffalo is in the Iola Limestone at about 190 feet depth; at Fredonia the "New Albany sand" is used at 240 to 270 feet depth. The Iola Limestone is the more permeable formation. At Buffalo 30 wells were drilled and plugged before conversion to gas storage; at Fredonia only 23. There are 13 input wells and 7 observation wells at the Buffalo unit; at Fredonia there are 11 input wells and 7 observation wells (C. W. Studt, personal communication, June 1959).

## Oil and gas fields

Descriptions of the oil and gas fields, including areas of oil production, areas of gas production, depths to producing horizons, history of drilling, initial production, and rock pressures at the time of initial production in the fields established by the Kansas Nomenclature Committee (~~see~~ Fig. ~~63~~ 40), add to the record of the development of the Wilson County part of the Midcontinent field. In areas as large as the Fredonia or Neodesha fields, a producing zone, because of the regional westward dip of the strata, may be 200 or more feet deeper in the western part of the field than in the eastern part. Thus, the vertical distance of the producing horizon below a stratigraphic datum such as the Fort Scott limestone ("Oswego lime") is the important measurement in correlating producing zones.

Figure 40 near here

~~Figure 63. Limits of oil and gas fields of Wilson County as established by the Kansas Nomenclature Committee.~~

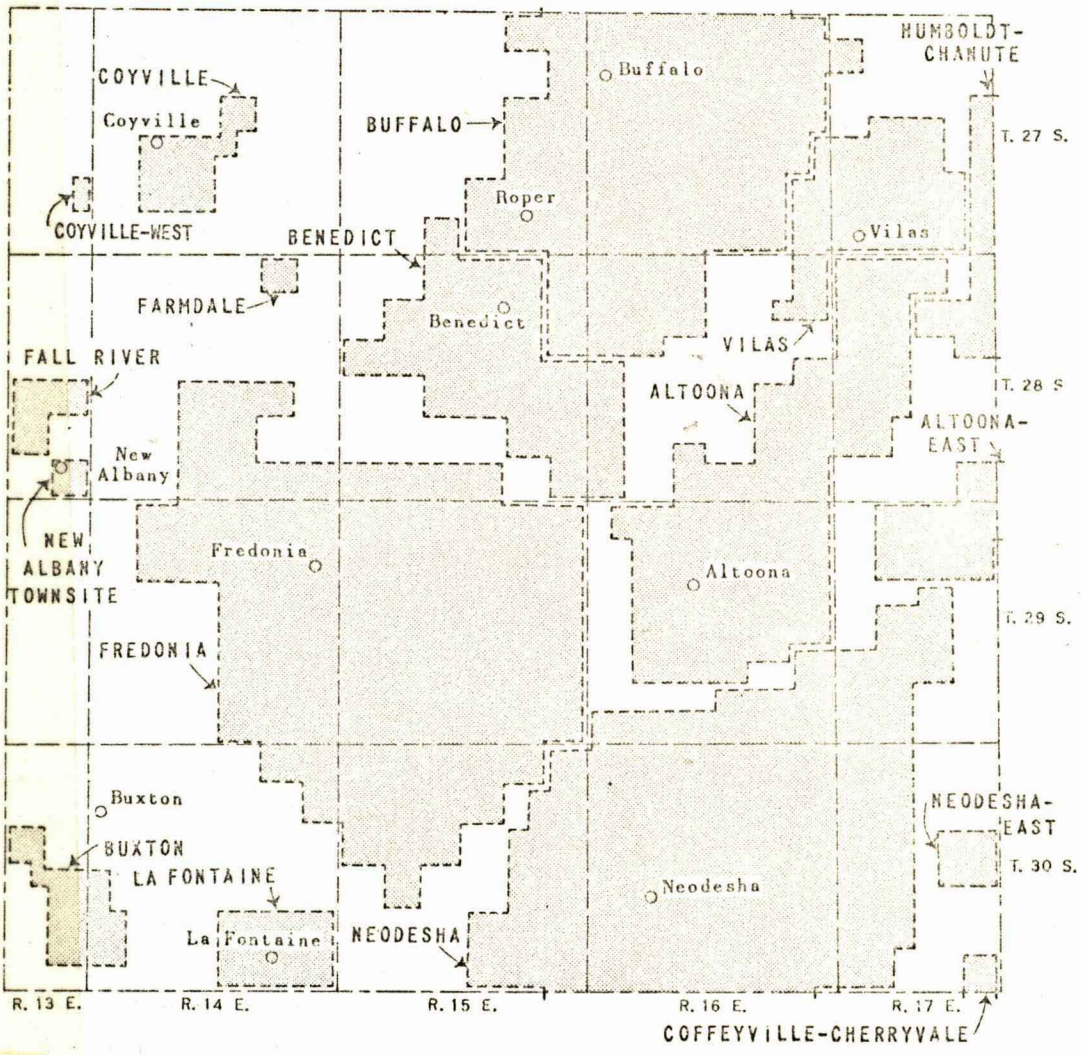



Figure 40.--Limits of oil and gas fields of Wilson County as established by the Kansas Nomenclature Committee.

## Altoona oil and gas field

Oil.--Possibly the first oil well recorded in Wilson County lies in the Altoona field. Edwards (1881, p. 41) records a "coal oil well" in the SE¼NE¼ sec. 27, T. 29 S., R. 16 E., on the C. W. Prange farm near the south line of the field. No total depth or other data are available for this well, however, and the Norman well at Neodesha is the undisputed first commercial well in the county.

Oil was discovered in the Altoona field near the turn of the century, and by 1907 (Haworth, 1908, pl. XIX) four oil pools had been developed. The largest lay just southwest of town across the Verdigris River; another was just northwest of town; another at the northeast corner of town; and the fourth about a mile northeast of town. Production was from the "First Bartlesville sand" between 800 and 850 feet depth in 5 to 20 feet of sand. Later discoveries extended production from the "First Bartlesville sand" to the northeastern part of the Altoona field, where exploration resulted in significant production from the "Second Bartlesville sand" also. Production from the "Squirrel sand" came from three pools northeast of Altoona. Production from the "Weiser sand" has been obtained only from the extreme southwestern corner of the field (see Plate 10 ~~fig. 64~~, A, C, D, and E).

Figure 64. Maps showing areas of oil production in Wilson County--by producing horizons.

Production from the "Second Bartlesville sand" was mainly from the "Wiggins pool" in secs. 17 and 20, T. 28 S., R. 17 E., in sand from 25 to 35 feet thick at depths between 900 and 1,000 feet. The pool was discovered in 1936, was developed ~~rather~~ slowly, and in 1958 had about 40 producing wells. Total production to 1958 was somewhat more than 100,000 barrels of 27° API gravity oil, as estimated from Kansas Geological Survey figures (Jewett, 1949; Ver Wiebe, ~~and others,~~ et. al., 1948, 1949, 1950, 1951, 1952, 1953, 1954, 1955; Goebel, ~~and others,~~ et. al., 1956, 1957, 1958, 1959). Oil from the "First Bartlesville sand" in the Altoona field ranges from 28° to 33° API gravity; oil from the "Squirrel sand" ranges from 22° to 28° API gravity; and oil from the "Weiser sand" ranges from 24° to 26° API gravity. Initial production in this field ranged from 5 to 50 barrels of oil per day.

Gas.--Gas was discovered near Altoona in 1901, was piped to the town that year, and by 1902 a large area of gas production had been outlined north and east of town (Haworth, 1903, map facing page 38). Drilling in 1903-~~1905~~ was mainly to the "Second Bartlesville sand" at ~~a depth of~~ about 900 feet, and to the "Oswego lime" at about 650 feet ~~depth~~. Initial production of some of the wells was 2 to 6 million cubic feet per day. Many shallow "shale gas" wells were drilled to the black shales of the "Oswego lime" in this area in 1916-17, and ~~a~~ again in 1923-24. Initial production in "shale gas" wells was about 500,000 cubic feet per day, only about one-fourth the production of "sand gas" wells, but production in "shale gas" wells continued in most areas for a considerably longer period than in "sand gas" wells. Continued search for gas extended the area of production and no clean-cut break exists between the Altoona, Altoona East, Vilas, or Humboldt-Chanute fields (~~see fig. 67~~ Plate II, A).

Figure 65. ~~Maps showing areas of gas production in Wilson County--by producing horizons.~~

Small shows of gas were recorded at about 300 feet depth in the first black shale above the base of the Kansas City group in a few wells, but the shallowest production of gas came from the "Weiser sand" at 450 to 500 feet depth. Gas production ranging from 20,000 to 500,000 cubic feet per day was reported in several wells in small areas east and south of Altoona. The gas was in a sandstone body 10 to 25 feet thick in the lower part of the Bandera shale. "Shale gas" from the black shales in the "Oswego lime" was recorded in nearly all gas wells in the Altoona field. Gas from this horizon contributed 50,000 to 250,000 cubic feet per day to the flow being obtained from other zones. Gas production from the "Squirrel sand" in this field was almost entirely east and northeast of Altoona at depths of about 650 feet. Maximum initial production of wells in this sand was greater than 1 million cubic feet per day. Production from the "First Bartlesville sand" supplemented that of the "Second Bartlesville sand" except near the center of the northeastern part of the field, where it extended beyond the production from the "Second Bartlesville sand" ~~production~~ (~~see fig. 65~~ Plate II, H, I). Production from the "Second Bartlesville sand" occurred at about 900 feet depth and was mainly in the northern part of the field and in the area around Altoona (~~see fig. 65~~ Plate II, I). Deepest production of gas in the Altoona field has been from 5 to 10 feet of "Third Bartlesville sand" at about 1,000 feet depth in sec. 36, T. 28 S., R. 16 E., and 2 miles southwest of Altoona in R. 16 E. (~~see fig. 65~~ Plate II, J).

## Altoona East oil and gas field

Oil.--The Altoona East oil and gas field lies near the center of the east boundary of Wilson County, and extends a few miles eastward into Neosho County. Discovery and production of oil in the Altoona East field came about 40 years after the field was established as a gas producer. In the early mid-thirties, oil in the "Second Bartlesville sand" became the prime target for drilling in this area, and as a result, the Three Mounds pool in secs. 9 and 10, T. 29 S., R. 17 E., was discovered in about 1935. Production was obtained from 20 to 55 feet of "Second Bartlesville sand" at about 850 feet depth. The pool had been fairly well outlined and developed by 1938, and was then subjected to water-flooding for a short period of time. Flooding was begun again in 1942, and again in 1956, but on only a small scale. From 1949 to 1958, about 60,000 barrels of 28° and 29° API gravity oil was produced from the Altoona East field (Ver Wiebe et al., 1950, 1951, 1952, 1953, 1954, 1955; Goebel et al., 1956, 1957, 1958, 1959).

Gas.--Drilling activity in the Altoona East field occurred in three general periods, at about 10-year intervals. As early as 1894 the area was tested for gas, and by 1908 several small gas producers had been drilled (Haworth, 1908, pl. XIX). The first good production, however, and the development of the field as a gas producer, was not until 1917, when production from the "First Bartlesville sand" at about 800 feet depth and from the "Third Bartlesville sand" at about 1,000 feet depth, was obtained in sec. 3, T. 29 S., R. 17 E. Wells came in at more than a million cubic feet of gas per day and lasted 3 to 7 years before depletion. By 1924 most of these wells had been abandoned, and the urgency for gas made smaller producers profitable. Between 1924 and 1928, therefore, many "shale gas" wells were drilled in this area. They obtained 50,000 to 100,000 cubic feet per day production at 600-650 feet depth. Many of the wells were drilled completely through the "Oswego lime" and into the top of the Cherokee group. These wells generally encountered the "Squirrel sand" directly under the "Oswego lime" and obtained an additional strong flow of gas from that zone. Since 1934, the search for oil in the Altoona East field has resulted in the discovery of many small areas of gas accumulation. Between 1950 and 1954, gas production from the Wilson County part of the "Altoona-Earlton pool" area of the Altoona East field totalled about 425,000,000 cubic feet (Ver Wiebe, et. al., 1951, p. 176; 1952, p. 178; 1954, p. 190; 1955, p. 199). Average production from 25 to 35 wells was about 86,500,000 cubic feet of gas per year.

## Benedict oil and gas field

Oil.--Oil production from the Benedict Field area was obtained at least as early as 1896. In that year several producing wells were drilled both north and south of Benedict. Production was from the "Second Bartlesville sand" at 1,000 to 1,100 feet depth in 25 to 80 feet of sand. Drilling and discovery of small production continued intermittently until 1919, when a period of increased activity was initiated and several new pools, mainly west and south of Benedict, were brought in. The wells produced either from the "First Bartlesville sand" at about 975 feet depth or from the "Second Bartlesville sand" at a depth of about 1,050 feet. Each sand was 10 to 20 feet thick. Activity declined in about 1923, but increased again in 1928, when the pools 2 miles south of Benedict were discovered. A new pool about 2 miles southeast of Benedict was discovered in 1953. Production was from the "First Bartlesville sand" at about 950 feet depth in 15 feet of sand. The wells produced 25 to 30 barrels per day of 31° API gravity oil. One well flowed natural for 5 weeks before being put on the pump. Oil from the "Second Bartlesville sand" in the Benedict field is 28° to 31° API gravity.

Gas.--The Benedict oil and gas field is the site of the first record of gas in large quantity in the county (see page 277), but there is no record of any specific attempt to obtain production of gas or oil from this area prior to 1895. In that year Guffey and Galey brought in a strong gas well near Benedict. After a period of idleness, a pipeline was laid to Chanute and for more than 2 years this one well supplied the entire city of Chanute (Haworth, 1908, p. 186). Gas in quantity was found northeast of Benedict in 1898, and several wells averaging more than one million cubic feet of gas per day were completed at about 1,050 feet depth and furnished the gas supply for both Benedict and Chanute. The main production was from the "Second Bartlesville sand," which was about 25 feet thick, but gas from the "Oswego lime" was obtained also. By 1902 the productive area extended 2 miles north and west of town, a mile east, and 4 miles south (Haworth, 1903, map facing page 38). Production from the "Second Bartlesville sand" had been developed in a large gas field northwest of Benedict by 1908 (Haworth, 1908, pl. XIX).

Between 1913 and 1916 several good gas wells of a million cubic feet per day or more initial production were drilled a few miles southwest of Benedict in the "First Bartlesville sand" at 950 to 1,000 feet depth, and in the "Second Bartlesville sand" at about 1,100 feet depth. Wells with a million or more cubic feet per day gas production from the "First Bartlesville sand" were also drilled during this period, 1 to 2 miles east of Benedict. Production from younger beds was of the "contributory" type only and from small areas (see Plate II, B, D, and E).

Buffalo oil and gas field

Oil.--The discovery of oil and gas in the Buffalo field preceded the turn of the century, as recorded in the May 12, 1899, issue of the Wilson County Citizen, which stated that "near Buffalo, 1 mile from town * * * is a magnificent gas well * * * . There are also 6 flowing oil wells nearby." By December 1902, 25 oil wells, classed as small producers, had been completed in a sand at 1,000 to 1,040 feet (Johnson, 1903, p. 335), and the area around Buffalo was considered to be one of the older fields of the district (Haworth, 1903, p. 35). The oil production was principally from wells to the west and southwest of the town; the wells west of town were on the pump from 1902 to about 1907, and by 1908 at least 20 wells were producing oil in the field southwest of town (Haworth, 1908, pl. XIX). An oil pool 2½ miles northeast of town had also been found by 1908, and was being extended. Major periods of activity in the development of that pool occured in 1911, 1948, and 1958. The pool was subjected to water flood in 1954 and again in 1958. Production is from the "First Bartlesville sand" at depths of 960 to 985 feet. Two sands, the upper one 5 feet thick, the lower one 10 feet thick, separated by about 20 feet of shale, both contain oil. The lower sand is the one generally produced, ~~however~~.

The "First Bartlesville sand" is the chief oil-producer of this field (~~see fig. 64~~ Plate 10, D). The "Second Bartlesville sand" produces mainly in the southern part of the field (~~see fig. 64~~ Plate 10, E), and a small amount of production from the "Mississippi lime" has been obtained 2 and 6 miles east of Buffalo (~~see fig. 64~~ Plate 10, F). Production from rocks of Mississippian age was from a sandy zone about 10 feet below the top at a depth of about 1,200 feet. The only production from rocks of Ordovician age in the Buffalo field was obtained just southeast of the town of Buffalo at a depth of 1,500 feet. The pool was discovered in November 1924, and the first well produced 75 barrels of oil of about 22° Bé gravity. The pool was very small, and its production was cut down rapidly by the encroachment of salt water (Folger and Hall, 1933, p. 23).

Gas.--Gas was discovered in 1899 in the Buffalo field, and in 1902 there were 30 gas-producing wells (Johnson, 1903, p. 335), the most prolific gas area being to the north of Buffalo (Haworth, 1904, p. 33). Folger records the discovery in 1928 of a gas pool in the center of the southern panhandle of the field that produced gas from about 1,505 feet. He stated (Folger and Hall, 1933, p. 24) that about 10 wells, the largest with an open flow of 1½ million cubic feet, were drilled, having rock pressures of about 315 pounds. He placed the production as being from the "salt sand," but study of drillers' logs in the area shows the horizon to ~~have~~ be (stet) the top of the "Arbuckle." The main gas production above the "Arbuckle" ~~has been~~ was obtained from the "Second Bartlesville sand" (~~see fig. 65~~ Plate II) from depths of 1,050 to 1,120 feet. Initial production ranged from about 350,000 cubic feet to 6,500,000 cubic feet per day, highest initial flow being from wells about 3 miles east of Buffalo. Rock pressures averaged about 370 pounds. Smaller amounts of gas production were obtained from the "First Bartlesville sand" east and west of Buffalo (~~see fig. 65~~ Plate II, H), from the "Squirrel sand" east and northwest of Buffalo and northeast of Roper (~~see fig. 65~~ Plate II, G), from the "Oswego lime" as supplementary flow throughout most of the area except for the central part of the field (~~see fig. 65~~ Plate II, F), from the "Weiser sand" northeast of Roper and west of Buffalo, from black shales in the lower part of the Kansas City group northeast of Roper, and from the Iola limestone just southeast of Buffalo. The Iola limestone

production was obtained about 1916 from a porous zone in the upper part at a depth of about 200 feet. Gas flow ranged from about 100,000 to 400,000 cubic feet per day at 20 to 30 pounds rock pressure. The pool was converted in 1942 to a gas storage reservoir with an ultimate storage capacity of at least 250 million cubic feet of gas. In April 1959 a well that had an initial production rated at more than 2 million cubic feet per day and a rock pressure of 315 pounds per square inch was completed just northeast of Roper in the "First Bartlesville sand" at a depth of about 985 feet.

## Buxton oil and gas field

Oil.--The Buxton oil and gas field is 2 to 4 miles south of Buxton in southwestern Wilson County. It was probably discovered during the period of increased drilling immediately following World War I, inasmuch as the field outlines were established prior to 1920 (Snider, 1920, map on p. 164). Moore and Boughton (1921, map opposite p. 16) show both oil and gas production. Although no logs of the producing oil wells were obtained, dry holes in the area record oil shows in the "First Bartlesville sand" at about 1,250 feet and in the top of the "Arbuckle" at about 1,700 feet. Presumably, production was small and was from the "Arbuckle," although both zones may have produced in the separated areas.

Gas.--Gas production was apparently from both the uppermost sandy part of the Stanton limestone and from the Cottage Grove sandstone member of the Chanute shale (see ~~fig. 65~~ Plate II, B, C), from depths of 400 to 500 feet.

## Coffeyville-Cherryvale oil and gas field

Oil.--The Coffeyville-Cherryvale field extends only a mile into Wilson County in the extreme southeastern corner. According to Jewett (1954, p. 301-302), the Cherryvale part of the field was developed in 1904, the chief oil-producing formation being the "Bartlesville sand." No oil production is indicated in the Wilson County part of the field.

Gas.--Logs of wells in sec. 34, T. 30 S., R. 17 E., indicate gas production from the "Oswego lime" at depths of 550 to 650 feet.

## Coyville oil and gas field

Oil.--Oil production from the Coyville field dates back at least to 1908, at which time oil was obtained from a well just east of town (Haworth, 1908, pl. XIX). This oil was apparently from the top of the "Mississippi lime" at about 1,300 feet depth. Exploration in about 1922 extended the Mississippian production to the southeast and discovered "Arbuckle" production south of town at a depth of about 1,650 feet. Relatively small production was obtained.

Gas.--Gas was produced from the "Squirrel sand" east and northeast of town at depths of 950 to 1,000 feet. Wells came in as strong as 1,600,000 cubic feet per day at 375 lbs. rock pressure. The "Oswego lime" augmented the production from the "Squirrel sand" locally, as did the "Weiser sand." Gas from the "Weiser sand" was also produced 3 miles north of Coyville, beyond the established limits of the field, in conjunction with flow from the upper part of the Plattsburg limestone, the black shales in the Kansas City group, and the "Second Bartlesville sand" (see Plate II).

## Coyville West oil and gas field

Oil.--Production, apparently from the "First Bartlesville sand," was obtained in the Coyville West oil and gas field in about 1920. Moore and Boughton (1921, pl. III facing p. 16) show two oil wells in the field in 1921. An extension of the field was made in 1955 in the "Squirrel sand" (Goebel, et al., 1956, p. 139), and production in 1958 was from both the "Squirrel sand" at about 1,100 feet and the "First Bartlesville sand" at about 1,200 feet depth. The combined production from 1953 to 1958 amounted to about 6,000 barrels of 24° API gravity oil from the "Squirrel sand" and 30° to 32° API gravity oil from the "First Bartlesville sand" (see Fig. 36, and Table 3).

Gas.--Gas has been produced from 10 feet of "First Bartlesville sand" in a few wells in the field. The strongest recorded flow is 250,000 cubic feet at 1,200 feet depth with a rock pressure of 500 pounds per square inch.

## Fall River oil and gas field

Oil.--The Fall River oil and gas field lies entirely in Wilson County. Its southwestern corner, however, adjoins part of the New Albany oil field of Elk County. Apparently little oil has been obtained from this field in Wilson County despite its proximity to the prolific New Albany field where the shallow "New Albany sand" has been a good producer since 1920. Oil shows are recorded in the southern pool at 500 feet depth in the Cottage Grove sandstone member of the Chanute shale (the correlative of the "New Albany sand" in the New Albany field) and in the "Weiser sand" of the Bandera shale. The northern pool produced from the "First Bartlesville sand" at 1,100 to 1,150 feet in 1920 and again in 1954 in 30 feet of sand. In 1954, 196 barrels of oil were reported from the field (Ver Wiebe, et al., 1955, p. 190).

A small pool about 3 miles north of the Fall River field, called the "Stryker pool," produced about 1,700 barrels of oil between 1954 and 1956 from the "Bartlesville sand" at about 1,300 feet depth (Ver Wiebe, et al., 1955; Goebel, et al., 1956, 1957; and W. L. Stryker, verbal communication, June 1959). Earlier production (in 1924 and 1925) was from a sandy zone at the top of the Plattsburg limestone, or from a sandstone at the base of the Vilas shale. Production was 50 to 150 barrels per day from a hard sandstone at 460 feet depth.

Gas.--Gas production was first obtained in the Fall River field in 1904 from the "Second Bartlesville sand" at about 1,200 feet depth, but later production has been mainly from the top of the "Mississippi lime" at 1,250 to 1,300 feet depth. Initial production in some wells in 1925 was greater than 1 million cubic feet per day. Lesser production has been obtained from the Iola limestone, "New Albany sand," "Squirrel sand," and "First Bartlesville sand." Gas was obtained from the area of the "Stryker pool" from the "First Bartlesville sand" at about 1,275 feet depth as early as 1898.

## Farmdale gas field

Gas was produced from the Farmdale field between 1922 and 1928. In 1924 and 1925 production was from the "Squirrel sand" at a depth of 950 feet. The field was small and short-lived.

## Fredonia oil and gas field

Oil.--The Fredonia oil and gas field covers an area of about 100 square miles and completely surrounds the town of Fredonia. Oil production has been obtained from five separate horizons ranging in depth from 300 to 1,200 feet. Throughout most of its life, gas has been more important than oil in the Fredonia field, but oil is now (1958) the important commodity. Oil was discovered in the Fredonia field in August 1893 on the Hopkins farm in sec. 3, T. 30 S., R. 15 E., in the "Second Bartlesville sand." The well was shot with 30 quarts of nitroglycerin between the depths of 1,023 and 1,034 feet, but was apparently not put into production until 1917.

Shallowest production has come from a small pool located northwest of Fredonia (see ~~fig. 64~~ Plate 10, B). No production figures are available, but apparently the oil was obtained from the "New Albany sand" at depths of 180 to 200 feet. The next shallowest production was in the northeastern part of the field in the "Weiser sand" (see ~~fig. 64~~ Plate 10, C). Drilling in this sandstone body was most active during the period 1917 to 1921, and production was at a depth of about 700 feet in 10 feet of sandstone near the top of the Bandera shale. Twenty-five barrels of oil from the "Weiser sand" were produced from this pool in 1953 (Ver Wiebe, and others, 1954, p. 182 and pl. 1), and 413 barrels were produced in 1954 (Ver Wiebe, ~~and others~~, 1955, p. 190 and pl. 1).

Oil production from the "First Bartlesville sand" has been obtained in only two small areas in the Fredonia field (see ~~fig. 64~~ Plate 10, D). In 1958, 36° API gravity oil was obtained from the eastern area at a depth of about 900 feet in 20 feet of "First Bartlesville sand." Production from 1951 to 1958 amounted to slightly more than 700 barrels. The pool was discovered in 1904, and the first wells came in at 3 to 10 barrels per day. The western pool was discovered in about 1929 and produced oil from about 10 feet of "First Bartlesville sand" at a depth of 1,060 to 1,070 feet.

The first oil obtained from the "Second Bartlesville sand" was in 1907 in sec. 12, T. 29 S., R. 15 E. at about 1,100 feet depth. The sand was about 40 feet thick and had gas in the upper 10 feet and oil in the lower 30 feet. This production from the "Second Bartlesville sand" was from two small separated pools (see ~~fig. 64~~ Plate 10, E) at depths of 1,080 to 1,120 feet. The largest and most prolific oil pool in the "Second Bartlesville sand" in the Fredonia field is located about 5 miles southeast of town. Oil was discovered at depths of 1,100 to 1,200 feet in 1917, and the pool was named the Volunteer Field. Gas was found in the upper 10 feet of the sand; oil was in the lower 30 feet. Development was fairly rapid, and by 1920 more than 30 wells were producing from about 30 feet of sand at a depth of about 1,150 feet. The wells were shot with 40 to 60 quarts of nitroglycerin and flowed 10 to 200 barrels initially. The March 8, 1918, issue of the Wilson County Citizen recorded that the Volunteer No. 6 well came in at "200 barrels initial production but should settle down to 35-50 barrels soon." This pool has been a very steady producer throughout the years averaging about 5,000 barrels per year between 1949 and 1958. A small water flood operation was started in 1955.

The "Second Bartlesville sand" is the main producer in the pools just north of Fredonia also. It is about 20 feet thick and at a depth of 1,050 to 1,080 feet. These pools were discovered about 1915 and were developed and produced until 1927, when most of the wells were plugged and abandoned. The area was reopened and produced about 60 barrels of 26 to 32° API gravity oil in 1953 (Ver Wiebe, et. al., 1954, p. 182). Production increased to about 300 barrels in 1954 (Ver Wiebe, et. al., 1955, p. 190) and in 1955 was about 2,000 barrels (Goebel, et. al., 1956, p. 219). In 1956 production declined to about 1,550 barrels (Goebel, et. al., 1957, p. 224), and in 1957 it was about 650 barrels (Goebel, et. al., 1958, p. 237).

The "Second Bartlesville sand" contained oil in two small pools about 3 miles south of Fredonia as well. The sand is 2 to 10 feet thick and at a depth of about 1,025 feet. First production was obtained in 1919, but the southernmost pool was reopened in about 1949, and approximately 3,500 barrels of 28° API gravity oil were produced between 1951 and 1956. [redacted] the wells were plugged and abandoned in [redacted] 1957.

Oil production in the southernmost part of the field came from both the "Second Bartlesville sand" and the top of the "Mississippi lime." Oil was first produced in 1918 and 1919 from the "Second Bartlesville sand" at depths of 1,200 to 1,250 feet. Initial production of 40 to 50 barrels was common. The pool was apparently reopened in 1953, and about 15 wells have been intermittently in production between 1953 and 1958. Production of a small amount of oil from the top of the "Mississippi lime" at about 1,300 feet ~~depth~~, is also indicated on well logs. Production records show that between 1954 and 1957, about 900 barrels of 27° API gravity oil were produced. A small pool 2 miles to the northeast was also reopened about 1953 and produced oil from the "Second Bartlesville sand" at about 975 feet depth in 15 feet of sand. Production between 1954 and 1957 amounted to 2,200 barrels of 33° API gravity oil. The pool was discovered and produced originally in 1920-21.

Gas.--Gas, too, has been found in abundance in the Fredonia oil and gas field, the area of occurrence being considerably greater than that of oil (see ~~fig. 65~~ Plate II, A). The first gas pool in this field was located 2 miles south of Fredonia in the NW¼ of sec. 24, T. 29 S., R. 14 E. and was developed by the Kansas Natural Gas Co. Production began in 1895, and in 1958 gas sufficient for local farm use was still flowing. By 1903 a number of fair gas wells had been obtained, some within a mile or less of the town. Concerning these wells, Haworth stated "one interesting feature is that Fredonia has some shallow gas, being obtained at a little over 300 feet beneath the surface" (Haworth, 1904, p. 34). The shallow gas occurred in the Cottage Grove sandstone member of the Chanute shale ("New Albany sand") in a small dome in secs. 7 and 8, T. 29 S., R. 15 E. on the flank of the Fredonia anticline. This initial period of drilling (1903-09) was followed by two other periods, 1913-~~19~~15 and 1928-30, in both of which additional good wells were drilled in this and adjacent pools. Elsewhere in the Fredonia field, ~~also~~ good flows of gas were obtained from the "New Albany sand."

Wells good for 2 million cubic feet per day ~~of gas~~ were drilled in this horizon in 1909 in sec. 25, T. 29 S., R. 14 E.; in 1918-20, 150,000 cubic feet per day or more was found in the "New Albany sand" at 260 feet in sec. 30, T. 29 S., R. 15 E.; and in 1924 and again in 1938, 300,000 to 2,~~000,000~~ million cubic feet of gas were obtained at 300 to 350 feet in the "New Albany sand" in secs. 27 and 28, T. 28 S., R. 14 E.

The next important gas-producing horizon below the "New Albany sand" is the "Weiser sand" (see ~~fig. 65~~ Plate II, E), although small contributing flows may have been obtained from black shales and sandy zones in the Kansas City group in several small areas (see ~~fig. 65~~ Plate II, D). The largest area of production from the "Weiser sand" was in the eastern part of T. 29 S., R. 15 E. A well drilled in sec. 5, T. 29 S., R. 14 E., came in at 650,000 cubic feet at a depth of 700 feet in 20 feet of "Weiser sand" in 1954. The black shales in the "Oswego lime" contributed generally to flow from other horizons throughout the area, but "shale gas" was not a prime target in this area as it was in the Altoona and Vilas fields. Production from the "Squirrel sand" was of minor ~~significance~~ importance in this field, occurring in small areas only (see ~~fig.~~ Plate II, G). As early as 1903, wells with 500,000 cubic feet per day were drilled to the "First Bartlesville sand" at a depth of 875 feet in a small area in sec. 36, T. 29 S., R. 15 E. Later and more significant production in this horizon came from areas north and south of Fredonia. The gas from the "First Bartlesville sand" north of Fredonia generally supplemented that of the "Second Bartlesville sand." South of Fredonia, however, the "First Bartlesville sand" was the principal producer. Flows of ~~half a~~ 1/2 to 3/4 million ~~to three-fourths million~~ cubic feet per day were obtained at about 1,060 to 1,070 feet around 1910 and 1930.

Deepest production of gas in the Fredonia field was from the "Mississippi lime" in the western, eastern, and southern parts (see ~~fig. 65~~ Plate II, J). Gas production was obtained from 1907 to 1914 from the top of the Fredonia anticline in sec. 10, T. 29 S., R. 15 E., from the top of the "Mississippi lime," and from a sandstone lying directly upon the beds of Mississippian age. The sandstone falls in the vertical interval of the "Second Bartlesville sand," and is so classed in this report, although it could also be classed as "Burgess sand." Wells came in at 3 to 5 million cubic feet per day at depths of 1,000 to 1,150 feet. Production was supplemented by flows from the "First Bartlesville sand." Wells with initial capacities of ½ million to 2 million cubic feet per day ~~obtained~~ produced from the "Second Bartlesville sand" and the "Mississippi lime" in the area around sec. 30, T. 29 S., R. 15 E., and as far south as sec. 20, T. 30 S., R. 15 E. The area was drilled in 1909-12 and again in 1918-20, production coming from depths of 1,075 to 1,124 feet.

The effect of these discoveries on industrial development in this area is well stated by Haworth (1908, p. 226) who noted that in 1907, "Another commercially important field developed within the past year lies east of Fredonia. The wells here are not very large, ranging from 3 to 5 million cubic feet, but the field is so situated that the flow is consumed by various nearby manufacturing industries."

Humboldt-Chanute oil and gas field

Oil.--Exploratory drilling was begun about 1897 in the part of the Humboldt-Chanute oil and gas field that lies in Wilson County, and oil was discovered there sometime prior to 1907. By 1908 separate pools had been developed in secs. 15 and 27, T. 27 S., R. 17 E., and sec. 15, T. 28 S., R. 17 E. (Haworth, 1908, pl. XIX). Production ranged from 5 to 20 barrels per day from 30 to 50 feet of "Second Bartlesville sand" at depths of 900 to 980 feet. These areas were redrilled in 1915-18 and again in 1949-51 with considerable success, the new hydraulic-fracturing techniques making possible initial productions of 10 or more barrels per day in the latter period.

Gas.--The first gas production from the part of the Humboldt-Chanute field that lies in Wilson County was in 1901, when a small gas well was discovered by the Forest Oil Company in sec. 9, T. 28 S., R. 17 E. The well produced "shale gas" from the "Oswego lime" at a depth of about 700 feet. The Wilson County part of the field did not, however, become an important gas producer until 1924-1927, when the area underwent intensive drilling for "shale gas." Most of the "Oswego lime" wells drilled in the field had initial productions of 100,000 to 500,000 cubic feet per day. Production was from depths of about 650 to 700 feet, and the wells averaged nearly 350,000 cubic feet per day. Several wells were drilled to depths of 950 to 1,000 feet and encountered 1 to 2 million cubic feet of gas in the "Second Bartlesville sand." Production was also obtained in a few wells from the "Weiser sand" at about 550 feet, from the "Squirrel sand" at about 750 feet, and from the "First Bartlesville sand" at about 800 feet.

## LaFontaine oil and gas field

Oil.--Exploratory drilling in this field began soon after the discovery of oil at Neodesha, and in 1896 drilling crews were active in the vicinity of LaFontaine (Morgan, 1902, p. 888). Schrader and Haworth (1906, p. 23) recorded that drilling in 1904 near LaFontaine resulted in oil wells of small production. The oil apparently came from the "First Bartlesville sand" at about 1,150 feet depth.

Gas.--The Wilson County Citizen (March 22, 1918) recorded several drilling companies at work near LaFontaine, the drilling resulting in a good shallow gas field (~~see fig. 65~~ Plate II, C) at 300 to 350 feet depth in the "New Albany sand". Wells came in at 50,000 to 600,000 cubic feet per day. Drilling records indicate that later drilling obtained gas in a small part of the field from the "Mississippi lime" with contributory flow from rocks of the Kansas City group and from the "First Bartlesville sand".

## Neodesha oil and gas field

Oil.--The Neodesha oil and gas field covers about 75 square miles in southeastern Wilson County. It is the major oil and gas producing field in the county. The first commercial oil well, the first commercial gas well, and the oil wells with the greatest initial production were drilled in this field. The first commercial oil well, the T. J. Norman No. 1, was drilled on November 28, 1892, at the southeast corner of Neodesha, but it was not shot or produced until October 4, 1893. When shot, it flowed more than 370 barrels per day, but dropped soon to 12 barrels per day (Smiley, 1931a, p. 15; 1931b, p. 99-100). Drilling was active the next 2 years, and by 1895, "sixty-eight wells were drilled, all within a radius of five miles of Neodesha, three being strong gas wells, and the greater majority of the remainder producing oil in paying quantities" (Morgan, 1902, p. 888). The 65 oil wells were netting about 800 barrels daily (Smiley, 1931b, p. 100), many of them had "an initial production of right around 100 barrels per day" (Haworth, 1904, p. 33), and about 150,000 barrels of oil was stored in tanks at the end of 1895. There were 161 producing oil wells in the field on July 1, 1903 (Haworth, 1904, p. 27), and oil activity reached a peak early in 1904 when the price of crude oil hit a high of $1.38 per barrel. This quotation lasted only a few days before the price began to drop and eventually reached the low price of 50 cents a barrel early in 1905 (Haworth, 1908, p. 215). At the peak period, development about Neodesha extended northwest, west, south, and southeast from that city (Haworth, 1904, p. 33). The number of producing wells in the field reached almost 300, resulting in the production of about 600,000 barrels of crude.

Oil production in the Neodesha field has been predominantly from the "First Bartlesville sand," areas of production from other horizons being relatively small and scattered except for the "Second Bartlesville" sand-trend pools in the northeastern and southeastern parts of the field (see fig. 64, Plate 10 C, D, E). The shallowest production came from the "Weiser sand" in the northern, eastern, and southwestern parts of the field. The northernmost "Weiser" pool in the Neodesha field has produced shallow oil since 1950 at depths of 425 to 430 feet. Withdrawal has amounted to an average of about 600 barrels per year of 24 to 26° API gravity oil. "Weiser sand" production has was also been obtained about 2 miles to the southwest (see fig. 64, Plate 10 C) at a depth of about 450 feet. Production from this pool also included 36° API gravity oil from the "First Bartlesville sand" at a depth of about 850 feet. The deeper production was first obtained between 1916 and 1917, but soon decreased in quantity. Later production, has been mainly between 1954 and 1958, and has averaged about 2,000 barrels per year.

The production from the "First Bartlesville sand" comes from depths ranging from less than 800 feet in the southern part of the field to more than 900 feet in the northwestern part of the field. An essentially continuous oil pool, about $3\frac{1}{2}$ miles in width and 8 miles or more in length, encompasses the area under and surrounding the town of Neodesha (see ~~fig. 64~~ Plate 10, D). Oil from this pool ranges in gravity from 33° to 39° API, the highest gravity being in the south-central part of the pool (see ~~Fig. 39~~ 36). Producing sands in this pool are not all interconnected, both structural and stratigraphic irregularities tending to separate the areas of accumulation. In some places small irregular upwarps seem to delimit the boundaries of production; in others structure has no apparent affect, but sand thickness and permeability seem to be the controlling characteristics.

This large pool at Neodesha was the discovery pool of the southeastern Kansas area. About 10 wells were drilled in sections 8, 17, 18, 19 and 20, T. 30 S., R. 16 E., between 1892 and 1894, and all were completed as producers with initial productions averaging 10-20 barrels per day. Drilling for oil was almost continuous between 1894 and 1908, wells ranging from 10-30 barrels upon completion being common. Several outstanding wells, all producing from the "First Bartlesville sand" at depths ranging from 775 to 825 feet, came in at 75 to 125 barrels during this period. A few wells went to the "Second Bartlesville sand" zone, but obtained only small production. It was not until the period of increased oil demand during World War I that the lower sand was thoroughly tested. Many of the wells producing from the "First Bartlesville sand" were deepened, and many new wells were drilled. In this area the "Second Bartlesville sand" has two separate horizons, one near the top at about 890 feet depth, the other near the base at about 975 feet depth. Oil from the upper "Second Bartlesville sand" was locally produced in conjunction with the "First Bartlesville sand" where both contained oil. Generally, however, the "Second Bartlesville sand" contained gas rather than oil. The wells drilled from 1916 to 1921 averaged 10 to 20 barrels initial production, 30- to 35-barrel wells being exceptionally good. Several good wells were brought in between 1933 and 1936, and again in the late 1940's and early 1950's, mostly by redrilling of old pools. Some of the wells drilled between 1950 and 1958 had excellent initial production following fracture-treatment. The third well in a small pool being redrilled in 1956 in sec. 26, T. 30 S., R. 16 E., for example, had an

initial production of 74 barrels per day and flowed for 8 months before being put on the pump. Most of the oil from this pool comes from about 20 feet of "First Bartlesville sand" at 770-800 feet depth. Production in the 1930's in this pool came from the "Second Bartlesville sand" as well at depths of 860 to 880 feet.

The large pool at Neodesha produced about 475,000 barrels of oil between 1949 and 1958 (~~see~~ Table 3), the figure including about 8,000 barrels produced between 1954 and 1958 from a small pool in the "Weiser sand" immediately to the southwest, and about 3,300 barrels from the small pool about 3 miles northeast of Neodesha. The production from the "Weiser sand" ~~production~~ came from about 10 feet of sandstone at depths of 460 to 480 feet. Production 3 miles northeast of Neodesha came from the "First Bartlesville sand" at depths of 820 to 840 feet.

The greatest production from the "Second Bartlesville sand" ~~production~~ in the Neodesha field was obtained from a sand trend in the northeastern part of the field. This sand trend was prospected at its southwestern end in 1894, but apparently without success. By 1921 a productive well had been drilled at the northeastern end of the trend (Moore and Boughton, 1921, pl. III), but the first developmental drilling seems to have been in 1927 and 1928. In 1935 a secondary recovery operation began, and between 1935 and 1938 many of the old wells were deepened and shot, and water input wells drilled. A third period of increased activity apparently occurred between 1940 and 1944 when the Gillilan and Carr water-flood project was in operation (Grandone, 1944, p. 142-144). The oil was from about 30 feet of "Second Bartlesville sand" at depths of 825 to 875 feet and averaged about 30° API gravity. Data on initial production of oil in wells drilled early in the history of this pool were not available, but six wells drilled between 1946 and 1949 recorded 6 to 25 barrels per day, and averaged 11 barrels. The pool was under flood from 1949 to 1958, and during that time nearly 200,000 barrels of 28° to 30° API gravity oil were produced. Just southwest of the pool, and probably on the sand trend, is another area in which production is from the "Second Bartlesville sand" at depths of 860 to 900 feet. Oil was not discovered there until about 1920, although a 12-barrel well was drilled in a very small pool about a mile west in the same zone in 1896 (see Plate 10, E). Production soon lagged, and in 1927 many of the wells were abandoned and plugged. The pool was apparently re-opened in 1949 with the production of 546 barrels of oil (Ver Wiebe, et al., 1950, p. 166). About 9,000 barrels of oil were produced from this pool between 1949 and 1958.

Gas.--The first search for a gas supply for the town of Neodesha was in 1892 and resulted in the discovery of oil. However, gas was found in June 1893 at the J. J. Haag farm, in sec. 14, T. 30 S., R. 15 E., on the banks of the Fall River (Morgan, 1902, p. 888), and although gas was the chief objective of exploration, 13 of the 15 wells drilled in 1893 produced oil rather than gas. Gas was soon found in sufficient quantity for the city, and on July 4, 1894, it was piped into the city and was lighted for the first time (Haworth, 1908, p. 29). Three strong gas wells were completed within 5 miles of Neodesha by the latter part of 1895 (Morgan, 1902, p. 888), and three more excellent gas wells were completed about 4 miles east of Neodesha in 1896. The wells had initial productions of 4,000,000 to 8,000,000 cubic feet. Gas wells completed in 1904 had initial productions of 10,000,000 to 12,000,000 cubic feet per day (Haworth, 1904, p. 34). The gas came from a sandstone body 50 to 80 feet thick in the stratigraphic interval normally occupied by the Ardmore limestone. For this reason, the area where this zone is productive is shown on both the "First Bartlesville sand" and the "Squirrel sand" maps (see ~~fig. 65~~ Plate II, G, H). The depth to the productive zone was 640 to 750 feet. The best producing wells were drilled between 1903 and 1908, and production ranged from 5,000,000 to 14,000,000 cubic feet per day per well. The average production of the wells was about 8,000,000 cubic feet per day. Recorded rock pressures averaged about 130 pounds per square inch.

Two other periods of drilling, 1935 to 1937 and 1943 to 1944, resulted in only moderate production from the "First Bartlesville sand" in this area. Shallower production from the "New Albany sand," sandstone and black shale of the Kansas City group, the "Weiser sand," the "Peru sand," and the "Oswego lime" in small, scattered areas throughout the Neodesha field (~~see fig. 65~~ Plate II, C, D, E, F) added 150,000 to 500,000 cubic feet per day to the open flow of the deeper producers. The "New Albany sand" and rocks of the Kansas City group were reached between 200 and 400 feet, the "Weiser sand" between 440 and 480 feet, and the "Oswego lime" between 625 and 650 feet. "Shale gas" from the "Oswego lime" was mostly contributory to other production and amounted to only 50,000 to 200,000 cubic feet per day. A few "shale gas" wells with capacities of 400,000 to 500,000 cubic feet per day were completed in the western part of the field. Shallow wells producing 125,000 to 225,000 cubic feet of gas per day were completed in the southeasternmost part of the field in 1910 to 1914, and many "shale gas" wells were drilled in several parts of the Neodesha field in 1928 and 1929.

Production from the "First Bartlesville sand" east of Neodesha but west of the belt in which production is obtained from both the "Squirrel sand" and the "First Bartlesville sand" (see Plate II, G, H) was obtained mainly between 1903 and 1911. Many wells had initial productions between 2 million and 4 million cubic feet per day with rock pressures of 230 to 275 pounds per square inch, but most had initial productions of 300,000 to 500,000 cubic feet per day. Locally, two sands 30 feet apart composed the "First Bartlesville sand". Each sand was about 20 feet thick and contained gas, but the lower of the two sands was the most productive, yielding as much as 700,000 cubic feet per day.

Production of gas from the northeastern part of the field was obtained from both the "First Bartlesville sand" at depths of 700 to 780 feet and the "Second Bartlesville sand" at depths of 850 to 910 feet, with contributary production from the "Squirrel sand" at about 700 feet, from the black shales of the "Oswego lime" at depths of 575 to 625 feet, and from the "Weiser sand" at depths of 450 to 500 feet. Highest initial production from wells in the "First Bartlesville sand" in this area was 1,500,000 to 3,800,000 cubic feet per day. Maximum initial production from the "Second Bartlesville sand" was between 1,000,000 and 3,000,000 cubic feet per day with rock pressures of 170 to 340 pounds per square inch. As late as 1949, several good wells in the "Second Bartlesville sand" were completed. Initial production was 250,000 to 500,000 cubic feet of gas per day at rock pressures of 140 pounds per square inch. Production from the "Squirrel sand," greater than 1 million cubic feet per day with a rock pressure of 280 pounds per square inch, was obtained in 1917 in the northeastern corner of the field. Very few "shale gas" wells in this part of the field had initial productions greater than a million cubic feet per day, and most of them produced only 200,000 to 400,000 cubic feet per day. Gas from the "Weiser sand" was practically all contributory production, but in places amounted to almost 600,000 cubic feet at 170 pounds per square inch rock pressure.

Other production from the "Second Bartlesville sand" was in the area immediately surrounding Neodesha (see ~~fig. 65~~ Plate II, I). Accumulation was somewhat spotty and ranged in depth from 800 feet in the small pools just east of town to as much as 1,000 feet in the small pools west of town. Wells drilled between 1902 and 1905 averaged about 3,000,000 cubic feet per day and commonly came in at 1,500,000 to 5,500,000 cubic feet per day. Rock pressures ranged from 190 to 315 pounds per square inch. Many of the wells lasted 5 to 10 years before abandonment. The history of the Sipple No. 1 well in sec. 7, T. 30 S., R. 16 E., is more or less typical of these wells. The Sipple No. 1 was spudded March 28, 1902, and was completed April 12, 1902, for 5 million ~~,000,000~~ cubic feet of gas per day in 19 feet of "Second Bartlesville sand" between 1,002 and 1,021 feet depth. On November 5, 1904, the well was cleaned out and drilled 5 feet deeper in the sand. Gas volume came back to 1 million ~~,000,000~~ cubic feet per day. On March 27, 1905, the well was cleaned out and drilled about 8 feet deeper. Gas volume increased to about 1,750,000 cubic feet per day. On September 1, 1905, the well was cleaned out and drilled deeper in sand. Gas volume increased again to about 1,750,000 cubic feet per day. In June 1911, the equipment was pulled, and the well was plugged. Wells completed in the "Second Bartlesville sand" between 1912 and 1917 generally came in at less than 500,000 cubic feet per day.

Deepest gas production in the Neodesha field was obtained in 1896 and 1916 from the "Mississippi chat" in secs. 28, 29, and 31, T. 29 S., R. 17 E. Production as great as 2,000,000 cubic feet per day was recorded, 1,000,000 cubic feet coming from the "chat" at 965 to 985 feet, and an additional 1,000,000 cubic feet from the "Third Bartlesville sand" at 875 to 900 feet. Several other good gas wells obtained production from the "Third Bartlesville sand" in this pool. Twenty feet of "Peru sand" in the Labette shale added contributory gas to the "Third Bartlesville," "First Bartlesville," and "Oswego lime" production in this area. This is the only gas from the "Peru sand" in the county.

## Neodesha East oil and gas field

Oil.--The Neodesha East oil and gas field is just north of the southeastern corner of Wilson County. Prior to 1950 it was considered to be a gas field only, but in that year, oil in sufficient quantity to be produced was found in the "Second Bartlesville sand" at 905 to 935 feet depth. Several additional wells were drilled, and the production was increased from 328 barrels in 1950 (Ver Wiebe, et al., 1951, p. 171) to 835 barrels in 1951 (Ver Wiebe, et al., 1952, p. 182). About 5,000 barrels of 28° API gravity oil were produced from this field between 1950 and 1958.

Gas.--Gas was found in the "Second Bartlesville sand" in 1912, the discovery well showing an open flow of 1,850,000 cubic feet per day. In 1954, 29 wells in the field produced 92,698,000 cubic feet of gas (Ver Wiebe, et al., 1955, p. 199).

## New Albany Townsite oil and gas field

Oil.--Oil was apparently discovered at New Albany in about 1903 (Williams, 1904) and again in 1918, when shallow oil was found at a depth of about 450 feet in the "New Albany sand." In 1920 encouraging shows of oil were recorded in the top of the "Mississippi lime" at 1,260 to 1,280 feet, but little if any oil was produced.

Gas.--According to Haworth (1904, p. 34), shallow gas was found at New Albany in about 1903. Driller's logs indicate that the production came from the "New Albany sand" at 400 to 500 feet depth. Williams (1904) stated that "oil and gas have lately been discovered at this place [New Albany] and the town uses natural gas for fuel and light."

Vilas oil and gas field

Oil.--Oil production from the Vilas field has been entirely from the "Bartlesville" zones. Production from the "First Bartlesville sand" was brought in as early as 1904 east and north of Vilas (see ~~Fig. 64~~ Plate 10, D) at about 825 feet depth. In 1958 the gravity of the oil produced from this sand was 28° to 30° API. "Second Bartlesville" production (see ~~Fig. 64~~ Plate 10, E) occurred generally at depths between 975 and 1,000 feet and consisted of 23° to 28° API gravity oil. More than 57,000 barrels of oil were recorded from this field between 1949 and 1958 (see Table 3).

Gas.--The earliest successful drilling for gas in the Vilas field area was in 1899, when wells were brought in about a mile southwest of Vilas at a depth of 1,050 feet in the "Second Bartlesville sand." In 1902 and 1903 the area north, east, and south of town was actively developed, and wells with initial flows of 11 million to 20 million cubic feet per day were drilled to the "First Bartlesville sand" at about 825 feet depth. The wells produced gas for 5 to 20 years before being plugged and abandoned. Development was at its peak about 1907 for, according to Haworth (1908, p. 225-226), "The most remarkable individual field discovered is about six miles southwest of Chanute. Here, on the high land between the Neosho and Verdigris Rivers, a field has been developed almost entirely within the past year; some wells of this district are so large as to compare favorably with the best wells drilled in Montgomery County two years ago. Wells ranging from 2 to 30 million cubic feet per day seem to be comparatively common."

By 1925, the larger producers were rarities, and drilling was mainly for "shale-gas" production from the "Oswego lime" (Landes, 1937, p. 99). In 1933, Folger (Folger and Hall, 1933, p. 23, 24) stated that "the best known gas field of the county [Wilson] is the old Vilas field, located about two miles east of that town. This pool, extending north-south, is five miles in length by three-quarters of a mile in width, and furnished wells of 5 million to 40 million cubic feet open flow. The lenticular sand body, in the upper Bartlesville zone, ranges in thickness up to a maximum of 140 feet. Some lenses were redrilled a second and a third time after the demand for gas increased with the dwindling of the eastern Kansas reserves. The original rock pressure of about 300 pounds is now only 2 pounds, and the volumes of the wells from the last redrilling only 50,000 to 100,000 cubic feet."

## Coal resources

Coal occurs in two formations ~~in the outcropping rocks of~~ at the surface in Wilson County and has been recorded in the Cherokee Group in the logs of several wells. The youngest coal bed is in the upper part of the Lawrence Shale. It is tentatively correlated with coal that is mined about 50 miles to the north near Williamsburg, Franklin County. The coal bed is only $\frac{1}{2}$ to $2\frac{1}{2}$ inches thick in Wilson County.

Coal in the Chanute Shale is locally of minable thickness in Wilson County. The coal is in three groups of beds; one group is at the base of a reddish-weathering sandstone, the second at the base of a whitish, platy siltstone, and the third at the base of a yellowish-gray, thin-bedded, silty sandstone (~~see p. 171-172 and fig. 36~~ Plate 4).

Outcrops of coal in the southeastern part of Wilson County were known from the time of the earliest settlement, and many farmers mined coal on their own properties, and let others dig a winter's supply for a dollar or two. A few small mines were operated commercially during the winters, and the coal was hauled by wagon to Neodesha and adjoining towns (Haworth, 1898a, p. 133). As noted by Haworth (1898a, p. 50), "The coal is most abundant near the surface to the west and southwest of Thayer where it is mined by stripping and by tunneling, and it supplies a large local demand." The locations of many of these mines were shown on the atlas maps of Wilson County prepared during the early days of settlement. Whitla (1940, p. 62) pointed out that most of the mines in Wilson County are drift mines, but that one strip mine, the Dunbar, was operated during 1939 in sec. 21, T. 29 S., R. 17 E., where the coal was 18 to 24 inches thick. The overburden at that mine averaged 12 feet in thickness and consisted mainly of siltstone and two thin limestone beds. [redacted]. The overburden was shattered by blasting, and removed by a small steam shovel of 1.5-yard capacity. The coal was pried loose and loaded into trucks by hand. Strip mining at this location continued at least until 1945 (Abernathy, 1946, p. 141), but the mine was inactive in 1958.

The most detailed report on the coal in Wilson County is by Schoewe, and much of the data on coal given below are from his report. Schoewe (1944, p. 91-93) recognized that the coal occurs at different horizons in the Chanute shale, and that at least one group of coal beds is above the Thayer coal. He pointed out also that the coal is generally in two or three layers separated by clay partings, and that it is as high in quality as the average coal mined elsewhere in Kansas (Schoewe, 1944, p. 97-99). Proximate analyses of two coal samples from Wilson County are given in Table 10. The coals average

Table 10 near here.

~~Table 9. Proximate analyses of coals from Wilson County.~~

51.1 percent fixed carbon, furnish 15,269 Btu per pound on a moisture and ash free basis, and are of bituminous rank.

Table 10.--Proximate analyses of coals from Wilson County, Kansas

| Sample No. | Moisture % | Volatile matter % | Fixed carbon % | Ash % | Sulfur % | Btu/lb | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | As received | Moisture free | Moisture and ash free |
| 163 | 3.78 | 35.80 | 52.30 | 8.12 | 1.34 | 13,479 | 14,009 | 15,316 |
| 202 | 2.15 | 29.19 | 49.89 | 18.77 | 2.70 | 12,099 | 12,365 | 15,222 |

From Schoewe, 1944, p. 100. Sample 163 from NW cor. SW$\frac{1}{4}$ sec. 36, T. 29 S., R. 16 E.; sample 202 from SW$\frac{1}{4}$ sec. 21, T. 29 S., R. 17 E. (Dunbar strip mine).

The coal area of Wilson and Neosho Counties was classed as the Thayer district by Whitla (1940, p. 11, 61-62), and was further subdivided by Schoewe (1944, p. 110-114) into the Thayer-Coal Hollow mining district in Neosho County and the Chetopa and Dry Creek mining districts in Wilson County (see ~~fig. 36~~ Plate 4). According to Schoewe (1944, table 7), a total of 18,661 tons of coal was mined between 1933 and 1942 in Wilson County. Most of this coal was from the Dunbar strip mine. Schoewe (1944, table 8) estimated the total production from the county as 271,875 tons.

Proved reserves of coal in Wilson County, following procedures established in 1947 by the State Geological Survey (Abernathy, ~~and others,~~ et al., 1947, p. 13-14), amount to approximately 13,000,000 tons of coal 10 inches or more in thickness. Included in this estimate are about 1,000 acres in the Chetopa coal mining district underlain by coal 16 or more inches thick and about 8,500 acres in the Dry Creek and Chetopa districts underlain by coal 10 to 16 inches in thickness. Abernathy and others (1947, p. 15, 18) estimated that 12,700,000 tons of proved reserves and 231 million tons of potential reserves of coal 10 or more inches in thickness were present in the Chanute Shale in Wilson County in 1946. In their calculation of potential reserves, known thickness of coal at an outcrop, at a drill hole, or in a mine, was regarded as indicating the presence of coal of the same thickness under 400 square miles.

## Fuels dependent industries

Industries using raw materials from outside Wilson County were attracted to the county by cheap fuel in the form of an abundant and continuous supply of natural gas. These industries included lead and zinc smelting, and window and bottle glass production.

In 1902 near the northwest corner of Neodesha the Lanyon Bros. Spelter Co. built a lead-zinc smelter (Haworth, 1903, p. 30) which was bought and enlarged in 1903 by the Granby Mining and Smelting Co. and operated until 1917. A similar smelter was built about a half a mile north of Altoona by the Cockerill Lead and Zinc Co. in 1902 or 1903 (Williams, 1904) and operated at least to 1910 (Douglas, 1910, p. 173).

The first glass plant in Wilson County was built by the Neodesha Bottle and Glass Co. near the northwestern corner of Neodesha in 1903 (Douglas, 1910, p. 207-208). Its first output was on October 19, 1904. The specialty of the plant was flint-glass bottles for the apothecary trade, and about 30 tons of glass sand per day was used in the production of about three carloads of bottles per week. The cost of gas increased in 1910, and the plant ceased operations in 1911. The Fredonia Window Glass Factory was built in 1904. It was rated as a 36-blower plant and had an output of one carload (500 boxes) daily. The plant appears on maps dated as late as 1921, and was presumably operating at least until then. The sand of the Tonganoxie sandstone member of the Stranger formation was selected for use at the Fredonia plant (Schrader and Haworth, 1906, p. 47) and was used in a few batches run by the Midland Co. at Independence (Douglas, 1910, p. 208), but only a small quantity of sand with a low enough iron content was available, and most of the sand used in the glass manufacture was brought from Illinois and from Pacific, Missouri (Douglas, 1910, p. 208). A third glass plant, built by the Altoona Glass Co., is shown at the southeast corner of Altoona in the Atlas of Wilson County (Ogle and Co., 1910).

## Other mineral resources

The mineral resources of Wilson County, other than fuels, include limestone, shale, sandstone, and gravel. Of these, limestone and shale have the greatest economic value.

Limestone.--Products derived from limestone are the most valuable economic materials obtained from the natural resources of Wilson County. Cement and crushed rock combined were valued at more than $6 million in 1958. Agricultural lime also formed a part of the product derived from limestone, and the manufacture of rock-wool may be of importance in the future.

Knowledge of the chemical composition and abundance of the limestone is important in determining the use and feasibility of any proposed limestone operation. Thickness and distribution of the limestone units are discussed elsewhere in this report; chemical data on limestones are shown in Tables 11 and 12. The purer limestones, which are 95 percent or more calcium carbonate, are commonly designated high-calcium limestones. In Wilson County, only one limestone unit, the Stoner limestone member of the Stanton limestone, contains in some areas more than 95 percent calcium carbonate (see Table 11). In selected areas, therefore, limestone from the Stoner

Table 11 near here

Table 10. Chemical analyses of limestone from Wilson County.

could be used in the metallurgical industry as a flux for both iron and steel production, in the manufacture of glass and glass-fiber, as the raw material for quick and hydrated lime (used in paper and pulp manufacture), in the textile industry, in water softening, and for structural purposes (Runnels, 1951, p. 88-93). Several limestone units in the county, the Plattsmouth, Leavenworth, and Toronto limestone members of the Oread limestone, the Haskell limestone member of the Stranger formation, and the Spring Hill limestone member of the Plattsburg limestone contain approximately 90 percent calcium carbonate (see Table 11), and are suitable for cement, crushed stone, and agricultural lime. Knowledge of the minor chemical constituents of the limestone is also necessary in some operations; for example limestones low in aluminum, phosphorus, arsenic, antimony, and sulfur

could be used in the manufacture of acetylene, and those low in iron, manganese, and vanadium could be used in the production of whiting. Spectrochemical analyses showing the presence and abundance of the minor constituents are given in Table 12.

Table 12 near here

Table 11. Spectrochemical analyses of limestone from Wilson County.

Table 12.--Spectrochemical analyses of limestone from Wilson County, Kansas

| Sample No. | Formation | Member | Location | Spectrochemical analysis, % | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | B | Zn | Ni | Mo | Cr | Ag | Ba | Pb | Sn | Cu | V | Mn | Ti | Sr |
| 1 | Oread | Plattsmouth | SW 23-27-13 | NP | NP | .0001 | NP | .0003 | NP | .002 | NP | NP | .0002 | .003 | .20 | .003 | ND |
| 2 | do | Leavenworth | SW 23-27-13 | NP | NP | .0002 | .0001 | .0004 | NP | .02 | NP | NP | .0005 | .005 | .30 | .004 | ND |
| 3 | do | Toronto | 23-27-13 | NP | NP | NP | NP | NP | NP | NP | NP | NP | .000025 | .003 | .30 | .002 | .072 |
| 4 | Stranger | Haskell | NW 5-27-14 | .001 | NP | .002 | NP | NP | .00005 | .15 | .008 | .003 | .000015 | .001 | .15 | .003 | .05 |
| 5 | do | do | SW 19-28-17 | .0008 | NP | .001 | NP | NP | .00005 | .02 | .0015 | .0015 | .000015 | .002 | .20 | .002 | .061 |
| 7 | do | Westphalia | NW 17-27-14 | NP | NP | .001 | NP | NP | NP | NP | NP | NP | .00002 | NP | .25 | .009 | ND |
| 8 | do | do | SW 19-28-14 | NP | NP | .0005 | NP | NP | .00005 | .02 | .0005 | NP | .000015 | .001 | .30 | .04 | ND |
| 10 | Stanton | Stoner | NW 19-29-15 | .001 | .007 | .0001 | NP | NP | NP | NP | .002 | NP | .000015 | .0067 | .015 | .006 | ND |
| 12 | Plattsburg | Spring Hill | NW 18-30-16 | .0003 | .0015 | .0003 | NP | .0002 | .00005 | .02 | .0005 | NP | .000025 | .0025 | .007 | .03 | ND |
| 13 | do | do | NW 18-30-16 | NP | NP | .0008 | NP | NP | NP | NP | NP | NP | .0001 | .0025 | .20 | .001 | ND |
| 14 | do | Merriam | SW 18-29-16 | .002 | NP | .003 | NP | .0003 | .00005 | NP | .0025 | .0007 | .00007 | .0005 | .04 | .11 | ND |
| 15 | Iola | Paola | SW 29-29-17 | .01 | NP | .004 | .003 | .01 | .00005 | .10 | .0008 | NP | .00015 | .0017 | .01 | .02 | .05 |
| 16 | Drum | ----- | SW 14-30-16 | .003 | NP | .003 | .0002 | .0001 | .00005 | NP | .002 | NP | .00004 | NP | .25 | .007 | ND |

From Runnels and Schleicher, 1956
NP, not present in detectable amount
ND, present but not determined

Cement is the most valuable product derived from limestone in the county. It has been produced continuously since 1905 near Fredonia, but three other cement plants, at Neodesha and Altoona, that produced large quantities of cement in the past, are defunct. The production of cement in Wilson County began in 1905 at three plants, two at Neodesha, and one at Fredonia. Construction of the American Portland Cement Co. plant at Neodesha was begun in the fall of 1904, and was completed in 1905. The plant ceased operations in 1909. The Indian Portland Cement Co., also at Neodesha, began operations in 1905 with a rated capacity of 1,800 barrels per day. In January 1908 the plant was purchased by the United Kansas Portland Cement Co., and its capacity was enlarged to 8,300 barrels in 1909 (Douglas, 1910, p. 189-192); it closed about 1912.

The Fredonia Portland Cement Co. plant was constructed in 1905 and had an initial capacity of 500 barrels per day (Douglas, 1910, p. 192). Modifications in 1908, 1936, and 1955 brought the plant to a rated capacity of 2,300,000 barrels per year--about 6,500 barrels per day (Schoewe, 1956, p. 295). The ingredients used in cement production at the Fredonia plant are comparable to those of other plants in the so-called Gas Belt of eastern Kansas. In general, about 590 pounds of dry solids are used in producing a barrel of cement. About 490 pounds is limestone, about 90 pounds is clay, and 11 pounds is gypsum. Thus, approximately $\frac{1}{2}$ million tons of limestone would be used during a year of peak capacity production, and almost $6 million worth of cement would be produced. The limestone used at the Fredonia plant is mainly Stanton Limestone and contains 85.22 percent calcium carbonate, 4.48 percent magnesium carbonate, and a calculated equivalent calcium carbonate of 89.64 (see Table 11, sample 10).

The Altoona Portland Cement Co. began operations in 1907 (Warne, 1955, p. 10) at the same site or very near the site of the first commercial crushed-rock limestone quarry in Wilson County. The crushed-rock quarry was located just east of Guilford, and ~~employed~~ supplied about 200 men in supplying rock for ballast on the Missouri Pacific Railroad (Williams, 1904). The Altoona Portland Cement Co. quarry was located high on the Stanton escarpment in the NW¼ sec. 30, T. 28 S., R. 15 E. and was operated until about 1928.

Table 11.--Chemical analyses of limestone from Wilson County, Kansas

| Sample No. | Formation | Member | Location Sec., twp., rge. | Chemical analysis, % CaO | MgO | L.O.I.* | $SiO_2$ | $Al_2O_3$† | $Fe_2O_3$‡ | $K_2O$ | $Na_2O$ | $SO_3$ | S | $P_2O_5$ | Total | Calc. $CaCO_3$ | Calc. $MgCO_3$ | Calc. $CaCO_3$ equivalent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Oread | Plattsmouth | SW 23-27-13 | 52.09 | 0.95 | 41.32 | 3.64 | 1.50 | 1.21 | 0.13 | 0.01 | nil | ND | Trace | 100.85 | 92.97 | 1.99 | 93.91 |
| 2 | do | Leavenworth | SW 23-27-13 | 50.99 | 1.94 | 41.82 | 1.83 | 1.10 | 1.42 | 0.09 | 0.02 | nil | 0.14 | Trace | 99.35 | 91.00 | 4.06 | 95.05 |
| 3 | do | Toronto | 23-27-13 | 50.22 | 1.09 | 40.27 | 5.65 | 1.76 | 1.24 | 0.18 | 0.03 | nil | ND | Trace | 100.44 | 89.63 | 2.28 | 91.52 |
| 4 | Stranger | Haskell | NW 5-27-14 | 51.27 | 0.99 | 41.31 | 3.92 | 1.21 | 1.27 | 0.12 | 0.07 | Trace | Trace | 0.06 | 100.22 | 91.38 | 2.07 | 93.89 |
| 5 | do | do | SW 19-28-17 | 49.08 | 1.06 | 40.24 | 5.24 | 1.62 | 2.05 | 0.16 | 0.07 | nil | 0.08 | 0.05 | 99.65 | 87.49 | 2.22 | 91.45 |
| 6 | do | do | 19-28-14 | 48.71 | 1.10 | 39.12 | 6.90 | 1.94 | 1.96 | ND | ND | 0.04 | nil | 0.06 | 99.83 | 86.76 | 2.30 | 88.91 |
| 7 | do | Westphalia | NW 17-27-14 | 45.50 | 1.78 | 38.20 | 8.22 | 2.00 | 3.67 | 0.28 | 0.10 | nil | 0.10 | Trace | 99.85 | 81.21 | 3.72 | 86.82 |
| 8 | do | do | SW 19-28-14 | 40.32 | 5.48 | 39.43 | 7.50 | 1.63 | 5.26 | 0.17 | 0.11 | nil | nil | 0.01 | 99.91 | 71.94 | 11.46 | 89.61 |
| 9 | do | do | 19-28-14 | 42.00 | 4.78 | 39.05 | 8.13 | 1.88 | 3.90 | ND | ND | 0.05 | 0.01 | 0.06 | 99.86 | 74.76 | 10.00 | 88.75 |
| 10 | Stanton | Stoner | NW 19-29-15 | 47.89 | 2.14 | 39.44 | 6.33 | 2.61 | 1.05 | ND | ND | 0.04 | 0.14 | 0.08 | 99.72 | 85.22 | 4.48 | 89.64 |
| 11 | do | do | SE 25-30-14 | 54.73 | 0.53 | 42.80 | 1.21 | 0.74 | 0.40 | ND | ND | 0.03 | nil | 0.06 | 100.50 | 97.50 | 1.11 | 97.27 |
| 12 | Plattsburg | Spring Hill | NW 18-30-16 | 50.65 | 1.48 | 41.27 | 3.95 | 1.32 | 0.80 | ND | ND | 0.04 | 0.08 | 0.07 | 99.66 | 90.18 | 3.10 | 93.80 |
| 13 | do | do | NW 18-30-16 | 49.65 | 1.75 | 40.77 | 4.80 | 1.73 | 1.09 | 0.22 | 0.06 | 0.06 | 0.10 | Trace | 100.23 | 88.54 | 3.66 | 92.66 |
| 14 | do | Merriam | SW 18-29-16 | 43.01 | 1.63 | 36.30 | 11.57 | 3.90 | 2.66 | 0.62 | 0.17 | 0.16 | 0.13 | 0.08 | 100.23 | 76.38 | 3.41 | 82.50 |
| 15 | Iola | Paola | SW 29-29-17 | 8.55 | 0.47 | 8.55 | 66.84 | 8.89 | 3.95 | 1.18 | 1.13 | nil | nil | 0.05 | 99.61 | ND | ND | ND |
| 16 | Drum | ----- | SW 14-30-16 | 38.70 | 1.42 | 32.26 | 19.36 | 3.63 | 3.02 | 0.73 | 0.29 | 0.11 | 0.06 | 0.24 | 99.82 | 68.36 | 2.97 | 73.32 |

From Runnels and Schleicher, 1956
* Net loss of weight on ignition from 105°C to 1000°C
† Includes MnO, $ZrO_2$, $V_2O_5$, and $TiO_2$ when present
‡ Total iron expressed as $Fe_2O_3$
ND, not determined

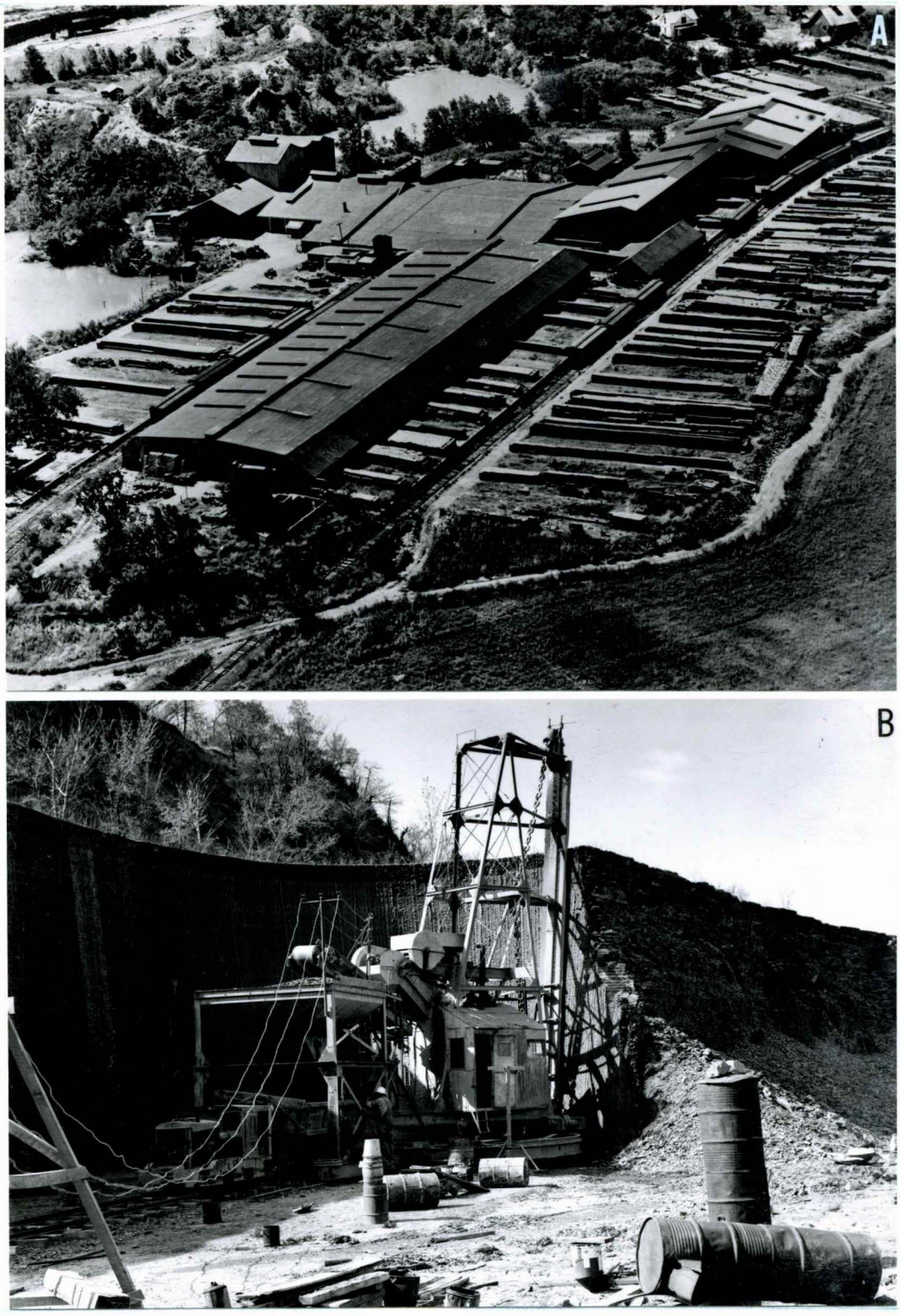



FIGURE 41.--Excelsior Brick Co. operation near Fredonia. (A) Aerial view of the plant taken in 1936---courtesy Excelsior Brick Co. (B) Planer in operation in pit, in 1958.

Other commercial operations utilizing limestone in Wilson County include crushed stone and agricultural lime. Railroad riprap was quarried as early as 1904. Many small quarries are shown on maps of Wilson County prepared by Edwards (1881), Schrader (1908) and Ogle and Co. (1910). Since 1940, crushed rock has been used more abundantly as road rock and as aggregate for construction work, and several sizable quarries have been opened in the Stanton Limestone, in the Plattsburg Limestone, and in the Haskell Limestone Member of the Stranger Formation. Many of the quarries are used only intermittently, and in 1958 only two permanent-type installations were in operation. One, operated by the Benedict Rock and Lime Co., was started in 1944 in the Stanton Limestone about a mile northeast of Benedict. The Stanton in that area is about 35 feet thick. The rock is crushed into a product that is roughly three-fourths crushed rock and one-fourth agricultural lime. The other large operation was opened in 1945 by the Carr Rock Products Co. and is located just northwest of Neodesha on Little Bear Mound. The rock quarried consists of both the Stanton and Plattsburg Limestones. The Carr Rock Products Co. utilizes its portable crushing units in five other quarries in the county, all in the Stanton Limestone. They are located in the SW¼ sec. 36, T. 27 S., R. 16 E., in the SW¼ sec. 19, T. 28 S., R. 14 E., in the NE¼ sec. 18, T. 29 S., R. 16 E., in the NE¼ sec. 26, T. 29 S., R. 14 E., and near the center of the south line of sec. 7, T. 30 S., R. 15 E. (see Plate 1). Approximately 300,000 tons of limestone is quarried each year in the county by these two companies, the State Highway Department, and small operators. Of the total, about 35,000 tons is used in making agricultural lime; the remainder is crushed rock used for construction and road metal.

Clay.--Brick and tile are the chief products made from clay in Wilson County. Two plants, one west of Buffalo and the other west of Fredonia, are currently active (1958) with a combined capacity of more than 200,000 bricks per day. The Buffalo Brick Co. west of Buffalo, operated by the Acme Brick Co. of Fort Worth, Texas, was constructed in 1903 with a capacity of 100,000 to 125,000 bricks per day. In their initial operations vitrified paving bricks, red building bricks, and repressed building bricks were the major part of their output (Williams, 1904), but in about 1930, face-brick and tile facilities were added. Because much of the raw material has a high shrinkage factor, tile is a minor product of the plant. Between 45,000 and 60,000 face and common bricks are made per day in the present operation (1958). The Excelsior Brick Co. plant, also still in operation, was constructed in 1904 at the foot of West Mound, Fredonia and went into production in 1905. The plant, as it appeared in 1936 and much as it appears today, is shown on Figure 41. Nine

Figure 41 near here

Figure 66. Excelsior Brick Co. operation near Fredonia.

round downdraft kilns and one 52-chamber Haigh continuous-chamber kiln are housed in the plant which has a capacity of 120,000 bricks per day. A large clay planer is utilized in the quarrying operation (see Fig. 41, B). Face bricks, common bricks, building tile, and drain tile are the major products. Six textures are added to the extruded bricks, which are then selectively fired to 14 different shades. About 40 percent of the face bricks are flashed.

In the past, five other plants were operated in Wilson County. The Chesnut hand-molded brick plant at Fredonia was apparently the first commercial brick-making operation in the county. It was located in the northwest part of Fredonia and operated between 1884 and 1893 with a capacity of 4,000 to 6,000 hand-molded bricks per day. The bricks were fired with wood and were the construction materials used in many of the old buildings in Fredonia including the hotel and the Opera House. With the discovery of gas in 1893 several large operations were started. The first was that of the Verdigris Valley Vitrified Brick and Tile Co. at the north edge of Neodesha. The plant operated only 2 years--between 1900 and 1902--before being moved to a new site about 4 miles south in Montgomery County. In 1902 the Fredonia Brick and Tile Co. constructed a plant that operated until about 1940 at South Mound, Fredonia, with a capacity of 100,000 to 125,000 bricks per day. Between 1903 and 1928 the Kansas Buff Brick and Mfg. Co. operated a plant with a capacity of 40,000 to 50,000 bricks per day at Buff Mound south of Altoona. They produced the only buff-colored bricks in the county, but also fired white, yellow, mottled, and red building bricks. From 1918 to 1920 the plants at Fredonia and Buff Mound produced bricks valued at about $900,000. The total value of brick production in the county during that 3-year period was almost $2 million (Norman Plummer, , July 1959, written communication).

The Durham Brick Plant, owned by D. W. Durham of Fredonia, operated for a short time prior to 1904 with a daily capacity of 40,000 to 50,000 bricks (Williams, 1904). The last brick plant to go into operation in Wilson County was that of the Altoona Vitrified Brick Co., located about 2 miles north of Altoona in the SW¼ sec. 32, T. 28 S., R. 16 E.. The company apparently marketed bricks between 1906 and 1912 when, according to county records, operations ceased.

The Neodesha and Buff Mound plants used the Lane-Bonner Springs shale in their operations; the Altoona plant used the Vilas shale; and the Fredonia and Buffalo plants used the Weston shale. Twenty-five to forty feet of shale is exposed in the working face at the Fredonia and Buffalo plants. The upper 5 to 10 feet is yellowish-gray and is somewhat more friable than the lower, light-bluish-gray portion. A mixture of the two colors produces the best results; the yellowish colored shale is generally kept at less than one-third of the total.

Production of brick and associated products by the Acme Brick Co. at Buffalo and the Excelsior Brick Co. at Fredonia amounts to more than 100,000 bricks per day, or roughly 30 million bricks per year. These include both common and face bricks in a ratio of 2 common to 1 face. The bricks are worth about three-quarters of a million dollars and use more than 75,000 cubic yards of shale per year.

An operation of considerable significance to the economy of Fredonia about the turn of the century was the preparation of railroad riprap from shale. The Weston shale from four long trenches (approximately 50 x 1,500 feet) adjacent to the ~~A. T. & S. F.~~ Atchison, Topeka, and Santa Fe line just north of Fredonia in the NW¼ sec. 1, T. 29 S., R. 14 E., furnished the raw material, which was then fired and the clinker distributed as base for the railroad. Weston shale, taken from trenches of similar size in the NW¼ sec. 11, T. 29 S., R. 14 E., furnishes clay used by the Consolidated Cement Corp. in the manufacture of cement.

The Ceramic Division of the State Geological Survey of Kansas has investigated the shale formations of Kansas for many years in order to determine which shales are best suited to particular uses. Chemical analyses of shale samples from the Weston shale at the brick plants at Buffalo and Fredonia, and from the Chanute shale in the NE¼ sec. 29, T. 29 S., R. 17 E., are given in Table 13. The Weston

Table 13 near here

~~Table 12. Chemical analyses of shale from Wilson County.~~

shale from the Buffalo plant is fairly high in both silica and alumina, and some care in drying would be required in tile making in order to prevent warping. The Chanute shale probably could not be used in tile manufacture. Results of kiln tests to determine optimum firing temperature for shale from the Buffalo and Fredonia plants are given in Table 14. The optimum firing temperature for the

Table 14 near here

~~Table 13. Ceramic data on the Weston shale from Wilson County.~~

sample from the Buffalo plant would be at about cone 03 (about 1990°F).

Table 14.--Ceramic data on Weston Shale, Wilson County, Kansas.

| Sample Location | Fired to cone | Fired color | Water of plasticity % | Drying shrinkage % | Total linear shrinkage % | Firing shrinkage | Percent absorption | | Saturation coefficient | Hardness as to steel |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 24 hours cold water | 5 hours boiling water | | |
| Buffalo Brick Co. Buffalo, Kan. | 07 | Red orange | 21.3 | 3.9 | 4.6 | 0.7 | 14.1 | 16.0 | 0.88 | Softer |
| | 04 | Red | 21.3 | 3.9 | 8.3 | 4.4 | 7.1 | 9.1 | 0.79 | Harder |
| | 02 | Red | 21.3 | 3.9 | 9.4 | 5.5 | 5.1 | 7.0 | 0.74 | Harder |
| Excelsior Brick Co. Fredonia, Kan. | 07 | Lt. red | 19.2 | 3.6 | 5.1 | 1.5 | 11.5 | 13.6 | 0.85 | As hard |
| | 06 | Red | 21.4 | 3.9 | 7.7 | 3.8 | 6.1 | 6.6 | 0.93 | As hard |
| | 04 | Red | 19.2 | 3.6 | 9.9 | 6.3 | 3.0 | 4.7 | 0.64 | Harder |
| | 06 | Orange red | 19.4 | 4.3 | 6.6 | 2.3 | 9.9 | 11.7 | 0.84 | Softer |
| Excelsior Brick Co. Fredonia, Kan. | 04 | Red | 19.4 | 4.3 | 8.0 | 3.7 | 6.6 | 8.1 | 0.84 | As hard |
| | 02 | Red | 19.4 | 4.3 | 9.1 | 4.8 | 4.0 | 5.0 | 0.80 | Harder |
| | 2 | Red | 19.4 | 4.3 | 9.6 | 5.3 | 1.8 | 3.3 | 0.56 | Harder |

Data furnished by Norman Plummer, State Geological Survey of Kansas.

Table 13.--Chemical analyses of shale from Wilson County, Kansas

| Formation | Location | $SiO_2$ | $Al_2O_3$* | $Fe_2O_3$ | $TiO_2$ | CaO | MgO | $P_2O_5$ | $K_2O$ | $Na_2O$ | S† | L.O.I.‡ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weston Shale | Buffalo Brick Co., Buffalo, Kan. | 59.53 | 19.24 | 7.23 | 1.37 | 0.30 | 1.74 | 0.14 | 2.94 | 0.78 | 0.07 | 6.44 |
| do | do | 60.04 | 19.13 | 6.94 | 1.60 | 0.42 | 1.86 | 0.18 | 3.04 | 1.31 | trace | 5.94 |
| do | Excelsior Brick Co., Fredonia, Kan. | 55.94 | 22.42 | 7.47 | 1.76 | 0.49 | 1.93 | <0.20 | 3.14 | 0.67 | ---- | 7.40 |
| do | do | 52.93 | 23.33 | 7.32 | 1.90 | 0.61 | 2.08 | <0.05 | 4.12 | | ---- | 7.66 |
| do | do | 55.19 | 23.86 | 6.02 | 1.27 | 0.36 | 1.84 | 0.16 | 2.82 | 0.67 | 0.07 | 7.42 |
| Chanute Shale | NE¼NE¼ sec. 29, T. 29 S., R. 17 E. | 72.22 | 12.69 | 4.54 | 0.87 | 0.95 | 1.02 | 0.07 | 1.75 | 1.35 | ---- | 4.22 |

Data furnished by Norman Plummer, State Geological Survey of Kansas
*Includes $MnO_2$, $Ga_2O_3$, etc.
† Sulfide sulfur
‡ Loss on ignition @ 1000°C

Other uses for which shales from Wilson County have been tested include lightweight concrete and constructional aggregate. Concerning these uses of shale, Plummer and Hladik stated (1951, p. 9): "The demand for lightweight concrete aggregates in preference to heavier materials is based on the two important advantages of decreased total weight of the concrete structure and better insulation against both heat and sound transmission. The decreased weight means that less material is required for foundations and supporting structure." They state further (1951, p. 10): "Although the use of these lightweight materials as concrete aggregate is doubtless of major importance, their utility is by no means limited to this application. Bloated shale is also an ideal aggregate for bituminous matt road surfacing." Bloating is the important characteristic in the production of lightweight aggregate. Almost any clay or shale will bloat under some conditions, but many are not suitable for the production of lightweight aggregate. Bloating should occur at less than 2,400° F or fuel costs generally will be excessive. Furthermore, bloating should occur over a wide range in temperature to allow the bloated product to form prior to the fluid glass stage. Otherwise the glass formed will stick to the kiln lining and cause excessive erosion of the refractories (Plummer and Hladik, 1951, p. 22).

The suitability of the Weston shale for the manufacture of light-weight concrete and constructional aggregate and for ceramic railroad ballast was determined by Plummer and Hladik (1951, p. 26-36). In order to test the bloating characteristics of the Weston shale, two samples, one from the shale pit at Buffalo and one from the shale pit at Fredonia, were subjected to the rapid-firing test, and samples from each pit were given the batch-type rotary kiln test. The rapid-firing test (see Table 15) showed that although the unbloated

Table 15 near here

Table 14. Bloating results from rapid firing of bricks made from Wilson County Weston shale in an electric kiln.

vitrified clays from Buffalo and Fredonia had an original density of 143 pounds per cubic foot, the density of both samples decreased after bloating at a temperature of 1,850°F with a slight reduction in volume. Considerable pore space is indicated by the 15.86 and 13.42 percent absorption for the two samples after 5 hours immersion in boiling water (see Table 15). The percentage loss on ignition gives an indication of the percentage loss of weight in changing from raw material to the finished product. Firing at 2,160°F produced little change in density from the 143 pounds per cubic foot original and resulted in a reduction in volume with very low absorption. The best results by the rapid-fire method were at 2,260°F at which temperature the shale had a large decrease in density, an expanded size, and a fairly high absorption percent. The shale from Buffalo had the

Table 15.--Bloating results from rapid firing of bricks made from Wilson County Weston Shale in an electric kiln.

| Sample Location | Temperature °F | Density g/cc | Density lbs/cu ft | Ratio of bloated to unfired volume | Absorption after 5 hours boiling % | Loss on ignition % |
|---|---|---|---|---|---|---|
| Buffalo Brick Co. Buffalo, Kan. | 1850 | 1.87 | 116.69 | 0.97 | 15.86 | 5.57 |
| | 2160 | 2.20 | 137.28 | 0.79 | 2.63 | 5.75 |
| | 2220 | 2.01 | 125.42 | 0.90 | 4.37 | 6.06 |
| | 2260 | 1.58 | 98.59 | 1.14 | 16.17 | 5.94 |
| Excelsior Brick Co. Fredonia, Kan. | 1850 | 2.00 | 124.80 | 0.93 | 13.42 | 7.09 |
| | 2160 | 2.30 | 143.52 | 0.81 | 2.60 | 7.32 |
| | 2220 | 2.13 | 132.91 | 0.88 | 2.60 | 7.32 |
| | 2260 | 1.74 | 108.58 | 1.07 | 6.10 | 7.39 |

From Plummer and Hladik, 1951, p. 36.

lowest density and the greatest pore space (~~see~~ Table 15). Chemical composition also affects the bloating properties. A clay having an alumina content in excess of about 25 percent is usually too refractory to bloat satisfactorily within a reasonable range in temperature. The alumina content of shale from the Fredonia plant is close to this maximum (~~see~~ Table 13). Shales or clays containing a relatively high proportion of calcium or magnesium compounds tend to form a fluid glass a few degrees above the initial softening point, and standardized products are difficult to obtain because incipient fusion and complete fusion are not separated by a sufficient range in temperature (Plummer and Hladik, 1951, p. 22).

In the batch-type rotary kiln the unit weight of crushed, unsized aggregate made from Weston shale from Wilson County, at the optimum bloating temperature of 2,150° to 2,170°F is 44.9 pounds per cubic foot for the sample from the Buffalo area and 28.2 for the sample from the Fredonia area (see Table 16). Kiln samples have lower densities than bricks formed during the rapid-firing procedures because, in the case of bricks, the density is that of a solid aggregate, whereas in the rotary kiln procedure, the density is that of crushed material of irregular shape and includes a large percentage of voids between particles. The size distribution of pieces of Weston shale aggregate from the kiln experiments is given in Table 17. Inasmuch as tests have shown that a certain percentage of sizes will produce aggregates that combine to form concrete building blocks of greater strength, an optimum grading scale has been experimentally determined (Table 17). The Weston shale aggregates

Table 16 near here

Table 15. Results of experimental production of lightweight aggregate in a batch-type rotary kiln.

Table 17 near here

Table 16. Screen analyses and unit weights of lightweight aggregates of Wilson County Weston shale crushed through rolls spaced 3/16-inch apart.

Table 17. Grading scale for optimum strength aggregates and

did not form sizes of the correct proportions, and therefore were resized by sending the coarser aggregate resulting from one pass through the rolls set three-sixteenths of an inch apart through rolls set about one-sixteenth of an inch apart. The additional passes increased the percentage of fines to approximately the optimum grading shown in Table 17, and the resulting size mixtures had unit weights of 51.6 and 40.5 pounds per cubic foot, as shown in the eighth column, Table 16.

Table 17.--Screen analyses and unit weights of lightweight aggregate from Weston Shale crushed through rolls spaced three-sixteenths inch apart.

| Sample location | Percent retained on screen sizes | | | | | | | | Unit weight lbs/cu ft |
|---|---|---|---|---|---|---|---|---|---|
| | 3/8 in. | No. 4 | No. 8 | No. 16 | No. 30 | No. 50 | No. 100 | Pan | |
| Buffalo Brick Co. Buffalo, Kan. | 0.7 | 31.5 | 32.4 | 13.5 | 7.5 | 3.9 | 3.5 | 7.4 | 44.9 |
| Excelsior Brick Co. Fredonia, Kan. | 3.5 | 39.7 | 27.6 | 12.8 | 6.2 | 3.3 | 3.0 | 4.9 | 28.2 |

From Plummer and Hladik, 1951, p. 30.

Percent retained on screens for optimum strength are: 0.0 on 3/8 in. screen, 11.4 on No. 4, 27.0 on No. 8, 21.0 on No. 16, 17.0 on No. 30, 11.0 on No. 50, 6.0 on No. 100, and 7.0 as pan (Plummer and Hladik, 1951, p. 18).

Table 16.--Results of experimental production of light weight aggregate from Weston Shale in a batch-type rotary kiln.

| Sample location | Time in kiln, min. | Firing temperature, °F | | | | Unit weight lbs/cu ft | | Color of crushed aggregate |
|---|---|---|---|---|---|---|---|---|
| | | Initial softening | Optimum for bloating | Formation of kiln roll | Maximum attained | Crushed, unsized | Crushed, sized | |
| Buffalo Brick Co. Buffalo, Kan. | 9 | 2140 | 2150 | 2160 | 2200 | 44.9 | 51.6 | Red & gray |
| Excelsior Brick Co. Fredonia, Kan. | $6\frac{1}{2}$ | 2150 | 2170 | 2180 | 2180 | 28.2 | 40.5 | Mostly red |

From Plummer and Hladik, 1951, p. 26-27.

A test was made in 1936 to determine the suitability of a mixture of Weston shale and Stanton limestone from Wilson County for use in the production of rock wool. In the test a sample of shale from the Excelsior Brick Co. quarry was combined with limestone from the Consolidated Cement Co. quarry and sandy clay from the top of West Mound at Fredonia (Plummer, 1937, p. 36-38). The mixture was blown at 1,550°C with a steam blast of 60 pounds per square inch. The result was a slightly coarse, white rock wool whose fibers ranged from 3 to 50 microns in diameter and averaged 12 microns (Plummer, 1937, p. 38). The chemical composition of the calcined mixture from which the wool was blown was estimated as 45 percent silica, 13 percent alumina, 5.3 percent ferric oxide, 34 percent calcium oxide, and 2 percent magnesium oxide. The carbon dioxide content of the raw mix was 24 percent (Plummer, 1937, p. 36).

Sandstone.--Sandstone was ~~a~~ an very important building material in the early days of settlement of Wilson County, and many small quarries were opened near the larger towns. Sandstone was quarried from the Ireland sandstone member of the Lawrence shale, ~~and~~ from the Tonganoxie sandstone member of the Stranger formation in the western part of the county, and from the Cottage Grove sandstone member of the Chanute shale in the southeastern part of the county. Edwards (1881, p. 23) reported that a good building and flagging stone quarry in the southwestern part of Newark township furnished the rock used in paving the sidewalks in Neodesha. Haworth (1898b, p. 71) reported that the stone for buildings in Neodesha was obtained "from the heavy sandstone immediately under the town, the quarries principally being along the bank of the creek just at the northeast border." Other quarries were opened near Altoona and Fredonia, and local sandstone can still be seen in the foundations and walks of many houses in these areas.

The Tonganoxie sandstone member of the Stranger formation near Fredonia was considered suitable for use as glass sand, and Schrader and Haworth (1906, p. 54) reported: "Perhaps the best is in the southern part of Fall River Township, in the SE¼ sec. 22, about 4 miles southwest of Fredonia. Here the rock is exposed over an area of 10 or 15 acres and appears to be about 12 feet in thickness." Concerning this same occurrence Schrader (1908, p. 6) stated: "It is reported that the glass factory at Fredonia procures its sand from the sandstone of this region." The iron content of the sandstone proved too high for satisfactory glass sand.

Chert gravel.--Abundant chert gravel from deposits in many parts of Wilson County (Plate 1) furnished road metal for most of the section-line roads. The thicker deposits have been exhausted and crushed rock has largely replaced the chert gravel.

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# GEOLOGIC MAP OF WILSON County, Kansas

Modified 1970

*Generalized stratigraphic column of outcropping rocks*

| Member | Formation | Group | Series | System |
|---|---|---|---|---|
| Alluvium and gravel deposits of Recent and Wisconsinan Stages | | | Pleistocene | Quaternary System |
| Chert gravel deposits of Illinoian (?) Stage | | | | |
| Chert gravel deposits of Kansan(?) and Nebraskan (?) Stages | | | | |
| Chert gravel deposits of late (?) and early (?) Pliocene age. | | | Pliocene | Tertiary |
| Plattsmouth ls. | | | | |
| Heebner Sh | | | | |
| Leavenworth ls. | | | | |
| Snyderville Sh. | Creed Limestone | Shawnee Group | Virgilian | Pennsylvanian System |
| Toronto Ls. (Williamsburg coal) | | | | |
| Almoosnie ls. | | | | |
| Ireland Ss. | | | | |
| Robbins Sh. | Lawrence Shale | Douglas Group | | |
| Haskell ls. | | | | |
| Vinland Sh. | | | | |
| Westphalia ls. | | | | |
| Tonganoxie Ss. | Stranger Formation | | | |
| Weston Shale | | | | |
| South Bend ls. | | | | |
| Rock Lake Sh. | | | | |
| Stonar ls. | | | | |
| Eudora Sh. | Stanton Limestone | Lansing Group | Missourian | |
| Captain Creek ls. | | | | |
| Vilas Shale | | | | |
| Spring Hill ls. | Platteburg Limestone | | | |
| Hickory Creek Sh. | | | | |
| Merriam ls. | | | | |
| Bonner Springs Shale | Lane Shale | Kansas City Group | | |
| Raytown ls. | Iola Limestone | | | |
| Muncie Creek Sh. | | | | |
| Paola ls. | | | | |
| (Thayer coal) Cottage Grove ls. | Chanute Shale | | | |
| Drum ls. | | | | |
| Winterset ls. | Cherryvale Shale / Dennis ls. | | | |

Key to lithology

- Unconsolidated clay, silt, sand and gravel
- Limestone, wavy-bedded
- Limestone, well-bedded
- Limestone, sandy
- Limestone, clayey
- Limestone, oolitic
- Shale, gray or yellow
- Shale, calcareous
- Shale, black
- Shale, black with phosphatic nodules
- Shale, red
- Shale with ironstone concretions
- Shale with limestone concretions
- Coal with underclay
- Siltstone
- Sandstone, well-bedded
- Sandstone, cross-bedded
- Sandstone, massive

Explanation

- Observable contact
- Approximate, gradational or inferred contact
- Joint system
- Operating quarry
- Limestone quarry
- Clay pit
- Sand-gravel deposit
- Chert-gravel pit
- Coal strip mine

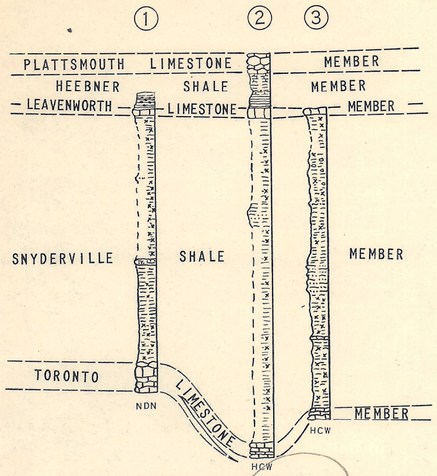
APPROXIMATE MEAN DECLINATION, 1959

Areal Geology of Wilson County, Kansas

Scale 1:48,000

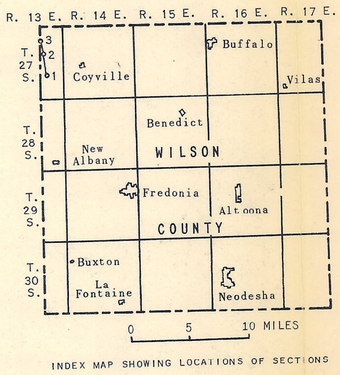
Geology mapped by H.C. Wagner 1950–1955

Kansas Geological Survey
Open-file Report 67-6



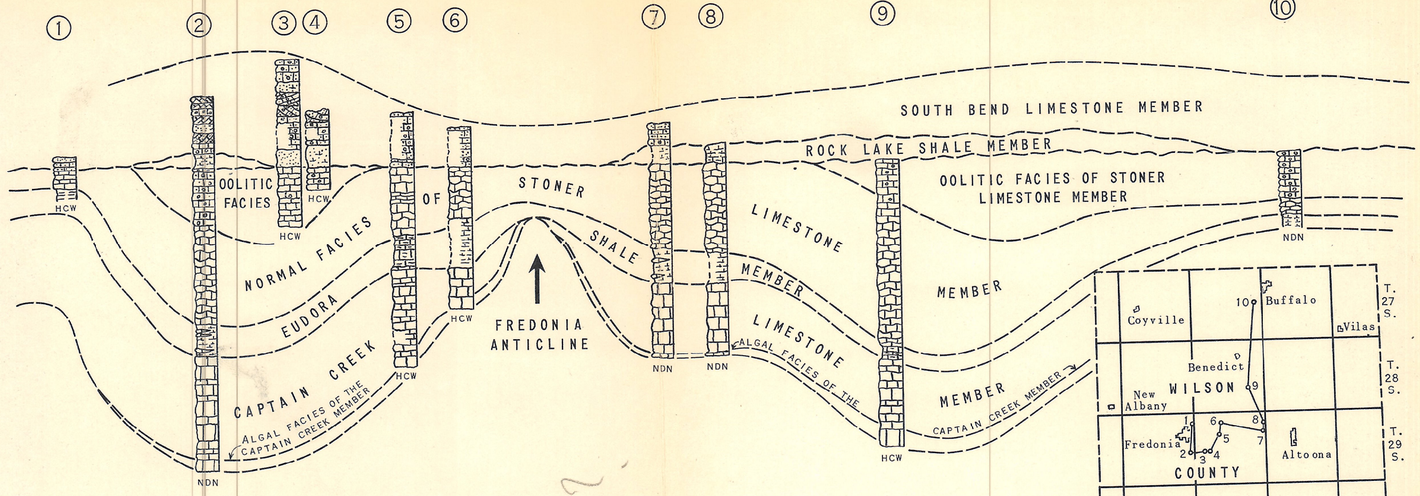

HORIZONTAL SCALE 1 INCH = 2 MILES
VERTICAL SCALE 1 INCH = 20 FEET
VERTICAL EXAGGERATION
APPROXIMATELY 500 TIMES

DATUM IS TOP OF LEAVENWORTH LIMESTONE MEMBER



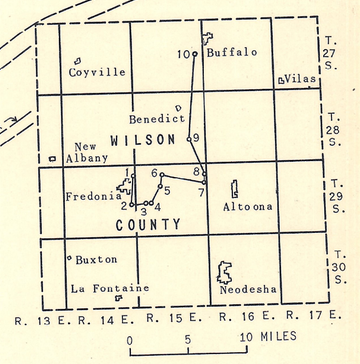

INDEX MAP SHOWING LOCATIONS OF SECTIONS

A. STRATIGRAPHY OF THE OREAD LIMESTONE



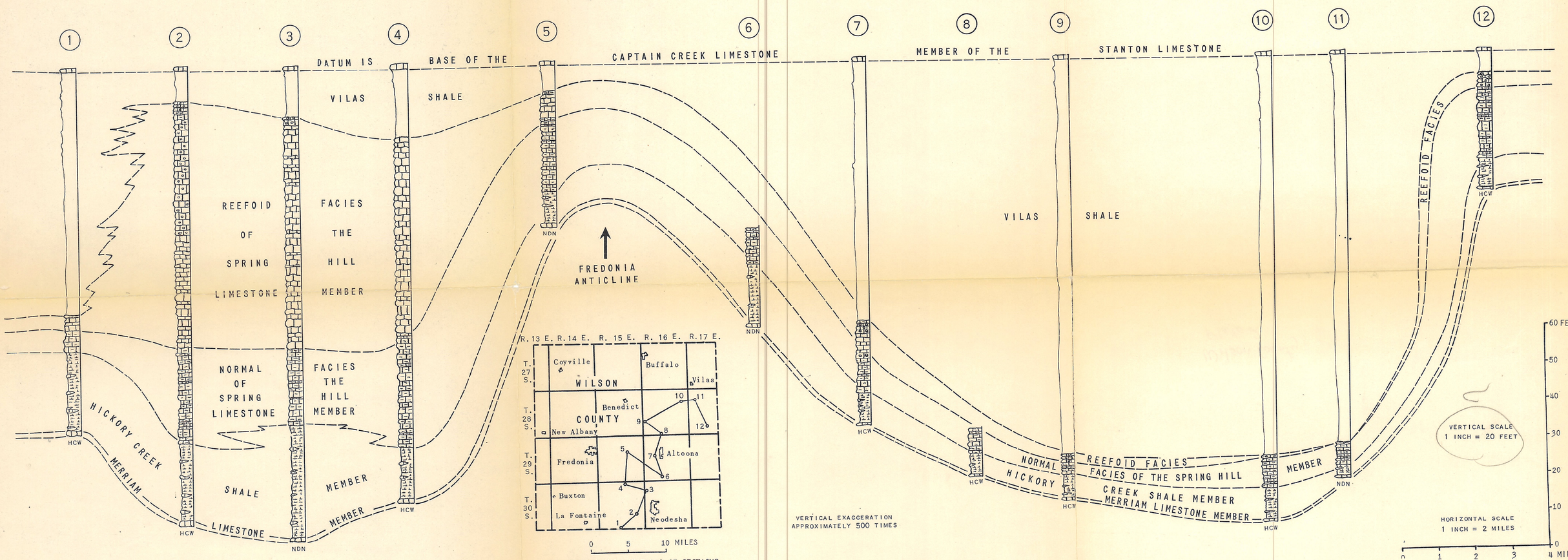

HORIZONTAL SCALE 1 INCH = 2 MILES
VERTICAL SCALE 1 INCH = 20 FEET
VERTICAL EXAGGERATION
APPROXIMATELY 500 TIMES

DATUM IS CONTACT BETWEEN STONER LIMESTONE AND OVERLYING ROCKS




INDEX MAP SHOWING LOCATIONS OF SECTIONS

B. STRATIGRAPHY OF THE STANTON LIMESTONE

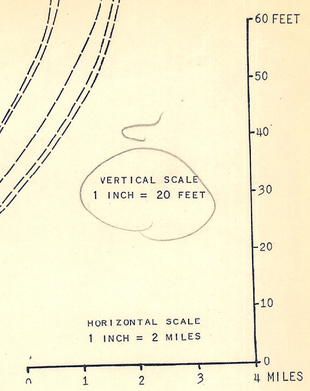




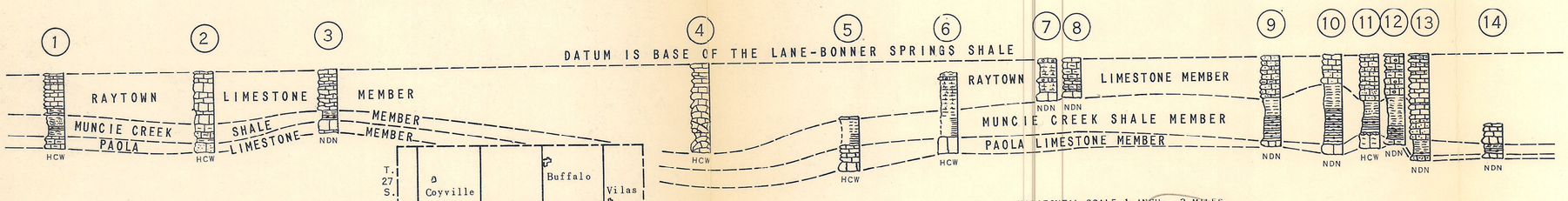


INDEX MAP SHOWING LOCATIONS OF SECTIONS

VERTICAL EXAGGERATION
APPROXIMATELY 500 TIMES




C. STRATIGRAPHY OF THE PLATTSBURG LIMESTONE




HORIZONTAL SCALE 1 INCH = 2 MILES
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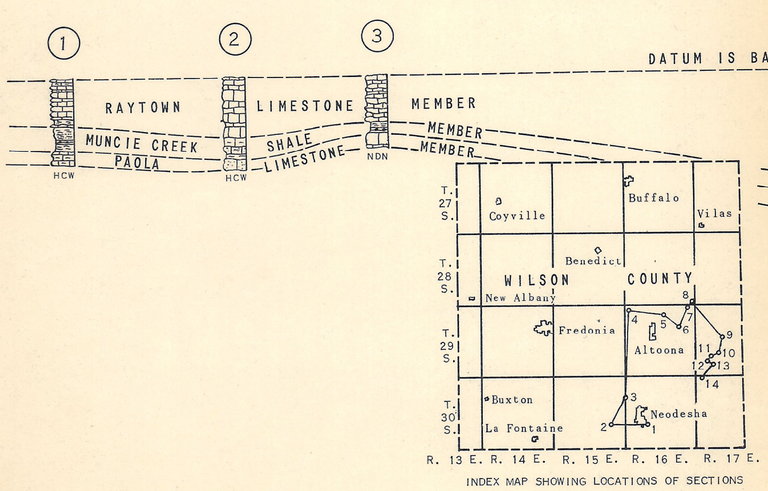
VERTICAL EXAGGERATION
APPROXIMATELY 1000 TIMES




INDEX MAP SHOWING LOCATIONS OF SECTIONS

D. STRATIGRAPHY OF THE IOLA LIMESTONE

EXPLANATION

- Shale
- Calcareous shale
- Black shale
- Limestone
- Wavy-bedded limestone
- Cross-bedded limestone
- Shaly limestone
- Sandy limestone
- Oolitic limestone
- Nodular limestone
- Sandstone
- Calcareous sandstone
- Cross-bedded sandstone
- Phosphatic nodules
- Covered interval
- Red shale

NDN: Section measured by N. D. Newell
HCW: Section measured by H. C. Wagner

Kansas Geological Survey
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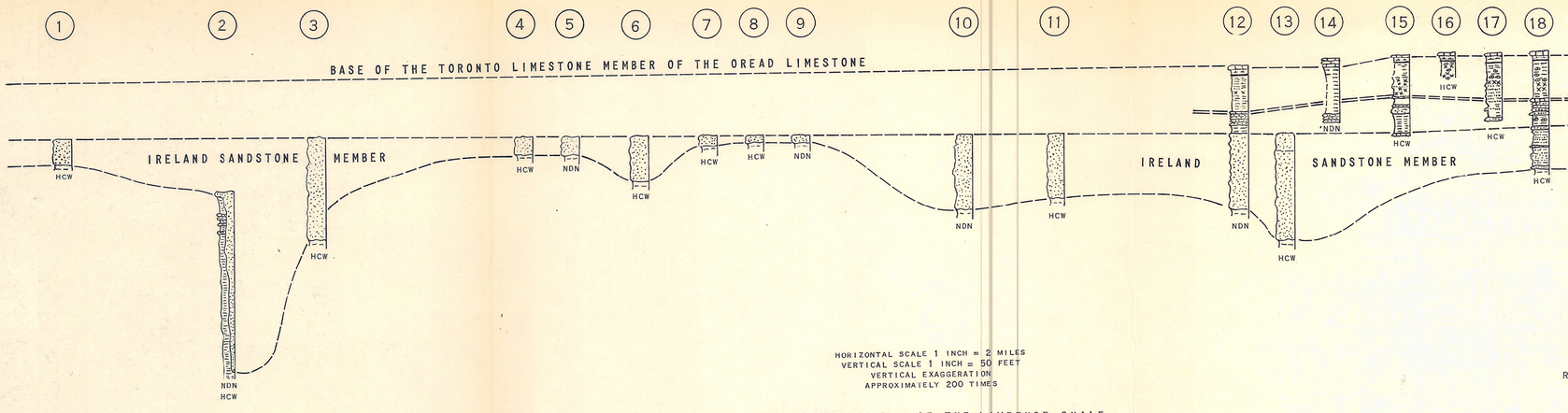
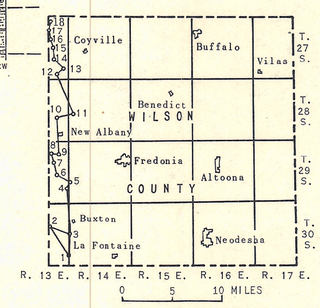
PLATE 2. Correlated sections of the Oread Limestone, Stanton Limestone, Plattsburg Limestone, and Iola Limestone

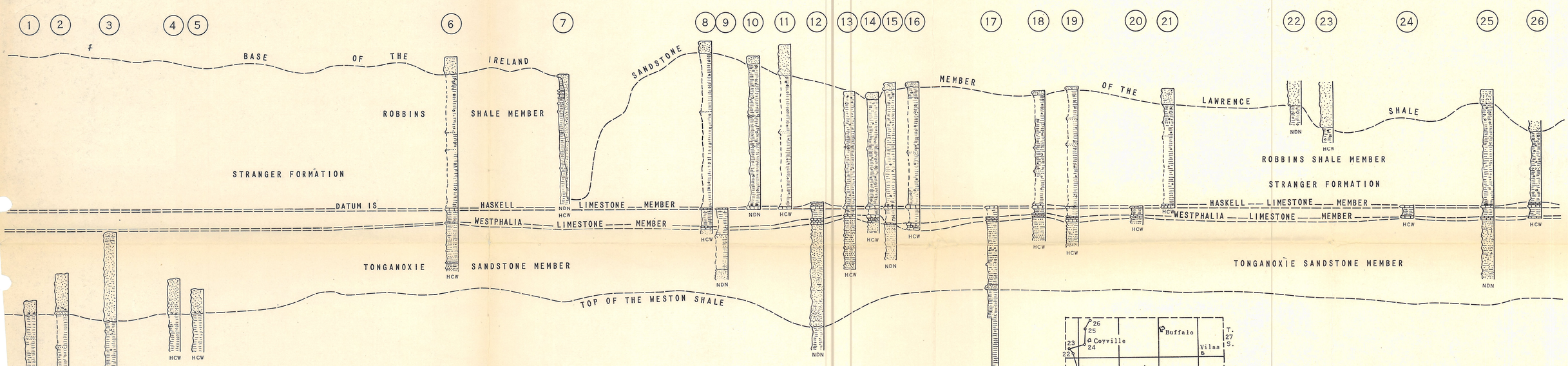



HORIZONTAL SCALE 1 INCH = 2 MILES
VERTICAL SCALE 1 INCH = 50 FEET
VERTICAL EXAGGERATION
APPROXIMATELY 200 TIMES

A. STRATIGRAPHY OF THE LAWRENCE SHALE

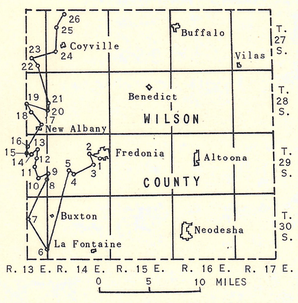



INDEX MAP SHOWING LOCATIONS OF SECTIONS

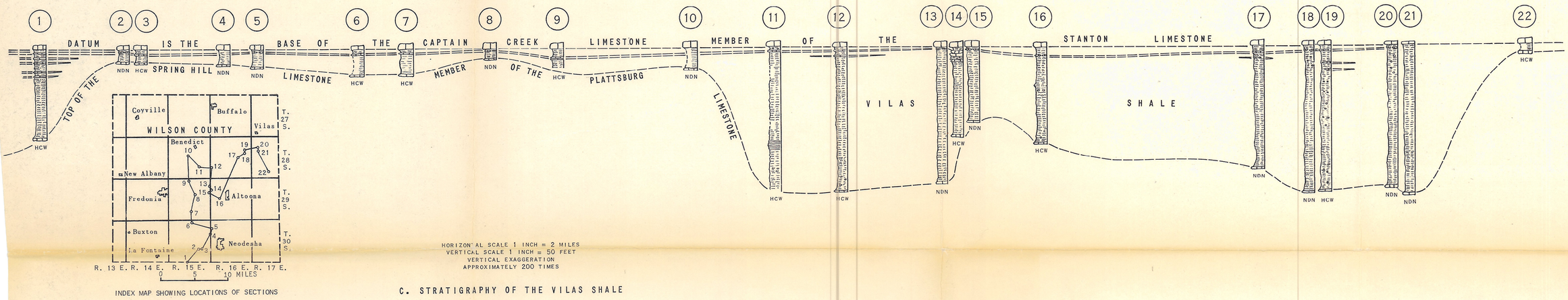



HORIZONTAL SCALE 1 INCH = 2 MILES
VERTICAL SCALE 1 INCH = 50 FEET
VERTICAL EXAGGERATION
APPROXIMATELY 200 TIMES

B. STRATIGRAPHY OF THE STRANGER FORMATION AND WESTON SHALE




INDEX MAP SHOWING LOCATIONS OF SECTIONS

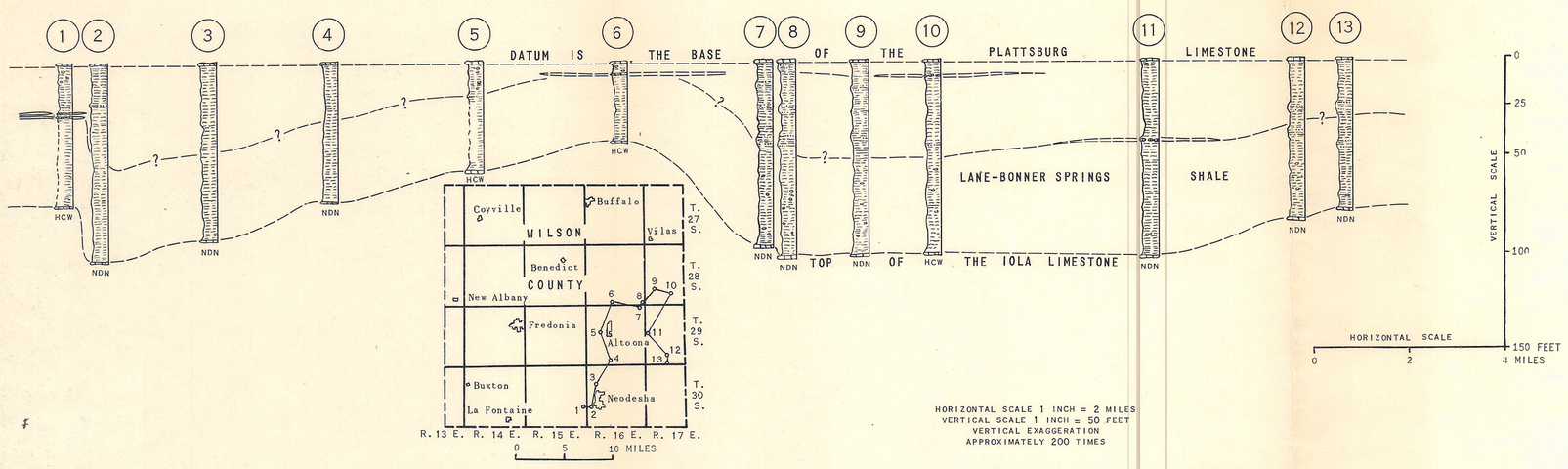



HORIZONTAL SCALE 1 INCH = 2 MILES
VERTICAL SCALE 1 INCH = 50 FEET
VERTICAL EXAGGERATION
APPROXIMATELY 200 TIMES

C. STRATIGRAPHY OF THE VILAS SHALE




INDEX MAP SHOWING LOCATIONS OF SECTIONS




INDEX MAP SHOWING LOCATIONS OF SECTIONS

HORIZONTAL SCALE 1 INCH = 2 MILES
VERTICAL SCALE 1 INCH = 50 FEET
VERTICAL EXAGGERATION
APPROXIMATELY 200 TIMES

D. STRATIGRAPHY OF THE LANE-BONNER SPRINGS SHALE

EXPLANATION

- Shale
- Red Shale
- Black shale
- Calcareous shale
- Siltstone
- Thin-bedded limestone
- Massive limestone
- Nodular limestone
- Sandstone
- Shaly sandstone
- Channel-fill sandstone
- Coal
- Breccia-conglomerate
- Phosphatic concretions
- Ironstone concretions
- Calcareous concretions
- Fossil zone in shale
- Covered interval
- Water-well data

NDN: Section measured by N. D. Newell
HCW: Section measured by H. C. Wagner

PLATE 3. Correlated sections of the Lawrence Shale, Stranger Formation, Weston Shale, Vilas Shale, and Lane-Bonner Springs Shale.

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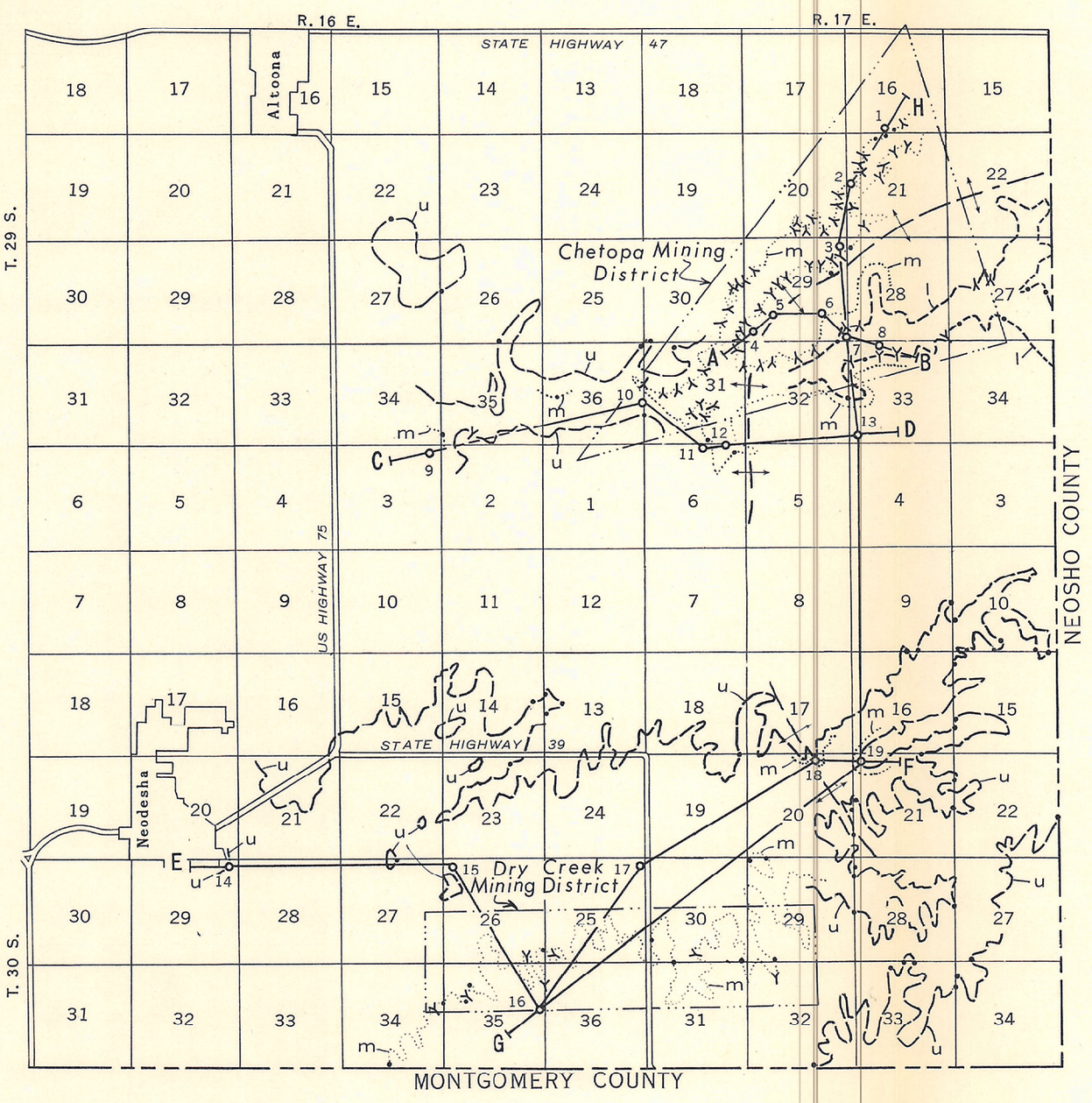



## MAP EXPLANATION

Line of cross section

Coal mine

Coal outcrop

Limit of Coal-mining District

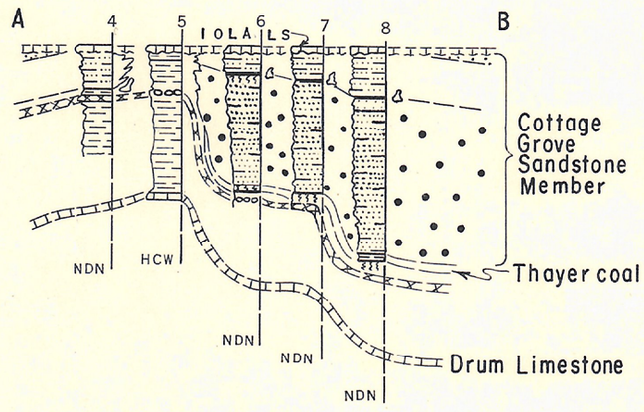
Approximate crest of anticlinal uplift

Coal bed at base of reddish-weathering sandstone

Coal bed at base of platy sandy siltstone

Coal bed at base of thin bedded silty sandstone

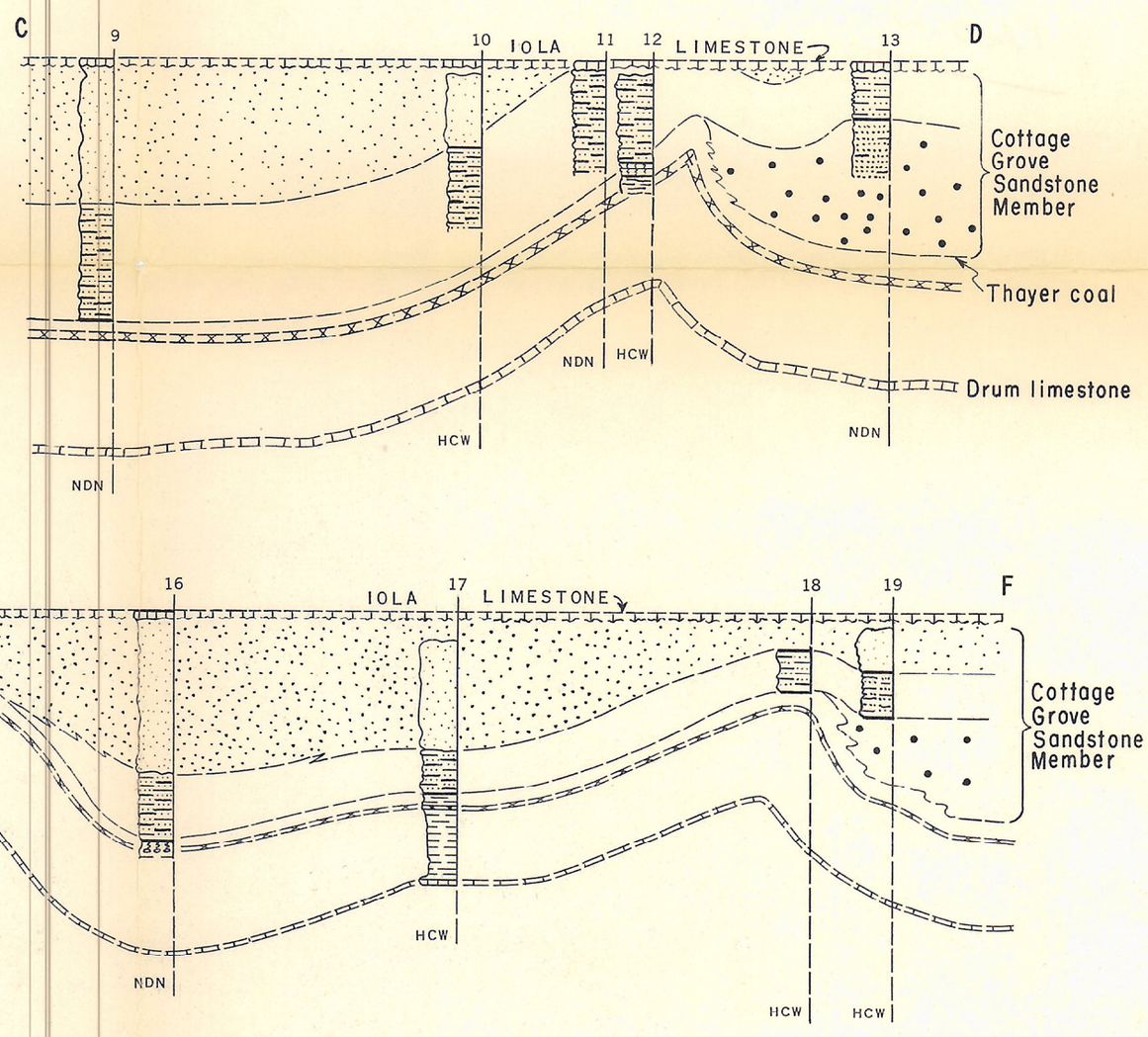
(Coal mine data largely from Schoewe, 1944)

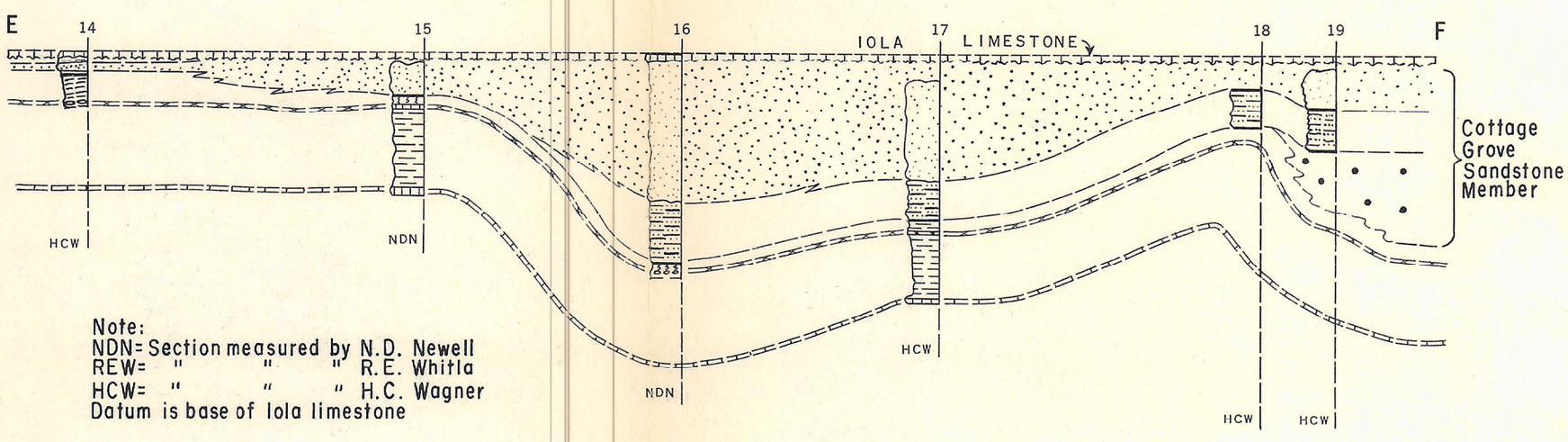


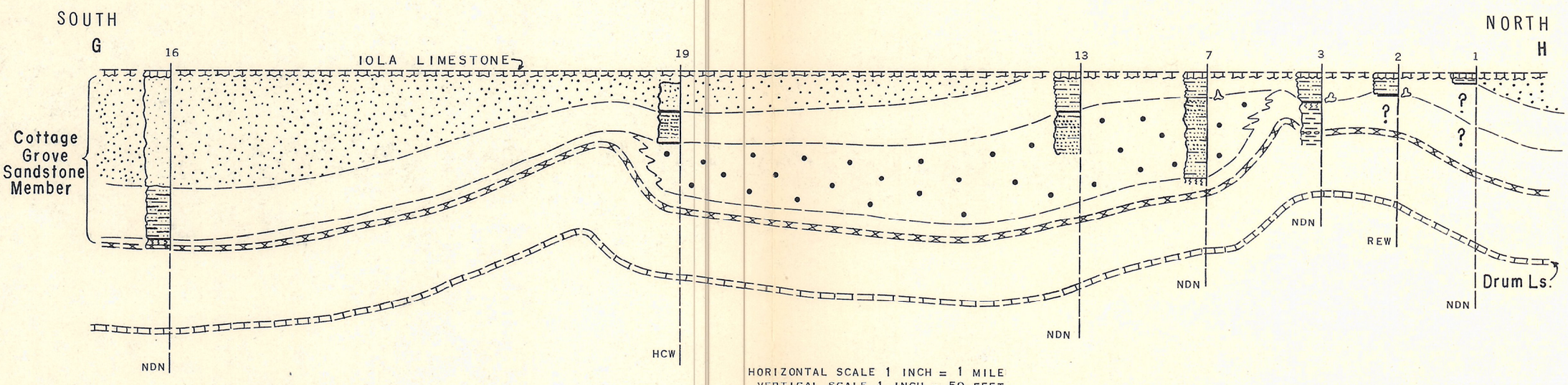

## EXPLANATION FOR MEASURED SECTIONS

- Gradational contact
- Thin-bedded sandstone reddish-weathering
- Sandy siltstone whitish, platy
- Silty sandstone yellowish-gray thin-bedded
- Gray shale
- Unconformity
- Limestone gray, fossiliferous
- Limestone Orange, clayey (and nodular shale)
- Coal and underclay
- Coal associated with silicified wood

Note:
NDN= Section measured by N.D. Newell
REW= " " " R.E. Whitla
HCW= " " " H.C. Wagner
Datum is base of Iola limestone



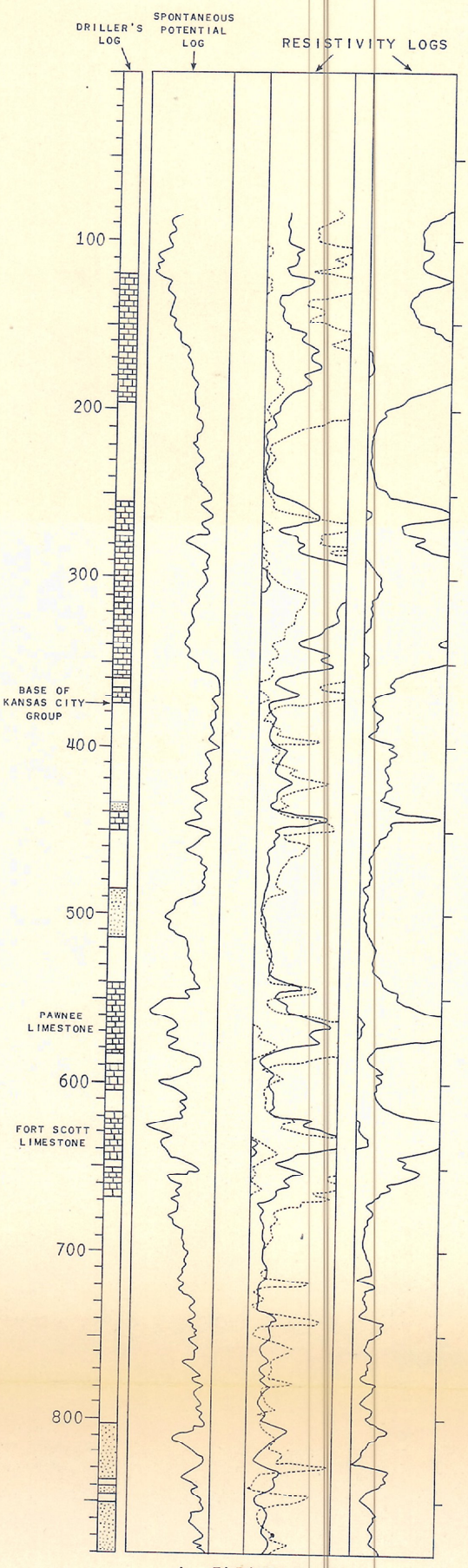




HORIZONTAL SCALE 1 INCH = 1 MILE
VERTICAL SCALE 1 INCH = 50 FEET
VERTICAL EXAGGERATION
APPROXIMATELY 100 TIMES

PLATE 4. Map and sections showing correlation of coal beds and other stratigraphic units in the Chanute Shale in southeastern Wilson County

Kansas Geological Survey
Open-file Report 67-6

CREST OIL AND GAS CO. MULLEN NO. 3
Sec. 21 , T. 29 S., R. 16 E.
T. D. 880'

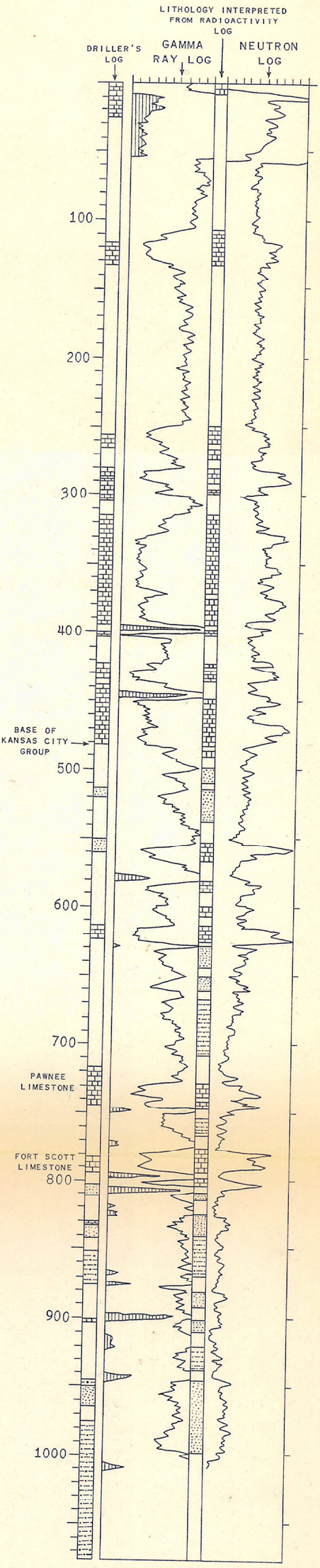



A. ELECTRIC LOG

EXPLANATION

Limestone
Sandstone
Shale
Sandy shale
Black shale in gamma ray log
Lateral A016' record in resistivity log

BUFFALO OIL CO. MOFFIT NO. 1
Sec. 30, T. 27 S., R. 17 E.
T. D. 1075'




B. RADIOACTIVITY LOG

PLATE 5. Typical electric, radioactivity, and drillers' logs from Wilson County.

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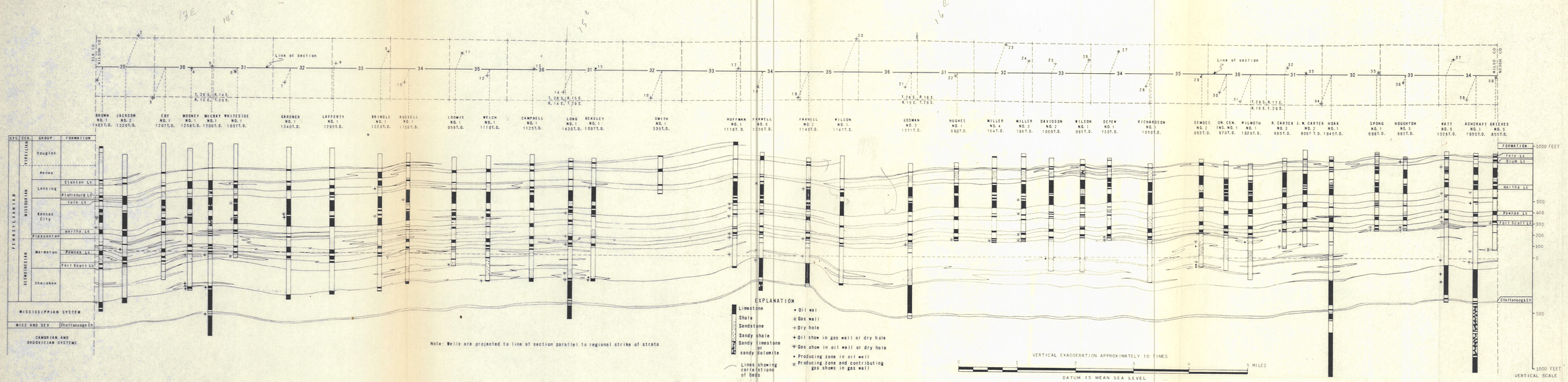


PLATE 6. East-west subsurface cross-section across central Wilson County.

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Plate 6

Plate 7




VERTICAL SCALE 1 INCH = 100 FEET

EXPLANATION

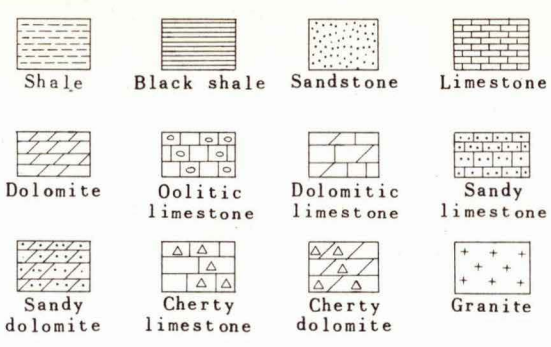


PLATE 7. Generalized well log showing important stratigraphic units and producing zones in the subsurface of Wilson County.

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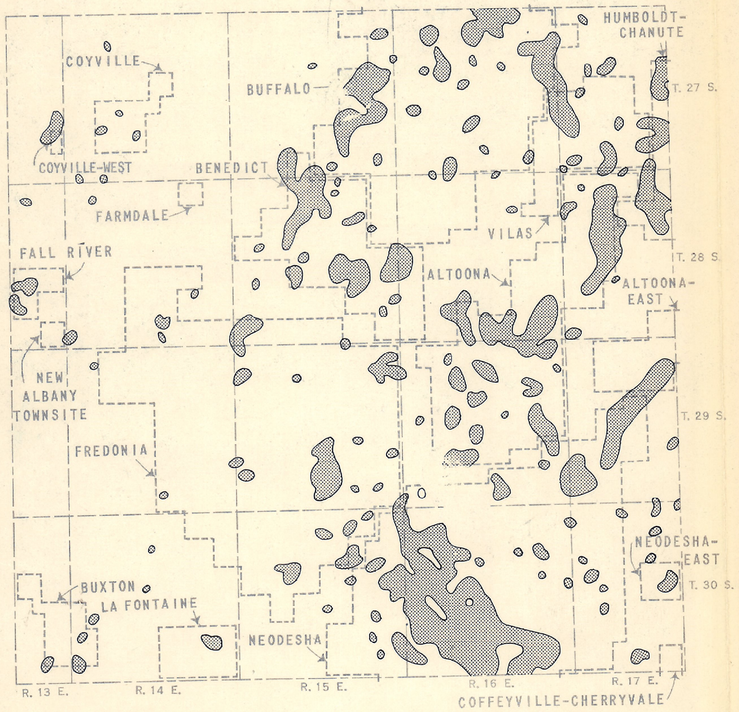
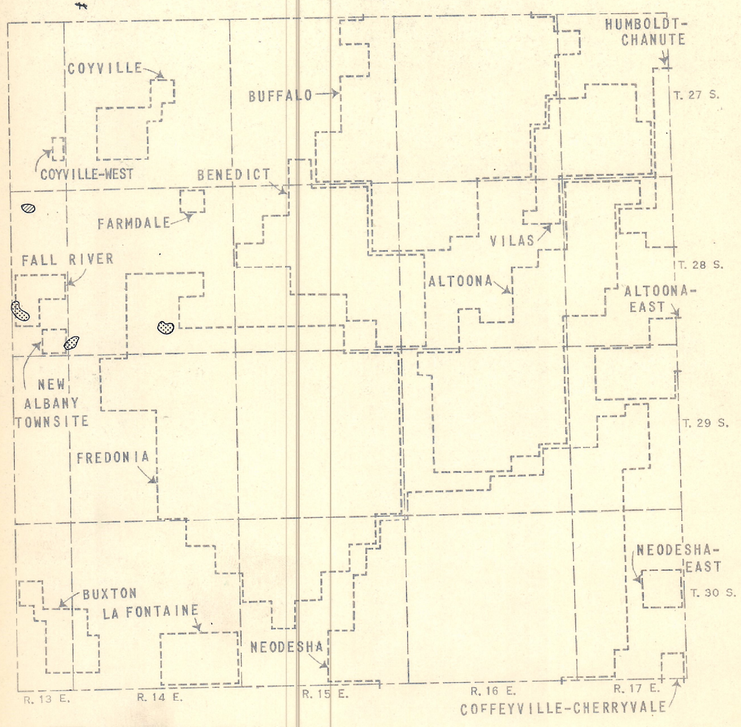


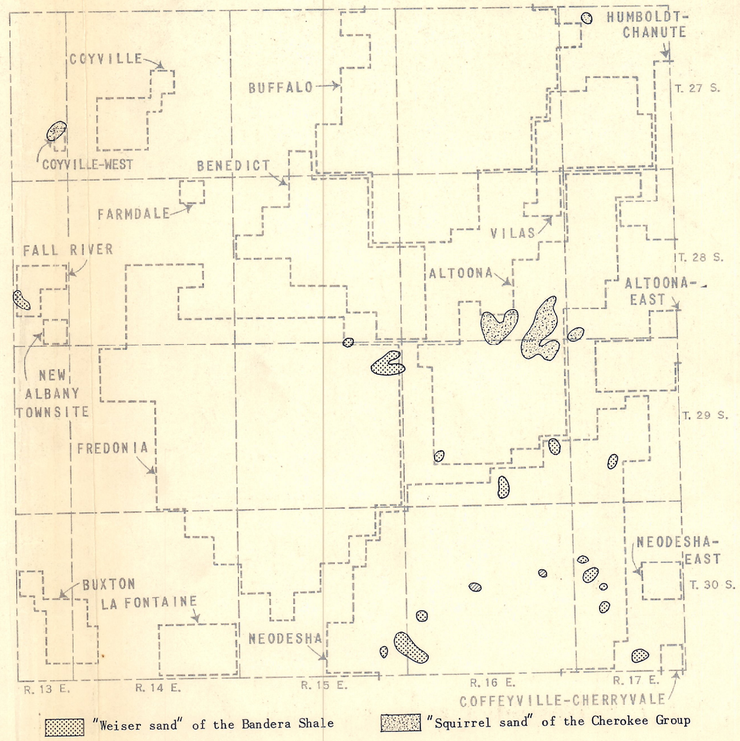

A. Areas from which oil has been produced in Wilson County




Sandstone in the Vilas Shale

"New Albany sand" of the Chanute Shale

B. Areas from which oil has been produced from the Vilas Shale and the Chanute Shale

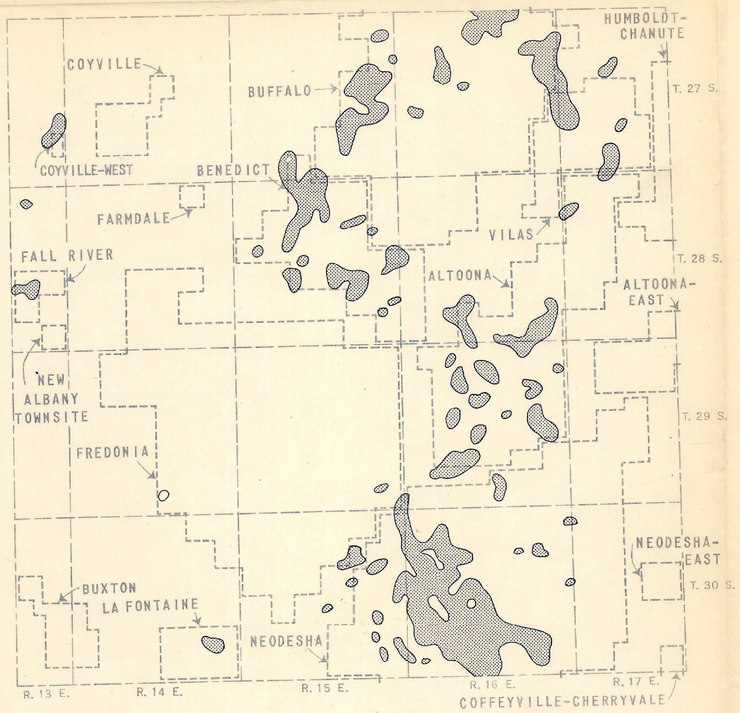



"Weiser sand" of the Bandera Shale

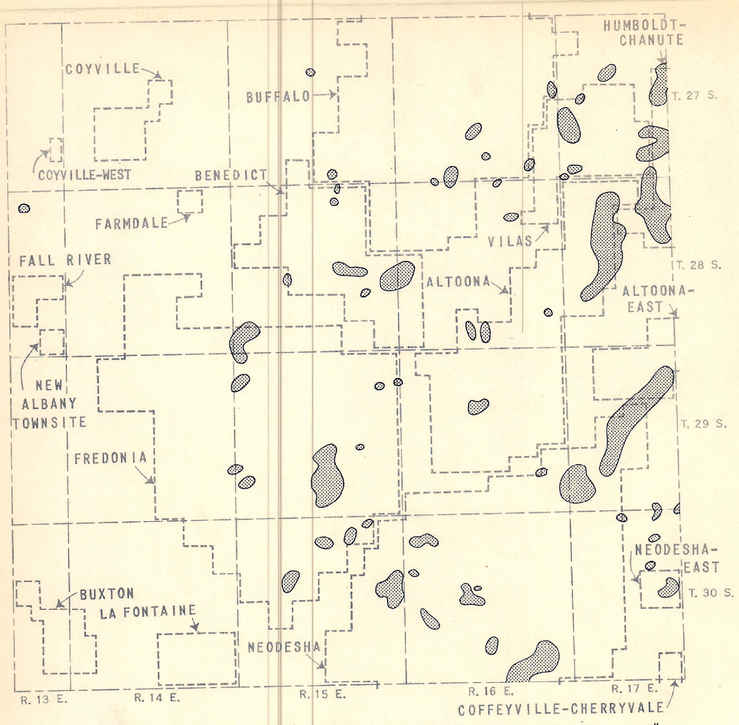
"Peru sand" of the Labette Shale

"Squirrel sand" of the Cherokee Group

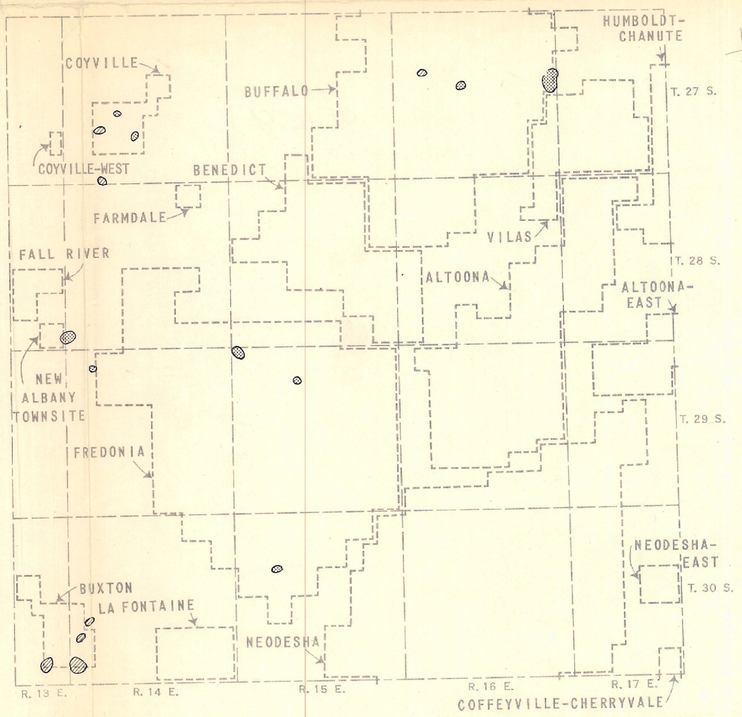
C. Areas from which oil has been produced from the Bandera Shale, the Labette Shale, and the Cherokee Group




D. Areas from which oil has been produced from the "First Bartlesville sand" of the Cherokee Group




E. Areas from which oil has been produced from the "Second Bartlesville sand" of the Cherokee Group




"Mississippi lime"

"Arbuckle"

F. Areas from which oil has been produced from rocks of Mississippian age and of Ordovician age

PLATE 10. Maps showing areas of oil production in Wilson County

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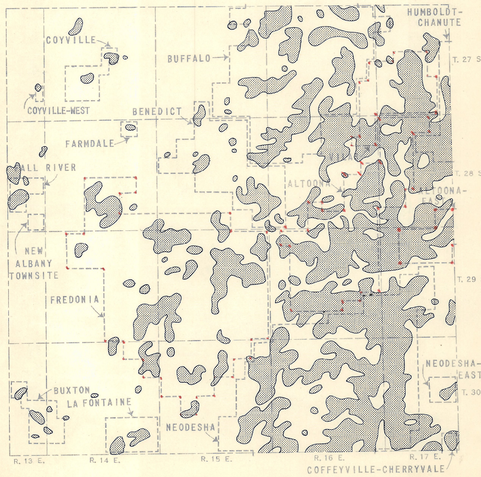
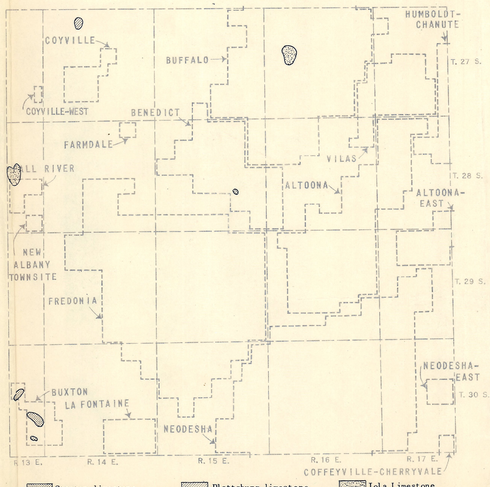
Plate 10

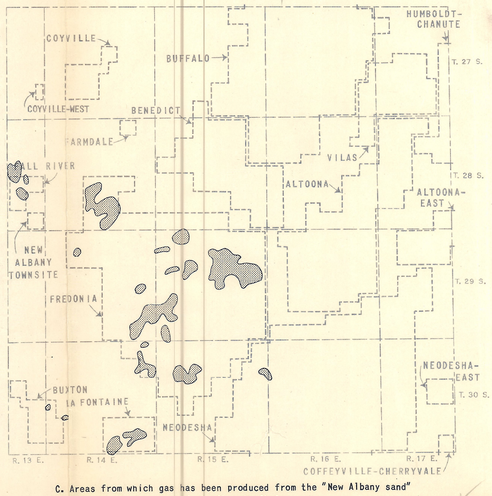



A. Areas from which gas has been produced in Wilson County

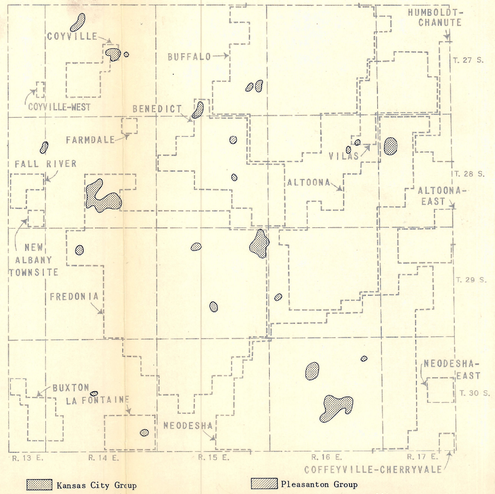



Stanton limestone  Plattsburg limestone  Iola Limestone

B. Areas from which gas has been produced from the Stanton, Plattsburg, and Iola Limestones

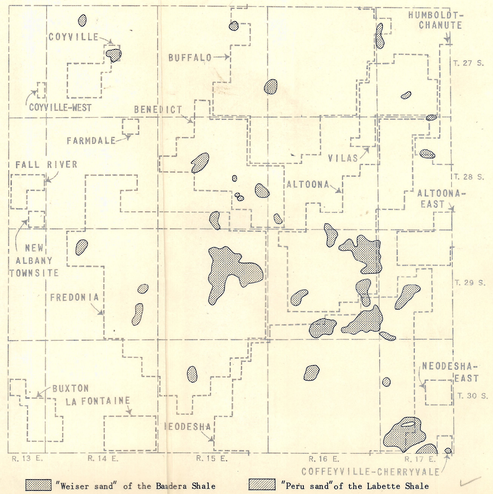



C. Areas from which gas has been produced from the "New Albany sand" of the Chanute Shale



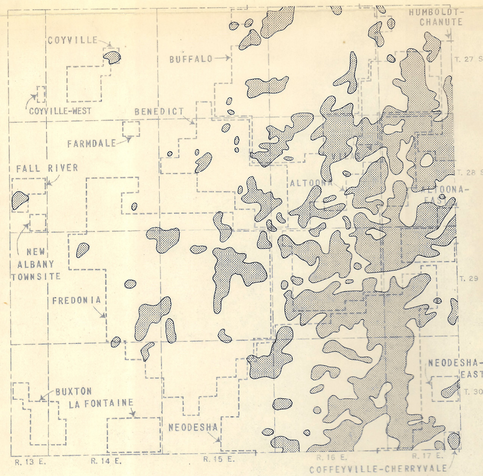

Kansas City Group  Pleasanton Group

D. Areas from which gas has been produced from the Kansas City and Pleasanton Groups

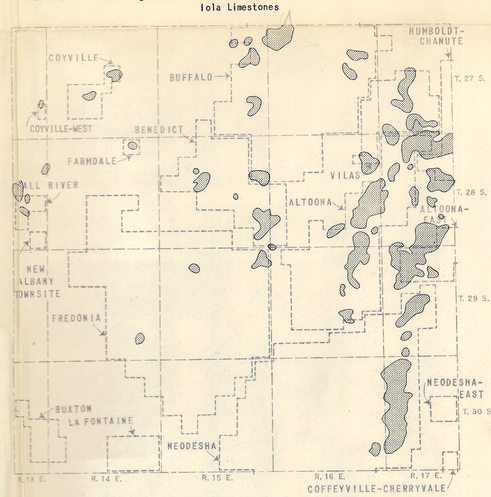



"Weiser sand" of the Bandera Shale  "Peru sand" of the Labette Shale

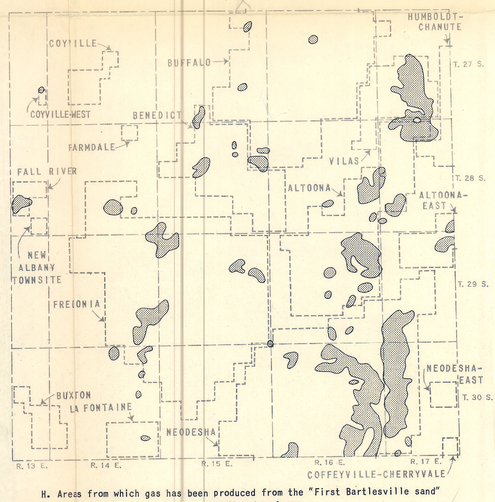
E. Areas from which gas has been produced from the Bandera and Labette Shales



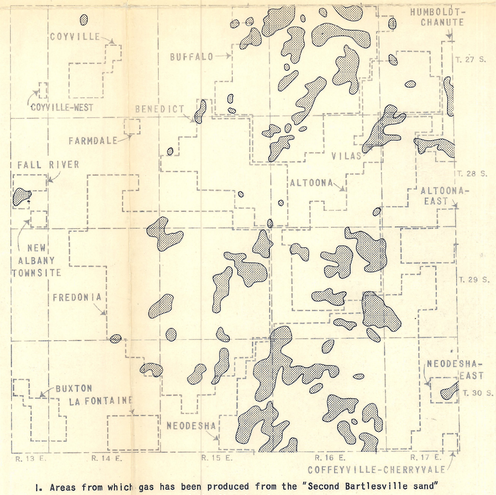

F. Areas from which gas has been produced from the "Oswego lime"



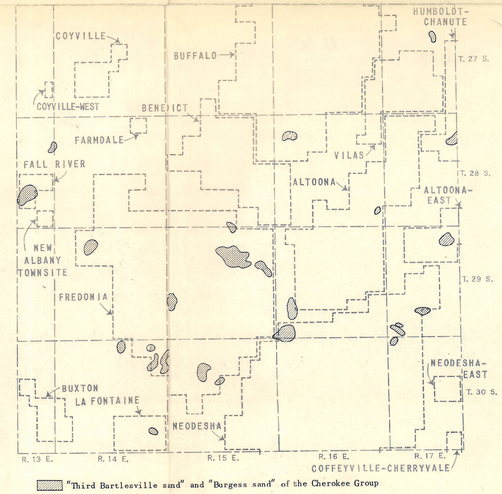

G. Areas from which gas has been produced from the "Squirrel sand" of the Cherokee Group




H. Areas from which gas has been produced from the "First Bartlesville sand" of the Cherokee Group




I. Areas from which gas has been produced from the "Second Bartlesville sand" of the Cherokee Group




"Third Bartleaville sand" and "Burgess sand" of the Cherokee Group  "Mississipi lime"  "Arbuckle"

J. Areas from which gas has been produced from the lower part of the Cherokee Group and rocks of Mississippian and of Ordovician age

PLATE II. Maps showing areas of gas production in Wilson County.

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