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CARL C. BRANSON, *Director*

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GEOLOGY AND OIL AND GAS RESOURCES OF CRAIG COUNTY, OKLAHOMA

PART I.—GEOLOGY OF CRAIG COUNTY

CARL C. BRANSON AND GEORGE G. HUFFMAN

Assisted by
Robert B. Branson, Cassius M. Cade, III, Louie P. Chrisman,
Charles D. Claxton, James R. Faucette, Clarence Lohman, Jr.,
Daniel M. Strong, L. E. Thomas, and John H. Warren

PART II.—OIL AND GAS IN CRAIG COUNTY

DANIEL M. STRONG AND GEORGE G. HUFFMAN

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Geology and Oil and Gas Resources of Craig County, Oklahoma

ABSTRACT

Craig County, Oklahoma, comprises an area of 764 square miles northwest of the Ozark uplift. Sedimentary strata dip gently westward as part of the Prairie Plains homocline.

Rocks exposed at the surface range in age from Late Devonian Chattanooga Formation to Middle Pennsylvanian Marmaton Group of Late Desmoinesian age. The black Chattanooga Shale (Noel Member) is succeeded disconformably by the St. Joe Group of Late Kinderhookian and early Osagean age and by the Reeds Spring and Keokuk Formations of Osagean age. The Meramecian is represented in subsurface by the Warsaw Limestone, which has been correlated in part with the Moorefield Formation on the south and west flanks of the Ozark uplift. Chesterian rocks, comprising the Hindsville Limestone and the Fayetteville Shale, rest unconformably upon the eroded Keokuk and Warsaw surface. The Late Mississippian Pitkin Limestone and overlying Early Pennsylvanian Hale and Bloyd Formations are absent because of regional truncation.

The Middle Pennsylvanian Atoka Formation is represented by cross-bedded channel sandstones now preserved in outliers in southeastern Craig County. The succeeding Krebs Group includes the Hartshorne, McAlester, Savanna, and Boggy Formations. These units are cyclic and are composed of sandstones, shales, thin coal beds, and thin limestones. Important named units include the Warner, Bluejacket, and Taft Sandstones.

The Cabaniss Group is represented by the Senora Formation; the underlying Stuart and Thurman Formations as developed in the Arkoma basin are absent because of regional truncation and offlap-overlap relationships. The beds are cyclic and include several important sandstones, limestones, shales, and coals. Some of the principal marker beds are the Tiawah Limestone, Chelsea Sandstone, Verdigris Limestone, and the Breezy Hill Limestone. The overlying Marmaton Group is composed of the Fort Scott (Oswego) Limestone, Labette Shale, Pawnee Limestone, Bandera Shale, and Altamont Limestone.

Two new names proposed for sandstone units of member rank are (1) Dickson Sandstone Member of the Savanna Formation, for exposures in eastern Craig County, T. 26 N., R. 20 E., and (2) Goldenrod Sandstone Member of the Senora Formation, for exposures in northeastern Craig County, T. 29 N., R. 20 E.

Subsurface strata beneath the Chattanooga Formation include the Arbuckle Group of dolomite and dolomitic sandstones, ranging from 750 to 1,500 feet in thickness, and Lamotte Sandstone (0 to 100 feet). The Lamotte and, where it is absent, the Arbuckle rest with unconformity upon a Precambrian complex of red, coarse-grained granite, andesitic tuff, and dacite.

In the subsurface of northern Craig County, a gray-green, dolomitic, silty shale containing abundant *Tasmanites* (''spores'') overlies the typical black Chattanooga Shale (Noel facies) and underlies the typical St. Joe as known in surface exposures. This unit is referred to as ''Kinderhook shale'' and is tentatively considered a facies of the upper part of the Chattanooga; its relationships to the St. Joe of the subsurface are as yet unsolved.

The regional westward dip of sedimentary strata in Craig County ranges from 15 to 50 feet per mile and averages 30 feet. The regional dip is interrupted locally by folding and normal faulting. Principal structural features include the Horse Creek anticline, Whiteoak Creek fault, Miami syncline, Dupree fault, Big Cabin fault, Little Pryor Creek fault, Booker School fault, Condry School fault, and Welch fault.

Mineral production in Craig County increased from \$373,065 in 1958 to \$1,018,863 in 1963. In order of value, the principal products are coal, oil, gas, and stone (McDougal and Ham, 1964). Future oil and gas possibilities appear to be limited, with deeper Arbuckle dolomite offering the greatest promise for future development. Additional shallow discoveries in the ''Burgess'' sand, ''Mississippi chat'' (Warsaw), and the Bartlesville are anticipated.

Part I.—Geology of Craig County

Carl C. Branson, George G. Huffman, and others

Junior authors are Robert B. Branson, Cassius M. Cade, III, Louie P. Chrisman, Charles D. Claxton, James R. Faucette, Clarence Lohman, Jr., and Daniel M. Strong. L. E. Thomas and John H. Warren contributed to the surface mapping.

INTRODUCTION

Location and extent of area.—Craig County comprises 764 square miles in northeastern Oklahoma (fig. 1). It is bounded on the east by Delaware and Ottawa Counties, Oklahoma; on the north by Cherokee and Labette Counties, Kansas; on the west by Nowata County and a portion of Rogers County, Oklahoma; and on the south by Rogers and Mayes Counties, Oklahoma.

The county line between Craig County and Ottawa County is at the "intersection with the center line of the Neosho River" (Constitution of the State of Oklahoma, article 17, section 8) of the state line between Kansas and Oklahoma. The Vinita topographic quadrangle of the U. S. Geological Survey, edition of March 1901 (surveyed in 1896-1897) and the edition of June 1913 (surveyed in

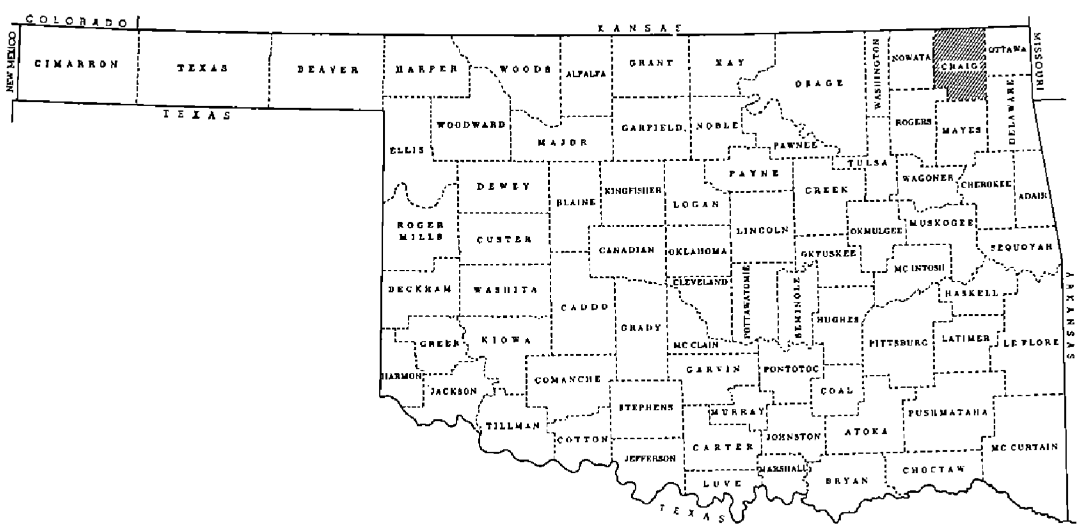

Figure 1. Index map of Oklahoma showing location of Craig County.

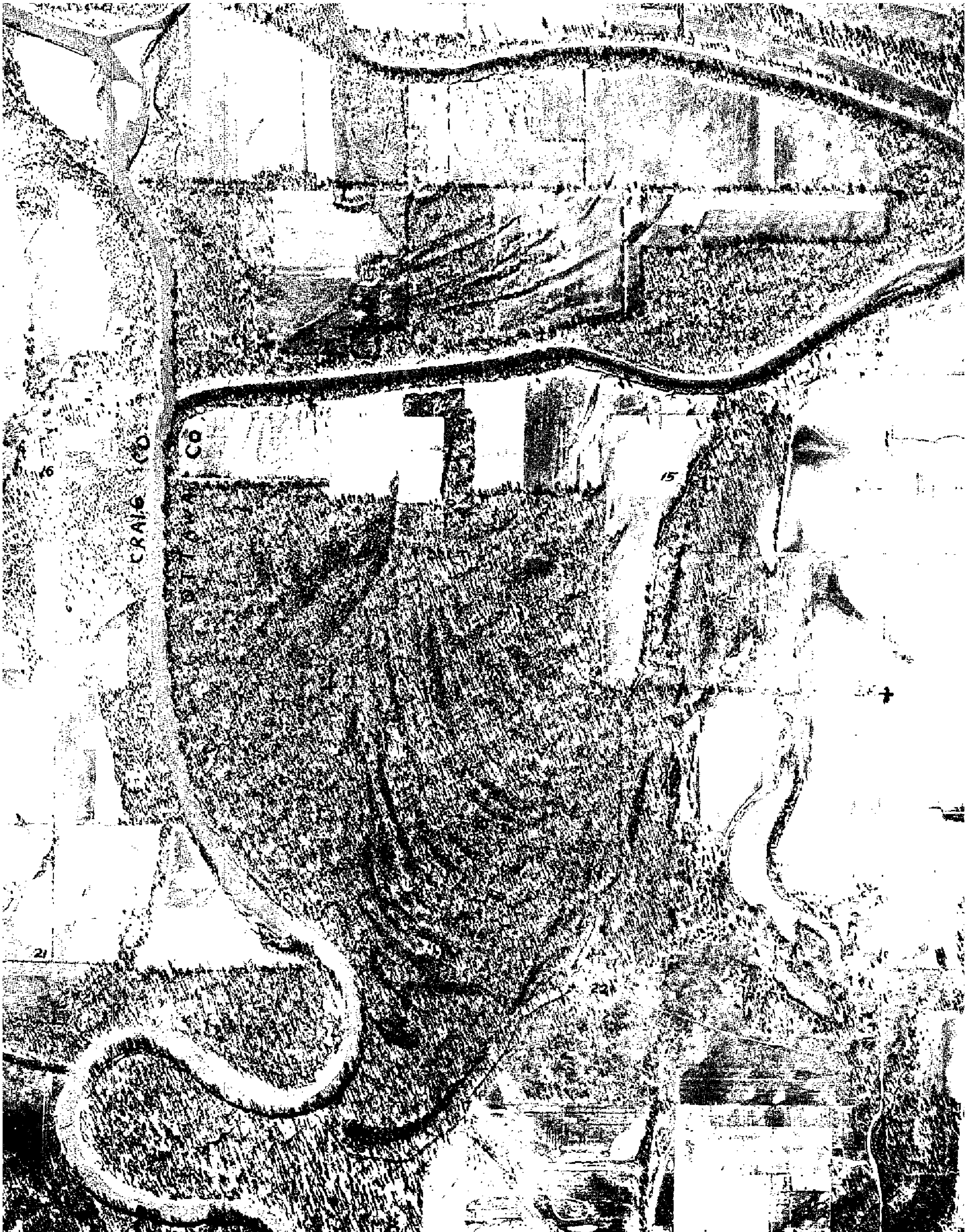

Figure 2. Airplane photograph of Neosho River crossing the Kansas-Oklahoma line, taken in 1941. Note the old channel partially filled with water, the cutoff, and the old meander scars.

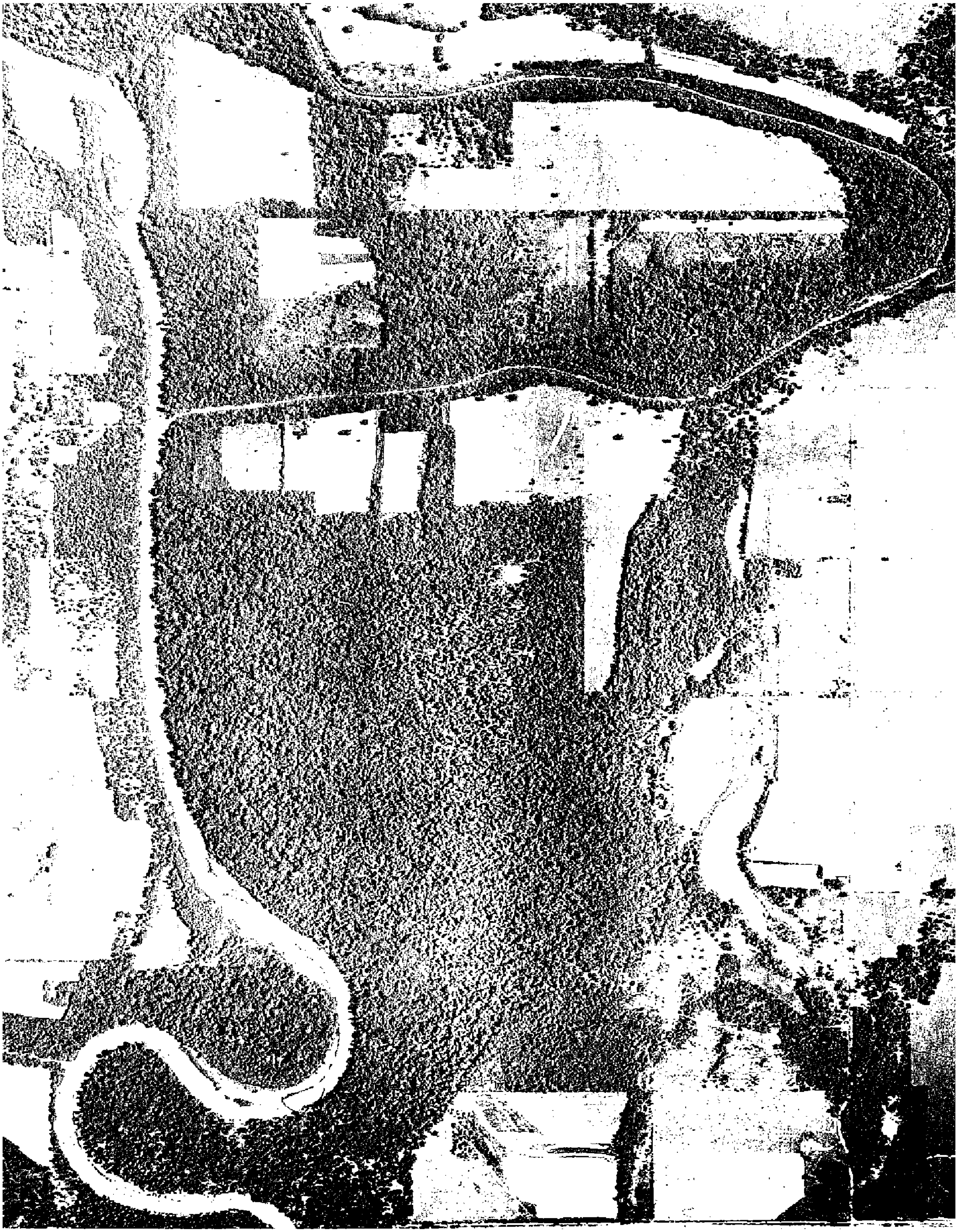

Figure 3. Airplane photograph of Neosho River crossing the Kansas-Oklahoma line, taken in 1958. Note that the old channel is almost abandoned, that almost all of the water now flows through the cutoff, and that the meander scars are no longer conspicuous.

1911-1912) both show the river entering the State in NW¼ sec. 14, T. 29 N., R. 21 E. In or about the year 1914, a cutoff occurred, and the main course of the river flows southward in sec. 16 (figs. 2, 3). The old channel is filled only by floods.

Craig County is roughly rectangular in outline, measuring 34 miles north and south and 24 miles east and west.

Purpose and scope of investigation.—Field work for this project was begun in the summer of 1951, at which time graduate students from The University of Oklahoma, working under the direction of Professors C. C. Branson and G. G. Huffman, started a detailed mapping program of this immediate area to complement work already underway in the adjacent Ozark uplift (Huffman, 1958). The eastern portion of Craig County was mapped by L. E. Thomas, Robert B. Branson, Louie P. Chrisman, and Charles D. Claxton; the western portion was mapped by James R. Faucette, Cassius M. Cade, III, and Clarence Lohman, Jr. Detailed mapping of the Fort Scott Limestone in western Craig County was done by John H. Warren, at that time on the staff of the Oklahoma Geological Survey.

The present report is a compilation of data assembled from maps made during the progress of this project and of theses upon portions of Craig County.

Previous investigations.—The earliest geological work in this area was by Drake (1897), who discussed the general stratigraphy and structure of the rocks of northeastern Oklahoma, subdivided the Pennsylvanian into the "Lower Coal Measures" and the "Upper Coal Measures," and made a sketch map showing the approximate position of the Mississippian-Pennsylvanian contact.

A preliminary study in Craig County was made by Siebenthal (1907). Ohern (1910) discussed the stratigraphy of older Pennsylvanian rocks in northeastern Oklahoma and, in the years 1908 to 1911, mapped the Vinita and Nowata quadrangles (Ohern, 1914).

Snider (1912, p. 34-49) discussed the stratigraphy and structure of northeastern Oklahoma and included a map of the Pennsylvanian-Mississippian contact across southeastern Craig County, and he included a discussion of stratigraphy, structure, and paleontology of the Vinita area in a report on northeastern Oklahoma (1915). The physiography of the region was discussed by Snider in 1917 (p. 59-64, 81-82).

Subsurface stratigraphy of northeastern Oklahoma was discussed by Aurin, Clark, and Trager (1921). Shannon (1926, p. 64-69) included the rocks of Craig County in his discussion on the Pennsylvanian rocks north of the Arkansas River. Gould (1925, p. 57-68) described the Mississippian and Pennsylvanian beds which crop out in Craig County.

The geology of Craig County was reviewed by Bloesch (1928) in one of a series of articles on oil and gas in Oklahoma. A portion of Craig County was mapped by Austin (1946) for a thesis on the Chelsea Sandstone. Howe (1951) studied the "Cherokee" group in northeastern Oklahoma and redefined the Bluejacket Sandstone at the type locality.

Since June 1951, graduate students at The University of Oklahoma have completed several theses covering parts of Craig County. These include the work of R. B. Branson (1952), Cade (1952), Chrisman (1951), Claxton (1952), Faucette (1954), and Lohman (1952). Closely related studies in adjacent areas include those by Reed, Schoff, and Branson (1955), Simpson (1959), and Gruman (1954).

Information on the geology of southeastern Craig County was included in a report by Huffman (1958). A report on the subsurface geology of Craig, Mayes, eastern Nowata and eastern Rogers Counties was completed by Strong (1961). Palynological studies involving the Mineral coal have been completed by Urban (1962); the paleoecology of the Iron Post cyclothem has been done by Gibson (1961); and the palynology and stratigraphy of the Drywood coal were studied by Bordeau (1963).

GEOGRAPHY

Climate.—Craig County is in a belt of warm, humid, subtropical- to continental-type climate. Summers are warm, with an average July temperature of approximately 80 degrees. Winters are generally mild, with an average January temperature of 38 degrees. Precipitation is moderate, with an average of 42.27 inches per year. Between the first killing frost in late October and the last killing frost in early April, is an average annual growing season of 200 days.

Cities and towns.—Vinita, county seat of Craig County, has a population of 6,027, according to the 1960 census, and is the only sizable city in the county (fig. 4). Smaller towns include Bluejacket (1960 population, 245), Centralia (1960 population, 80), Big Cabin (1960 population, 228), Ketchum (1960 population, 255), and Welch (1960 population, 557). Small communities, including the typical church, store, school, and a few houses, are Banzet, Hollow, Pyramid Corners, Cornatzar, and Whiteoak.

Roads and railroads.—Craig County has an excellent highway and road system. State Highway 10 crosses the county from west to east, passing through Welch. U. S. Highway 60 from Nowata and U. S. Highway 66 from Chelsea enter the county from the west, merge five miles west of Vinita, and continue eastward through Afton in Ottawa County. U. S. Highway 69 enters from the south and joins U. S. Highways 60 and 66 west of Vinita. State Highway 82 from Spavinaw and Langley enters southeastern Craig County and joins U. S. Highways 60-66-69 four miles east of Vinita. State Highway 85 connects State Highway 82 and Ketchum in the southeast corner. State Highway 2 follows U. S Highway 69 from Big Cabin to Vinita, turns northward at Vinita, joins U. S. Highway 59 at Welch, and continues to the Kansas line. State Highway 25 extends from Bluejacket and joins State Highway 2 at Pyramid Corners.

The Will Rogers Turnpike (Interstate Highway 44) enters southern Craig County 3½ miles southwest of Big Cabin and continues diagonally northeastward across southeastern Craig County, passing through the east side of Vinita.

Figure 4. Airplane photograph of Vinita, Oklahoma, taken in 1958. Note the Will Rogers Turnpike and interchange in the lower right-hand corner of the picture.

Adequate section-line roads provide Craig County with a good network of secondary routes.

Three major railroad lines cross Craig County. The St. Louis-San Francisco (Frisco) Railway crosses southern Craig County on the Tulsa-St. Louis route, and the Missouri-Kansas-Texas Railroad runs north-south from Big Cabin through Vinita and Welch into Kansas. The Kansas, Oklahoma and Gulf Railroad cuts across the southeast corner of the county near Ketchum.

Industries.—Craig County is essentially an agricultural area with grazing and crop growing. Several large cattle ranches occupy the northwestern part. Coal, stone, petroleum, and natural gas constitute the mineral industry which produced an income of $1,018,863 during 1963 (McDougal and Ham, 1964). Some manufacturing is done in Vinita, the home of a large Munsingwear plant in which ladies' hosiery is made.

Topography and drainage.—All of Craig County except the southeastern part is in the Claremore Cuesta Plains physiographic province (Curtis and Ham, 1957), which adjoins the Ozark uplift on the west. Here gently dipping shales and sandstones of Late Mississippian and Pennsylvanian age give rise to an undulating surface characterized by eastward-facing escarpments and by buttes capped by resistant limestones and sandstones and separated by wide valleys developed on weakly resistant shales. Southeastern Craig County is in the Neosho Lowland, a maturely dissected region underlain by Mississippian chert, limestone, and shale.

The area lies in the drainage basin of the Arkansas River and its major tributary, the Neosho (or Grand) River. A small portion in the northeast corner of Craig County is drained by the Neosho and its tributaries, Russell Creek and Mud Creek. Most of Craig County is drained by Big Cabin Creek and its tributaries, Wolfe Creek, Deer Creek, Middle Fork, West Fork, Thompson Creek, Whiteoak Creek, Bull Creek, Locust Creek, Little Cabin Creek, and Mustang Creek. Big Cabin Creek enters the Neosho River near Pensacola in Mayes County. The extreme western part of the county is drained by Big Creek, Salt Creek, and Lightning Creek, westward-flowing tributaries of the Verdigris River. Pryor Creek and Rock Creek, tributaries of the Neosho River, drain the extreme southwest corner.

Relief and elevations.—The highest elevation noted on the topographic map of the Vinita quadrangle is 1,001 feet. The topographic feature is a small hill enclosed by the 1,000-foot contour near Grant Mound School in T. 29 N., R. 19 E. The lowest elevation of 600+ feet is on Big Cabin Creek on the Mayes-Craig county line. This difference gives a maximum relief of approximately 400 feet.

STRATIGRAPHY

General Statement

Rocks exposed at the surface in Craig County range in age from Late Devonian (Chattanooga Formation) to Middle Pennsylvanian (Marmaton Group). The black Chattanooga Shale (Noel Member) is succeeded disconformably by the St. Joe Group of late Kinderhookian and early Osagean age and the Reeds Spring and Keokuk Formations of Osagean age. The Chesterian Series, comprising the Hindsville Limestone and Fayetteville Shale, rests with great unconformity upon the eroded Keokuk surface. Late Mississippian Pitkin Limestone and overlying Early Pennsylvanian Hale and Bloyd Formations are absent through regional truncation. Middle Pennsylvanian beds include the Atoka Formation and the overlying Krebs, Cabaniss, and Marmaton Groups. The Krebs Group includes the Hartshorne, McAlester, Savanna, and Boggy Formations. The Cabaniss Group is represented by the Senora Formation; underlying Stuart and Thurman Formations are absent owing to regional truncation and northward overlap. The Marmaton Group is composed of the Fort Scott Limestone, Labette Shale, Pawnee Limestone, Bandera Shale, Altamont Limestone, and higher units cropping out west of Craig County.

Late Devonian Rocks

Chattanooga Formation.—The Noel Member of the Chattanooga Formation is a black, fissile, carbonaceous shale. Thickness in this area ranges from 40 to 75 feet. Cone-in-cone structure is common near the base.

The Chattanooga (Noel Shale) is exposed in Craig County only along the east bank of Big Cabin Creek in secs. 23, 26, T. 24 N., R. 20 E., where a maximum of 25 feet may be observed along the axis of a small anticlinal uplift. The top 3 inches is green and nonfissile.

The base of the Chattanooga is not exposed in Craig County, but in nearby areas, as at Spavinaw and in the subsurface of eastern Craig County, it rests with great unconformity upon eroded Arbuckle dolomite.

Mississippian System

KINDERHOOKIAN AND OSAGEAN SERIES

*St. Joe Group**.—The St. Joe Group in northeastern Oklahoma comprises three well-defined subdivisions. The uppermost (Pierson Formation) includes a maximum of 25 feet of gray, thick-bedded, finely crystalline limestone, which passes locally into a thick, crinoidal reef facies. The middle portion consists of 3 to 5 feet of gray-green, calcareous shale or marlstone (Northview Formation). The basal part (Compton Formation) is a gray, nodular-weathering, heavy-bedded limestone with a maximum thickness of 10 feet.

The St. Joe Group is exposed in Craig County only along the east bluff of Big Cabin Creek in secs. 23, 26, T. 24 N., R. 20 E., where approximately 27 feet is present. The base is a massive limestone unit, the Compton, 2.5 feet thick. This bed is succeeded by 4 feet of gray-green limestone and shale, largely covered (Northview?), which weathers to form a recess beneath the massive ledges of the Pierson Limestone (20 feet thick). A small cave occurs in the Pierson, and masses of limestone 40 feet by 20 feet by 15 feet have fallen from the undermined base. The St. Joe is unconformable with the subjacent Chattanooga Shale.

Reeds Spring Formation.—The Reeds Spring Formation consists of gray to blue, fine-grained limestone interbedded with layers of gray-blue to tan chert. The beds are resistant to erosion and, where exposed in stream valleys, form nearly vertical cliffs. Thickness of the Reeds Spring ranges from 130 to 175 feet in adjacent areas. Good exposures are few in Craig County and thickness there has not been established. A thickness of 71 feet of interstratified chert and limestone was reported by Ohern (1914) for the exposure on the east bank of Big Cabin Creek in sec. 23, T. 24 N., R. 20 E.

The Reeds Spring rests unconformably upon the St. Joe Group.

Keokuk Formation.—The Keokuk consists of massive, white to buff and gray-mottled, fossiliferous chert and irregular masses of gray, compact, fine-grained limestones. Locally reefs or bioherms of coarse-crystalline, crinoidal limestone are present. The

* In 1952, Beveridge and Clark raised the St. Joe to group rank and defined it as comprising the Compton, Northview, and Pierson Formations. This procedure was followed by Huffman (1958) for comparable rocks in northeastern Oklahoma. This usage is not now followed by the Missouri Geological Survey (Howe and others, 1961), which placed Compton and Northview in the Chouteau Group of Kinderhookian age and compared the Pierson Limestone with the type St. Joe of Arkansas.

cherty phase of the Keokuk is typically fractured and brecciated and weathers white and tripolitic. Continued weathering and percolation of water produce a buff to reddish, "vermicular," tripolitic residue.

Thin-section studies (R. B. Branson, 1952, p. 20) indicate that the Keokuk chert is a secondary replacement of a coarse-crystalline calcarenite by less soluble silica. Scattered through the chert are tiny calcite fragments of probable echinoderm plates which show incomplete chertification.

The Keokuk Formation is the surface rock in approximately 50 square miles in southeastern Craig County. Nowhere in this area is the true thickness known because top and bottom are not exposed in any single section. Measured sections in nearby areas indicate a thickness ranging from 60 to 120 feet. The Keokuk lies unconformably upon the Reeds Spring and is succeeded unconformably by the Hindsville Limestone.

The Keokuk Formation is abundantly fossiliferous. Preservation of fossils is poor and is generally in the form of casts and molds from which accurate identification is almost impossible. R. B. Branson (1952, p. 25) listed 27 species of bryozoans, brachiopods, and trilobites from collections along Mustang Creek, sec. 32, T. 24 N., R. 21 E. Some of the more abundant forms in the Keokuk are *Brachythyris suborbicularis* (Hall), *Werriea keokuk* (Hall), *Spirifer keokuk* Hall, *Spirifer mortonanus* Miller, *Polypora varsoviensis* Prout, and *Griffithides* sp.

CHESTERIAN SERIES

Hindsville Formation.—The Hindsville is a gray, medium-crystalline, thick-bedded, oölitic, fossiliferous limestone (fig. 5). Locally, soft, green, calcareous shales occur in lower portions. The upper part is calcareous and silty and weathers to a porous, buff siltstone.

Thin-section studies (R. B. Branson, 1952, p. 27) show that the Hindsville is composed of well-sorted and well-rounded fossil fragments and associated oölites. Most of the fossil fragments appear to be recrystallized fragments of echinoderm plates. Nuclei of the oölites are tiny fragments of arenaceous limestone or chert.

The Hindsville Formation is exposed at the surface of approximately 15 square miles in southeastern Craig County, where it unconformably overlies the Keokuk Chert and is succeeded conformably by the Fayetteville Formation. Prominent inliers of Hindsville project through the Fayetteville in sec. 7, T. 25 N., R. 21 E.; in secs. 3, 4, T. 25 N., R. 21 E.; and in secs. 15, 16, 21, 22, T. 25 N., R. 21 E.

Thickness of the Hindsville in Craig County ranges from 25 to 30 feet. Fossils are abundant and well preserved. R. B. Branson (1952, p. 34) listed 27 species of corals, crinoids, brachiopods, bryozoans, mollusks, and trilobites. Some of the more abundant forms are *Amplexizaphrentis spinulosus* (Edwards and Haime), *Agassizocrinus globosus* Worthen, *Cryphiocrinus bowsheri* (Strimple), *Athyris cestriensis* Snider, *Diaphragmus cestriensis* (Worthen), *Cranaena arkansana* Weller, *Eumetria verneuiliana* (Girty), *Flexaria arkansana* (Girty), *Kozlowskia adairensis* (Drake), *Werriea subglobosa* (Girty), *Reticulariina spinosa* (Norwood and Pratten), *Spirifer leidyi* Norwood and Pratten, and *Paladin mucronatus* (Girty).

Fayetteville Formation.—The Fayetteville Formation is essentially shale with local beds of limestone of varying lithology. Near the base are thin beds of blue-gray, iron-stained, sublithographic limestone, which weathers into subcubical blocks. A thick bed of gray,

Figure 5. Hindsville Limestone in quarry, SE¼ sec. 16, T. 25 N., R. 21 E.

medium-crystalline, fossiliferous limestone forms the upper part (fig. 6). Local beds of medium-crystalline, fossiliferous limestone occur within the main body of the shale. The shale ranges from dark gray to gray green and is calcareous. Cone-in-cone structure occurs locally in the Big Cabin area.

The Fayetteville is limited to the southeastern part of the county, where it is the surface rock in an area of approximately 40 square miles. Thickness ranges from 50 to 60 feet. The formation rests conformably upon the Hindsville and is succeeded unconformably by the Atoka and Hartshorne Formations.

An abundance of the spiral axis of the bryozoan *Archimedes* characterizes the Fayetteville of this area. Forty-seven species of corals, crinoids, blastoids, bryozoans, brachiopods, and trilobites have been collected (R. B. Branson, 1952, p. 42-43). Some of the more common of these are *Paleacis cuneata* Snider, *Michelinia meekana* Girty, *Pentremites, Agassizocrinus, Rugosochonetes chesterensis* (Weller), *Neochonetes oklahomensis* (Snider), *Cleiothyridina sublamellosa* (Hall), *Diaphragmus cestriensis* (Worthen), *Cranaena illinoisensis* Weller, *Echinoconchus alternatus* (Norwood and Pratten), *Flexaria arkansana* (Girty), *Inflatia cherokeensis* (Drake),

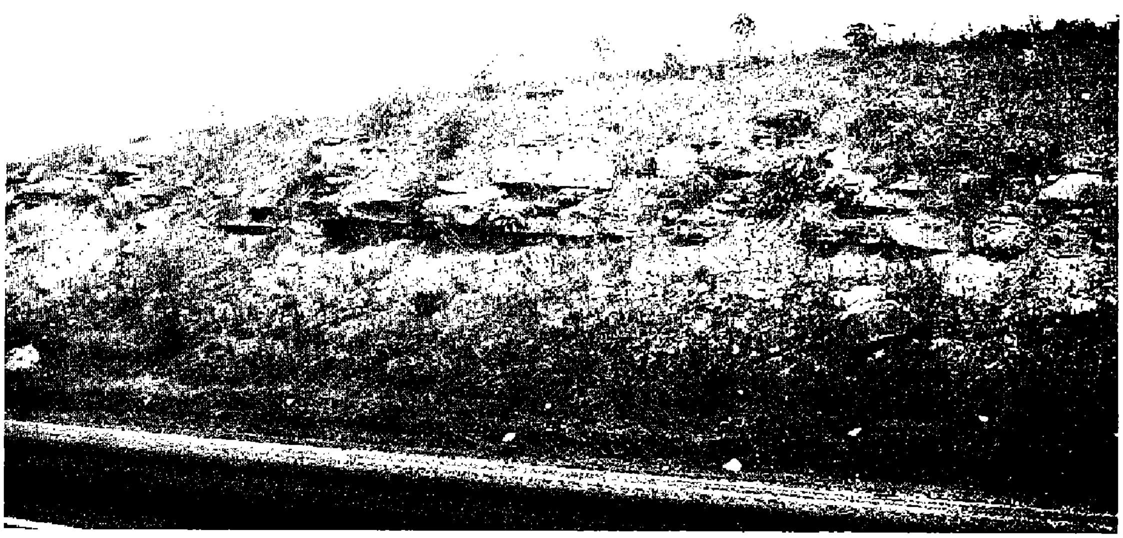

Figure 6. Heavy-bedded limestones in the upper part of the Fayetteville Formation along State Highway 82, sec. 28, T. 25 N., R. 21 E.

Punctospirifer transversus McChesney, *Reticulariina spinosa* (Norwood and Pratten), *Spirifer increbescens* Hall, *Spirifer leidyi* Norwood and Pratten, *Coledium cestriense* (Snider), *Torynifer setigerus* Hall, *Werriea kaskaskiensis* (Girty), *Caneyella nasuta* Girty, *Rayonnoceras vaughanianum* (Girty), and *Paladin mucronatus* (Girty).

Pennsylvanian System

ATOKAN SERIES

Atoka Formation.—The Atoka Formation is represented in southeastern Craig County by brown, fine- to medium-grained, cross-bedded, locally bituminous sandstones, which fill channels cut down into the Fayetteville Formation (figs. 7, 8) and which are succeeded by 30 to 50 feet of shales and siltstones assigned to the Hartshorne Formation (Reed, Schoff, and Branson, 1955, p. 64). The hydrocarbon content of a specimen taken in the roadcut (fig. 9) on the south line of SE¼ sec. 36, T. 25 N., R. 20 E., is 3.8 percent (analysis by J. A. Schleicher, Oklahoma Geological Survey).

Figure 7. Channel sandstones in the Atoka Formation, east side of State Highway 82, sec. 3, T. 24 N., R. 21 E.

Figure 8. Channel sandstones in the Atoka Formation, west side of State Highway 82, sec. 4, T. 24 N., R. 21 E.

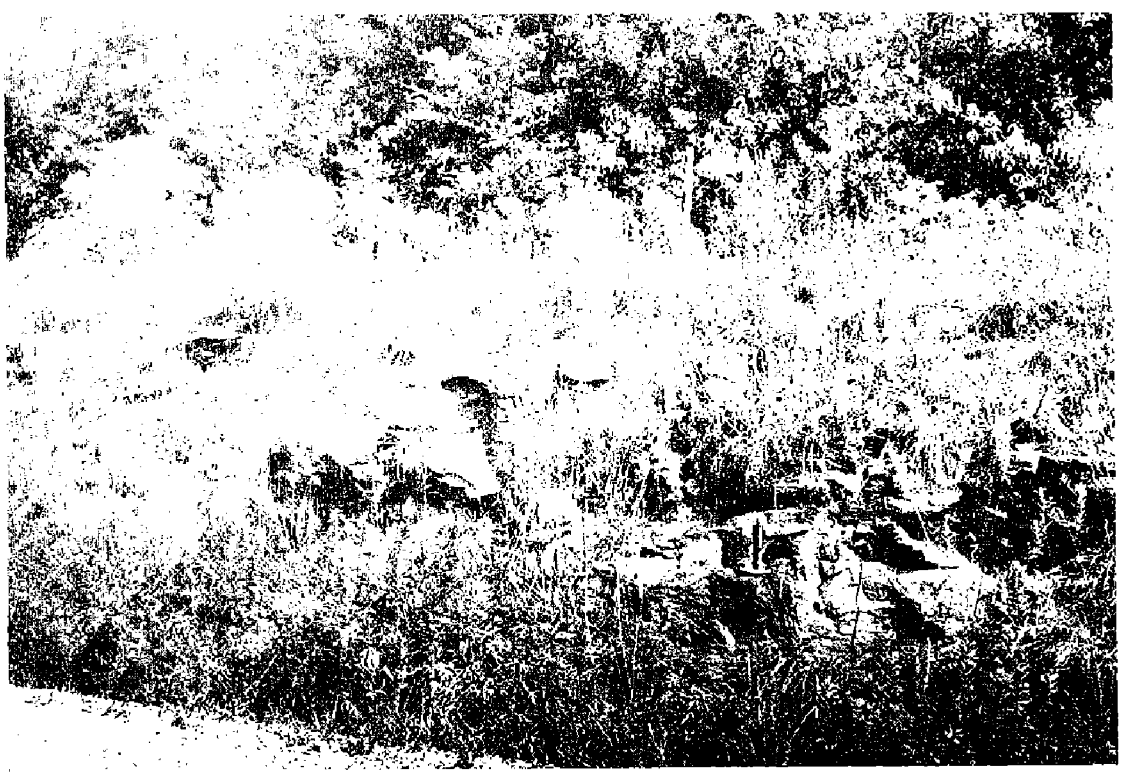

Figure 9. Asphaltic sandstone in the Atoka Formation along north side of road, south line of sec. 36, T. 25 N., R. 20 E.

The Atoka Formation forms several scattered outliers in the southeastern part of Craig County in secs. 2, 3, 6, 7, 8, 10, 16, 17, T. 24 N., R. 21 E., and in secs. 21, 22, 28, 33, T. 25 N., R. 21 E. (fig. 10). It also forms the base of a large outlier in secs. 35, 36, T. 25 N., R. 20 E.

DESMOINESIAN SERIES

Krebs Group

The Krebs Group, named from the town of Krebs, T. 5 N., R. 15 E., in central Pittsburg County, Oklahoma, includes all rocks between the top of the Atoka Formation, below, and the top of the Boggy Formation, above (Oakes, 1953, p. 1523). It comprises in ascending order the Hartshorne, McAlester, Savanna, and Boggy Formations and constitutes the lower part of the rocks of the Desmoinesian Series.

The Krebs Group is 6,000 to 8,000 feet thick in the Arkoma basin but thins northeastward to 540 feet along the Arkansas River and to 340 feet at the Kansas-Oklahoma line. It lies with unconformity upon Atokan and older rocks and is succeeded unconformably by the rocks of the Cabaniss Group.

Figure 10. Small outlier of Atoka sandstone and conglomerate, east side of road, sec. 22, T. 25 N., R. 21 E.

In Craig County, the Krebs Group has at its base an unnamed coal cycle which lies beneath the "*Taonurus*" siltstone. The top of the Krebs is the top of the Boggy, which is drawn at the base of the Weir-Pittsburg coal that lies below the Tebo coal and the overlying Tiawah Limestone cap rock.

Hartshorne Formation.—The term Hartshorne has been extended from the Arkoma basin to the Craig-Ottawa county area by C. C. Branson (Reed, Schoff, and Branson, 1955, p. 64) and applied to the beds between the top of the Atoka (or, in its absence, the Fayetteville) and the base of the Warner Sandstone. The Hartshorne of the platform environment is a sequence of conglomerate, underclays, thin coals, siltstone, shale with clay-ironstone layers, and dark-gray to black, fissile shales. The Riverton coal occurs locally at or near the top.

The lower part of the Hartshorne consists of gray shale, an underclay, a thin, coaly clay, and a tan, platy siltstone characterized by abundant "rooster-tail" markings, commonly called *Taonurus* (fig. 11). Wilson and Newell (1937, p. 54, 184) classed the siltstone as Blackjack School (?) Member of the Atoka Formation. Above

Figure 11. Lower part of the Hartshorne Formation showing the *Taonurus* siltstone (see hammer), underclay, and underlying shales as exposed along U. S. Highways 60-66-69 east of Vinita, sec. 19, T. 25 N., R. 21 E. Here the Hartshorne rests upon the limestones of the upper part of the Fayetteville.

the *Taonurus* bed is 16 feet of dark-gray, fissile shale, capped by a thin, clay-ironstone bed, probably the bed named Elm Creek limestone by Weidman (1932, p. 25). The name Elm Creek is preoccupied by the Elm Creek Limestone Member of the Admiral Formation of north-central Texas, a name published by Drake in 1893, and by the name Elm Creek Limestone of Boese, given to a Canyon limestone of north-central Texas in 1918. At the type exposure, in the west bank of Elm Creek about 300 yards south of the half-section-line road (NW¼ SE¼ sec. 10, T. 28 N., R. 22 E., Ottawa County), the bed is approximately 20 feet below the Warner Sandstone and is underlain by 3 feet of weathered shale. Weidman's locality on Four Mile Creek could not be found, and his locality on the Neosho River is an exposure of a different limestone, the Doneley Limestone. Because the type locality is obscure and because only two other localities are known, the bed is here left without a valid name. The bed is exposed in the north ditch east of Coal Creek in sec. 28, T. 26 N., R. 21 E.

Above the clay-ironstone bed is 21 feet of silty shale, containing below the middle an underclay and discontinuous thin coal up to two inches thick.

The Hartshorne is excellently exposed in two new artificial excavations in Ottawa County. In a borrow pit south of Will Rogers Turnpike in the north center of sec. 13, T. 28 N., R. 23 E., a sandstone unit is exposed. Five feet above it is a 10-inch bed of coal, overlain by 18 feet of gray shale with zones of clay-ironstone concretions. At the top is the Riverton coal, 4 inches thick. On the Will Rogers Turnpike near the center of sec. 8, T. 27 N., R. 23 E., a middle coal bed is exposed. The bed is 4 inches thick at the north end of the west roadcut and thins to zero near the south end. The best exposures of the Hartshorne in Craig County are in the road ditches and cuts on the north side of U. S. Highways 60-66-69 east of Vinita, in sec. 19, T. 25 N., R. 21 E. (fig. 12), and in SE¼ sec. 23 and the section-line road between secs. 23 and 24, T. 25 N., R. 20 E.

The Hartshorne is in a belt of exposures trending northeastward from the Craig-Mayes county line through Big Cabin and Vinita, thence to the Craig-Ottawa county line in secs. 24, 25, T. 26 N., R. 21 E. It characteristically forms a grass-covered slope capped by the overlying Warner Sandstone.

McAlester Formation.—The McAlester Formation of the platform area is markedly thinner than the type McAlester of the basin area to the south. The basal member is the Warner Sandstone, a light-buff, thin-bedded, cross-laminated unit ranging in thickness from 6 to 23 feet and averaging about 10 feet. It consists of rounded quartz sand grains of medium size and contains some iron oxides. It is resistant to erosion and forms a series of outliers and low, rounded cuestas. These have been traced by C. C. Branson (Reed, Schoff, and Branson, 1955, p. 66) across Wagoner, Mayes, Craig, and Ottawa Counties.

The Warner Sandstone was named for exposures northeast of Warner, Muskogee County. This unit was called the Little Cabin sandstone by Ohern (1914) for exposures on Little Cabin Creek near Vinita. The name Little Cabin was first published by Cooper (1928, p. 161). Weidman (1932) had named the unit Narcissa sandstone on his map (pl. 1), but called it Little Cabin sandstone in his text (p. 23). The Warner Sandstone extends northeastward into Ottawa County, across southeastern Kansas, and into Missouri.

The Warner Sandstone is the member that rims the hill upon which the principal buildings of Eastern State Hospital are built.

Figure 12. Upper Fayetteville limestone underlying shales and siltstones of the Hartshorne Formation in roadcut east of Vinita along U. S. Highways 60-66-69, sec. 19, T. 25 N., R. 21 E.

It forms bluffs along the west side of Little Cabin Creek northeast of Vinita, and supports outlying hills east and southeast of Vinita, some of which are steep and nearly conical, such as the hill near the north center of sec. 2, T. 25 N., R. 21 E. The Warner forms low, sandy hills near Big Cabin and supports prominent outliers in the east half of T. 26 N., R. 21 E.

McAlester rocks above the Warner Sandstone Member are dark-gray to black, laminated to fissile shales with layers of clay-ironstone. Three thin coals and associated underclays are present in Ottawa County but have not been observed in Craig County. A thickness of 100 feet is postulated. The McAlester forms a belt of outcrop from 1 to 2 miles wide from the Craig-Mayes county line northeastward to the middle of T. 26 N., R. 21 E., where the outcrop belt widens to nearly 5 miles.

Savanna Formation.—The Savanna Formation includes approximately 150 feet of limestone, shale, sandstone, coal, and underclay lying between the top of the McAlester Formation and the base of the Bluejacket Sandstone. The belt of outcrop extends diagonally across the east-central portion of the county and ranges in width from 1 to 8 miles. Prominent marker beds include the Spaniard Limestone, Sam Creek Limestone, Rowe coal, Doneley Limestone, Dickson Sandstone (new), and the Drywood coal.

The Spaniard Limestone marks the base of the Savanna in southern Craig County, where it consists of 3 to 8 inches of compact, brown to red, fossiliferous limestone which weathers to a soft, spongy, limonitic clay. The Spaniard is known in only four exposures north of the Whiteoak Creek fault: south center sec. 31, T. 25 N., R. 20 E.; in the creekbed in SE¼ NE¼ sec. 9 and NW¼ sec. 10, T. 25 N., R. 20 E.; one mile south of Bluejacket in sec. 32, T. 27 N., R. 21 E.; and in a creek bank east of Bluejacket. The discontinuous nature of the Spaniard is such that the base of the Savanna is mapped in northern Craig County at the base of the Rowe coal.

Separating the Spaniard from the overlying Sam Creek Limestone is a 50-foot unit of shale, at most places poorly exposed. The Sam Creek Member consists of 2.5 to 3 feet of alternating gray shale and fossiliferous clay ironstone. The Sam Creek is characterized by abundance of specimens of *Desmoinesia* and crinoid stem ossicles.

The Sam Creek is separated from the overlying Doneley Limestone by 23 to 30 feet of gray to green shale and gray siltstone, underclay, and coal. Beneath the Doneley is a 2-foot bed of dark, calcareous, fossiliferous shale resting upon the Rowe coal. The coal is 2 to 6 inches thick and at places has an 18-inch underclay.

The Doneley Limestone, named by Chrisman (1951, p. 29) for exposures in NW cor. sec. 16, T. 26 N., R. 20 E., near the site of the former Doneley School, is a dark-gray, silty, fossiliferous limestone which forms the cap rock above the Rowe coal. The name was first published by Branson (1954a, p. 192). The Doneley is more or less continuous from southern Craig County northeastward to the vicinity of Bluejacket, the best exposures being along Big Cabin Creek, T. 26 N., R. 20 E. It is exposed in northwestern Ottawa County and adjacent parts of Kansas. Thickness ranges from 0 to 2 feet in Craig County. Howe (1956, p. 36) believed the Oklahoma Rowe coal and Doneley Limestone to be the Neutral coal and its cap rock.

The Doneley is exposed at a crossing in the now-abandoned channel of the Neosho River (fig. 3). It is 2 feet thick, and the dip is westward at 5 degrees. Beneath the Doneley is 1.5 feet of dark, fossiliferous shale, which rests upon the Rowe coal (7 inches thick). Spores in the Rowe at this exposure have been described by Gibson (1961).

A faunule collected by Chrisman (1951, p. 49) includes the brachiopods *Chonetinella flemingi crassiradiata* (Dunbar and Condra), *Cleiothyridina orbicularis* (McChesney), *Composita* sp., *Derbyia crassa* (Meek and Hayden), *Linoproductus prattenianus* (Norwood and Pratten), *Desmoinesia muricatina* (Dunbar and Condra), *Kozlowskia splendens* (Norwood and Pratten), *Mesolobus mesolobus decipiens* (Girty), *Punctospirifer kentuckiensis* (Shumard), *Spirifer opimus* Hall, and *Spirifer rockymontanus* Marcou.

Other forms include *Delocrinus* sp., *Eupachycrinus* sp., *Fenestella* sp., *Lophophyllidium profundum* (Edwards and Haime), *Naticopsis ventricosa* (Norwood and Pratten), and *Rhombopora* sp.

Beds immediately above the Doneley consist of 15 feet of dark-gray to gray, silty and sandy shale. The overlying Dickson Sandstone (new) is light brown to light grayish yellow, fine grained, and interbedded with gray, micaceous shale and grayish-yellow siltstone (figs. 13, 14). The Dickson Sandstone can be traced almost

Figure 13. Dickson Sandstone, north side of State Highway 25, center south line, sec. 19, T. 27 N., R. 21 E.

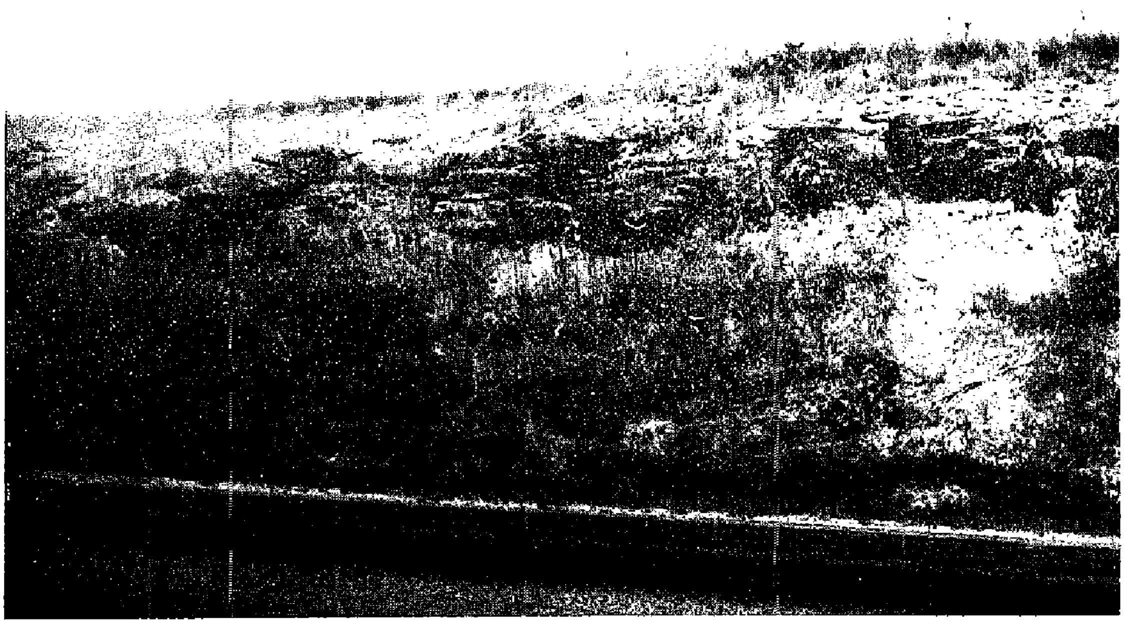

Figure 14. Dickson Sandstone, north side of U. S. Highway 60, west of junction with U. S. Highway 69, sec. 23, T. 25 N., R. 19 E.

continuously from T. 25 N., R. 20 E., to the Craig-Ottawa county line in sec. 1, T. 27 N., R. 21 E. It is well developed along the escarpment half a mile east of Dickson School along the boundaries of secs. 1, 2, 11, 12, T. 26 N., R. 20 E., from where it takes its name. Thickness averages about 12 feet.

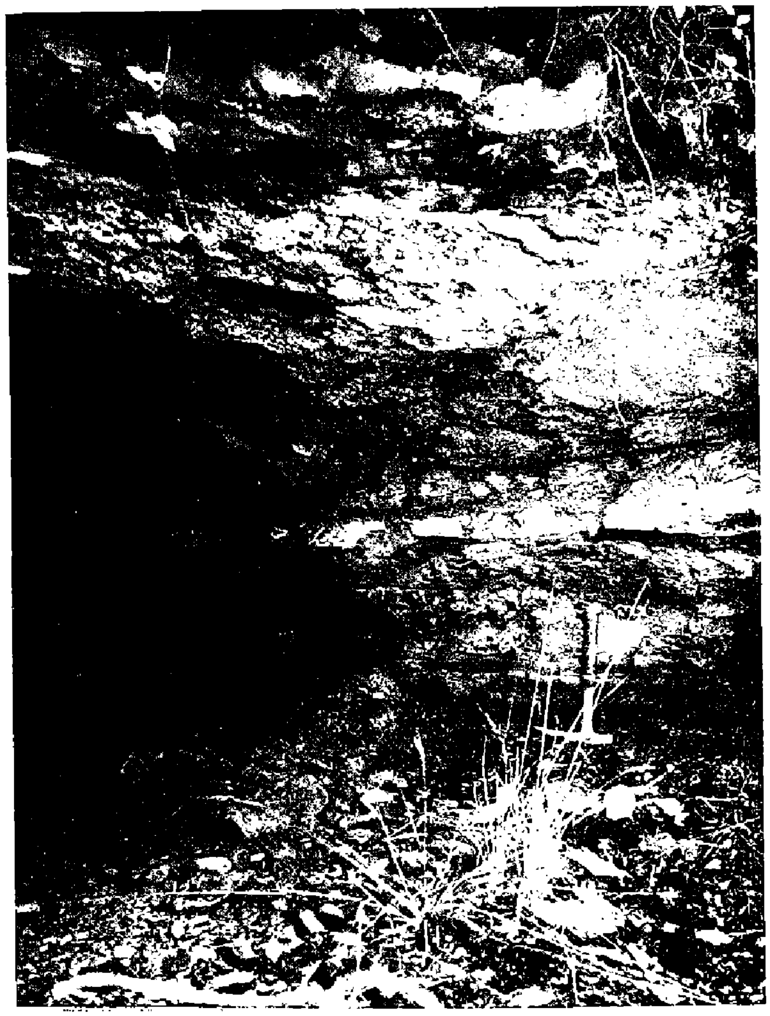

Figure 15. Drywood coal and overlying Bluejacket Formation in abandoned mine in SW¼ sec. 13, T. 26 N., R. 19 E. The hammer rests against the coal seam to the right of the mine opening.

The upper 50 feet of the Savanna is composed of tan, silty, micaceous shale with layers of clay-ironstone and with local sandstone tongues. The Drywood coal and underclay occur in the upper part of this unit and just below the Bluejacket Sandstone. The type locality of the Drywood coal is on Dry Wood Creek in southwestern Missouri. In Craig County the coal seam is from 0 to 6 feet below the Bluejacket Sandstone. At many places the coal is but a carbonaceous seam, and at other places the coal has been removed by streams which channeled into pre-Bluejacket beds. At one locality the basal Bluejacket is a conglomerate containing coal pebbles (NE cor. sec. 35, T. 24 N., R. 18 E.). The Drywood coal, 6 inches thick, is at the immediate base of the Bluejacket in the roadside ditch north of Pecan Creek near Whiteoak (SE cor. NE¼ NE¼ sec. 21, T. 25 N., R. 19 E.). On Timbered Hill (sec. 36, T. 27 N., R. 20 E.) the Drywood coal is 14 inches to 26 inches thick and is 0 to 6 feet below the Bluejacket Sandstone, which contains, in its basal 3 feet, tabular masses of coal. In the now-abandoned coal mines in SW¼ sec. 13, T. 26 N., R. 19 E., the Drywood coal is 36 inches thick and is immediately overlain by conglomerate (figs. 15, 16). The conglomerate contains numerous pebbles which were clay-ironstone concretions. The conglomerate and interbedded sandstone contain tabular masses and local beds of coal in layers up to 3 feet above the main coal. Above the coal-bearing conglomerate is a 2-foot shale, overlain by a clay gall conglomerate; this is succeeded by the main body of the Bluejacket Sandstone. The only locality at which the Drywood has a cap rock is in Mayes County (base of the big cut on State Highway 20, SE cor. sec. 7, T. 21 N., R. 18 E.).

Figure 16. Bluejacket sandstones and conglomerate resting upon the Drywood coal, north side of creek near abandoned mine in sec. 13, T. 26 N., R. 19 E.

In this exposure the coal is discontinuously capped by several inches of dense, nodular, dark limestone.

Boggy Formation.—The Boggy Formation has been defined by the Oklahoma Geological Survey as the strata between the base of the Bluejacket Sandstone and the unconformity at the base of the Cabaniss Group. In Craig County this includes the beds between the base of the Bluejacket and the base of the Weir-Pittsburg coal or, in its absence, the top of the Taft Sandstone. The Inola Limestone, which is present in areas to the south, barely reaches the Mayes-Craig county line.

The Boggy Formation forms a band of outcrop ranging from ½ mile to more than 3 miles in width extending diagonally across the central one-third of Craig County. The basal Bluejacket Sandstone (figs. 17, 18), which was named for exposures near the town of Bluejacket, forms a prominent escarpment along much of its extent and forms the cap of numerous outliers. A type section was established by Howe (1951, p. 2090) on the east side of Timbered Hill along State Highway 25 (NW¼ NE¼ sec. 25, T. 27 N., R. 20 E.).

The Bluejacket Sandstone, which ranges in thickness from 0 to 50 feet, rests upon an undulating surface and in channels which cut into older rock units. The lower part is a buff to tan, heavy-bedded, cross-laminated, medium-grained, well-sorted, micaceous, ferruginous sandstone ranging in thickness from 20 to 30 feet. Locally within the lower 15 feet are beds of conglomerate. The lower part of the Bluejacket is resistant and locally forms a prominent escarpment. The upper 15 to 20 feet of the Bluejacket is thin-bedded, fine-grained, tan, micaceous sandstone and shale. The upper part is weak and weathers back from the face of the escarpment.

The Bluejacket Sandstone is the Bartlesville sand of the subsurface. The unit is unfossiliferous except for molds and casts of the scale-tree root, *Stigmaria* (Lohman, 1952, p. 21).

The interval between the Bluejacket Sandstone and the base of the Taft ranges from 2 to more than 40 feet. The unit contains gray shale, silty shale, and discontinuous sandstone beds. In Mayes County to the south, the Inola Limestone occupies the middle part of this interval. Below the Inola horizon is a sequence of gray to buff shale, a thin, poorly developed coal and underclay, and a gray to buff shale below the underclay. This coal, which ranges from 0

Figure 17. Bluejacket Sandstone, south side of Timbered Hill along east side of road, center sec. 36, T. 27 N., R. 20 E.

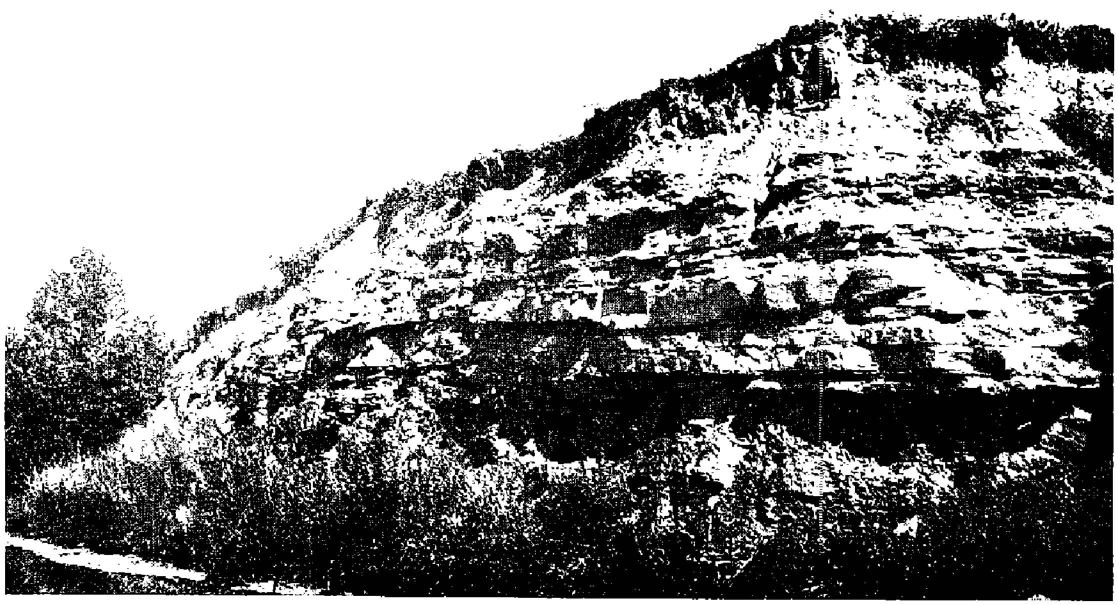

Figure 18. Bluejacket Sandstone, north wall of strip pit in west center of sec. 27, T. 26 N., R. 19 E.

to 26 inches in thickness, is the Bluejacket coal of the platform classification. The Bluejacket coal was once mined on Timbered Hill, where it is overlain by the Chelsea Sandstone. The coal is 2 feet thick and can be seen in the abandoned drift near C sec. 35, T. 27 N., R. 20 E. The bed mined by stripping west of Estella (secs. 5, 6, T. 25 N., R. 19 E., and sec. 32, T. 26 N., R. 19 E.) is the Bluejacket coal, and the seam is exposed in the roadcut on U. S. Highway 60 (NW¼ SE¼ sec. 8, T. 25 N., R. 19 E.).

The Taft Sandstone and associated shales are well developed in northern Mayes County, where they reach a thickness of 146 feet of interbedded sandstones, shales, and coal. The sandstones form three fairly consistent units separated by tan to gray-black, fissile, silty, ferruginous shale with clay-ironstone concretions. The lower Taft sandstone is tan to buff, massive, micaceous, fine to medium grained, ferruginous, and contains *Stigmaria.* Thickness ranges from 5 to 41 feet. The sandstone of the lower part of the Taft is the more persistent of the Taft sandstones and is the Taft Sandstone known to extend into Craig County. There it has been recognized only in southern Craig County, having been traced into T. 25 N., R. 19 E.

The upper and middle Taft sandstones are buff to tan, fine grained, thinly bedded, and silty. These grade laterally into shale in northern Mayes County and fail to reach into Craig County.

Cabaniss Group

The Cabaniss Group, named from the village of Cabaniss in T. 6 N., R. 12 E., northwestern Pittsburg County, Oklahoma (Oakes, 1953, p. 1525), includes all rocks above the Krebs Group and below the base of the Marmaton Group. The Cabaniss Group is 1,000 feet thick near Cabaniss, where it includes the Thurman Sandstone, the Stuart Shale, and the Senora Formation; it thins northeastward by convergence and by overlap of lower units by higher units to 350 feet near the Arkansas River and 160 feet at the Kansas-Oklahoma line.

The Cabaniss is unconformable upon the underlying Krebs Group. The Thurman Sandstone, lower formation of the Cabaniss Group, is apparently overlapped by the Stuart Formation beneath the alluvium of the Canadian River. The Stuart is overlapped by the Senora Formation in T. 13 N., R. 16 E., in southwestern Muskogee County. Northeastward toward the Kansas-Oklahoma line, the Senora rests unconformably upon the Boggy Formation (Oakes, 1953, p. 1525).

The Senora Formation is the sole representative of the Cabaniss Group on the platform area of northeastern Oklahoma.

Senora Formation.—The Senora includes the strata between the base of the Weir-Pittsburg coal cycle and the base of the Blackjack Creek Member of the Fort Scott Formation.

Named units occurring within the Senora include the Weir-Pittsburg coal, Tebo coal, Tiawah Limestone, Chelsea Sandstone, Mineral coal, Russell Creek Limestone, Fleming cap rock, Goldenrod Sandstone, Croweburg coal, Verdigris Limestone, Bevier coal, Lagonda Sandstone, Iron Post coal, Kinnison Shale, Breezy Hill Limestone, and Excello Shale. The units are cyclic, and each cycle in general consists of a sandstone, shale, underclay, coal, and cap rock, generally limestone.

The Weir-Pittsburg coal is well developed in the Welch area, where it reaches a thickness of 20 inches and has been extensively mined by open-pit method in secs. 27, 28, 32, 33, 34, T. 28 N., R. 20 E. (Claxton, 1952, p. 10). The term "Pawpaw" has been applied locally to a 19- to 23-inch coal which lies 20 feet above the Taft Sandstone and below the Chelsea in nearby areas of Rogers and Mayes Counties. Lohman (1952, p. 30) correlated the "Pawpaw" coal with the Weir-Pittsburg.

The interval between the Weir-Pittsburg coal and the Tiawah Limestone is occupied by shale and argillaceous, fine-grained sandstone. Thickness of the unit ranges from 22.5 to 41 feet.

Immediately below the Tiawah Limestone is a black, fissile shale containing small phosphatic nodules. Thickness of the shale is 1.5 to 5 feet. Below the black, fissile shale is the Tebo coal, a thin, poorly developed, lensing unit, which reaches a thickness of 6 inches at exposures near Welch, sec. 15, T. 28 N., R. 20 E., north of Estella in secs. 20, 32, T. 26 N., R. 19 E., and east of Centralia in sec. 26, T. 27 N., R. 19 E. A 2- to 3-foot underclay lies beneath the Tebo. Below the underclay is a tan, silty, micaceous shale and a light-buff, slightly ferruginous, micaceous, massive, fine-grained sandstone.

The Tiawah Limestone was named by Lowman (1932, p. 24) for the village of Tiawah in Rogers County. The limestone is recognized at widely spaced localities from southwestern Wagoner County northward into Missouri. In Wagoner County it grades northward from a myalinid coquinite into a dense, crystalline limestone with abundant fusulinids. In the type section, selected by Tillman (1952, p. 23), which is in the outlier along State Highway 20, 0.1 mile east of SW cor. sec. 12, T. 12 N., R. 16 E, Rogers County, the Tiawah is 6.3 feet thick and is dense, light-gray limestone with small gastropods.

In Craig County, the Tiawah was traced in part by observing an overlying zone of phosphatic nodules. An exposure in the creek bank in NW cor. sec. 32, T. 26 N., R. 19 E., consists of black shale resting upon 0.4 foot of black Tiawah Limestone, 1.5 feet of black, fissile shale with phosphatic concretions and pyritized fossils, and the limestone is 3.5 feet above the Tebo coal. A similar section is exposed 0.2 mile south of NW cor. sec. 21 in the same township. In an exposure in the east bank of Middle Fork of Big Cabin Creek (NE cor. sec. 26, T. 27 N., R. 19 E.) the Tiawah is a double bed, 0.3 foot of clay-ironstone, over 0.1 foot of black, fissile shale, over 0.3 foot of dark clay-ironstone. The Tebo coal, 0.5 foot thick, is 2 feet below. The northernmost known Oklahoma exposure is in Wolfe Creek, just south of the bridge (NE¼ NW¼ NW¼ sec. 15, T. 28 N., R. 20 E.). Here the Tiawah is 0.2 foot of clay-ironstone containing *Desmoinesia* and gastropods.

In continuous exposures along Pawpaw Creek (secs 20, 21, T. 26 N., R. 19 E.), the Tiawah is a clay-ironstone ledge 2 feet above the 4-inch Tebo coal (fig. 19). Southwestward along the creek bank the Tiawah abruptly changes to clay-ironstone concretions with cone-in-cone structure on the periphery. The Tebo wedges out into a sheared slice, and it, the Tiawah, and associated strata are cut off by a body of siltstone and shale. This body is interpreted as a channel fill of Chelsea age, along the edge of which there was slipping of the sediments (fig. 20).

Faunules collected by Chrisman (1951, p. 48) from NE cor. sec. 20, T. 26 N., R. 19 E., and from NW cor. sec. 32, T. 26 N., R. 19 E., include *Aviculopecten* sp., *Cleiothyridina* sp., *Lophophyllidium* sp., *Desmoinesia muricatina* (Dunbar and Condra), *Mesolobus mesolobus* (Norwood and Pratten), and *Nuculopsis girtyi* Schenck. *Crurithyris planoconvexa* (Shumard) was reported by Claxton (1952, p. 21-23) from NW¼ sec. 15, T. 28 N., R. 20 E.

The interval between the Tiawah Limestone and the Chelsea Sandstone ranges from 0 to 30 feet, pre-Chelsea erosion and channeling having removed the Tiawah from parts of Craig County. The intervening beds are gray to dark-gray shales containing small black ironstone concretions, thin local coals, and phosphatic shale. The interval decreases northward, and locally the Chelsea Sandstone cuts down to within 5 feet of the Bluejacket Sandstone.

The Chelsea Sandstone, named by Ohern (1914, p. 41), for exposures near Chelsea, Rogers County, Oklahoma, lies approximately 200 feet above the Bluejacket in southwestern Craig, northern Mayes, and Rogers Counties. It ranges in thickness from 0 to 70 feet and is typically about 50 feet thick. It is continuous from the Craig-Mayes county line northeastward to sec. 33, T. 27 N., R. 19 E., where its identity becomes lost in a thick shale section.

Lithologically, the Chelsea is a reddish-brown to yellow, medium-grained, well-sorted, ferruginous, micaceous, massive, cross-laminated sandstone. It grades upward into micaceous, tan to buff, silty shale, which is covered with vegetation to form a grassy slope. Locally the basal beds are conglomeratic. The Chelsea lies unconformably upon the older beds and locally fills deep channels in the underlying surface.

The interval from the Chelsea Sandstone to the Verdigris Limestone in southern Craig County is 90 to 110 feet. There the beds are chiefly gray shale and silty shale, dark-gray shale, and grayish-yellow, silty sandstone. The Croweburg coal, which ranges in thickness from 15 to 19 inches, lies 40 to 50 feet above the top of the Chelsea. Plant microfossils of the Croweburg coal, including those from two Craig County localities, have been described by Wilson and Hoffmeister (1956).

The shale which separates the Croweburg coal from the overlying Verdigris Limestone is 20 to 40 feet thick. Ten to fifteen feet below the Verdigris is a 6- to 10-foot-thick, grayish-yellow, fine-grained, silty sandstone lentil, which grades laterally and vertically into silty shale. At the top of the shale unit and immediately below the Verdigris is a 2-foot bed of black, fissile shale containing phosphatic concretions.

In north-central Craig County, the Chelsea Sandstone is absent. There the Mineral coal, which ranges from 14 to 22 inches in thickness, lies 54 feet above the Weir-Pittsburg coal and 28 feet above the

Figure 19. Tebo coal (at base of hammer), overlying shales, and the Tiawah Limestone exposed along Pawpaw Creek, on section line of secs. 20, 21, T. 26 N., R. 19 E.

Figure 20. Chelsea Sandstone in a channel fill cutting down into the Tiawah Limestone and associated strata along Pawpaw Creek, secs. 20, 21, T. 26 N., R. 19 E.

Tebo coal. The Mineral coal is overlain by the Russell Creek Limestone, a dense, black, finely crystalline, impure limestone 2 to 3 feet thick. The Mineral coal has been mined extensively in Tps. 28, 29 N., where it averages 18 inches in thickness.

Claxton (1952, p. 21-23) collected the following fossils from the Mineral cap rock (Russell Creek Limestone) from a pit in north center sec. 23, T. 29 N., R. 20 E.: *Lophophyllidium* sp., *Neospirifer cameratus* (Morton), *Composita* sp., *Desmoinesia muricatina* (Dunbar and Condra), and *Naticopsis meeki* Knight. Alexander (1954, p. 24; pl. 2, figs. 1-4) collected *Fusulina equabilis* Alexander from the Russell Creek Limestone in SE¼ sec. 11, T. 28 N., R. 20 E.

Locally the Fleming cap rock lies 5 to 15 feet above the Russell Creek Limestone and the Mineral coal. At this only known Craig County locality it consists of 6 inches of dense, yellowish, finely crystalline limestone. Immediately below is a yellow underclay.

Lying above the Fleming cap rock and channeling downward to the top of the Russell Creek Limestone is a previously unnamed sandstone. The name Goldenrod (new) is herein proposed for this unit for exposures along Russell Creek approximately 3 miles northeast of Goldenrod School in the high walls of the strip pit and in the hill above the strip pits, secs. 23, 24, T. 29 N., R. 20 E. (fig. 21). This unit is a tan to reddish-brown, slightly calcareous, fine- to medium-grained sandstone (fig. 22) interbedded with gray shale. Thickness ranges from 0 to 35 feet. The Goldenrod Sandstone is mappable from the Kansas-Oklahoma line southward to sec. 31, T. 28 N., R. 20 E.

The Croweburg coal is separated from the Goldenrod Sandstone by 10 to 20 feet of tan, silty shale and argillaceous, fine-grained sandstone. The Croweburg ranges in thickness from 6 to 16 inches and occurs 25 feet above the Fleming cap rock where the Goldenrod Sandstone is absent. The coal is overlain by approximately 25 feet of tan to gray, silty shale and lenticular sandstone.

The Verdigris Limestone (fig. 23) is gray to dark-gray, finely crystalline, compact, fossiliferous limestone that weathers yellow brown. Fusulinids and brachiopods, including *Condrathyris perplexa* (McChesney), *Fusulina equilaqueata* Alexander, and *Desmoinesia muricatina* (Dunbar and Condra), occur in the upper portion. Thickness ranges from 2 to 7 feet. The Verdigris is a per-

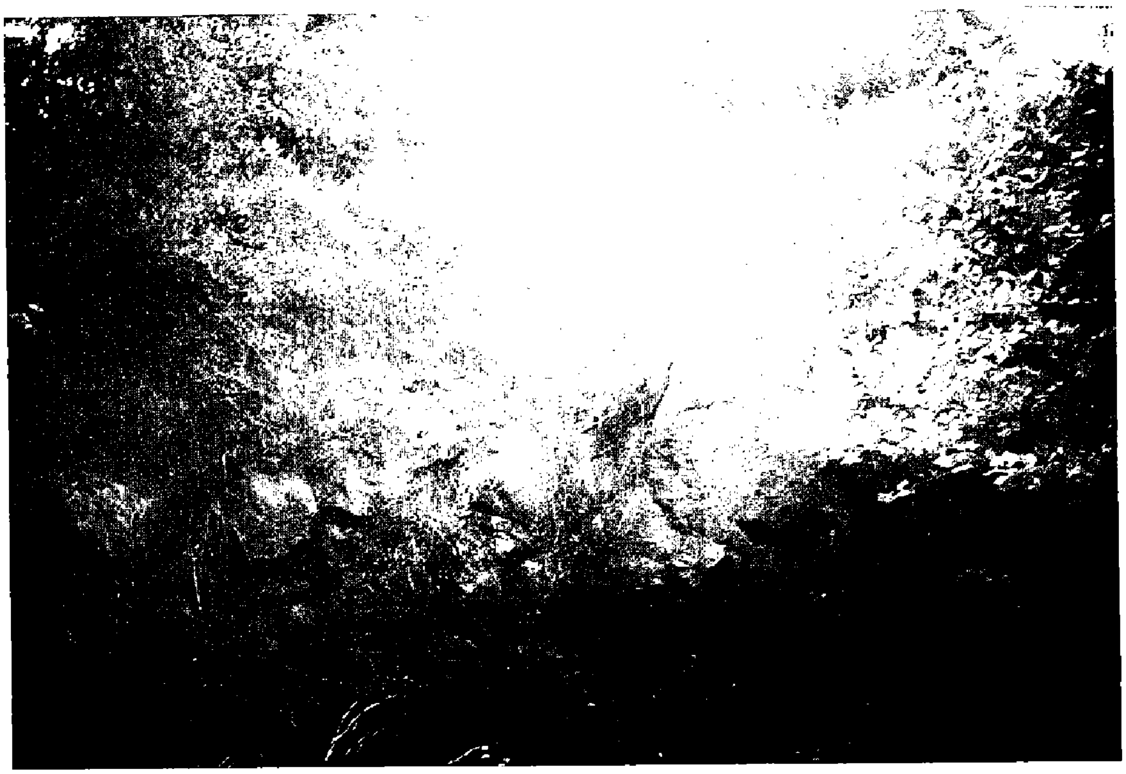

Figure 21. Goldenrod Sandstone, high wall of strip pit in sec. 23, T. 29 N., R. 20 E. This exposure is approximately 3 miles northeast of Goldenrod School and is the type locality of the Goldenrod Member of the Senora Formation.

Figure 22. Goldenrod Sandstone exposed in strip pit in the southern part of sec. 18, T. 28 N., R. 21 E.

sistent unit and has been mapped completely across Craig County. It lies approximately 100 feet above the Chelsea Sandstone.

The Verdigris is overlain by a sequence of gray shale and thin sands and silty beds. Thickness reaches a maximum of 30 feet and averages between 15 and 20 feet.

At one locality (SE¼ SE¼ sec. 21, T. 25 N., R. 18 E.) a dense, gray limestone bed 0.5 foot thick is 4 feet above the Verdigris Limestone. The bed is interpreted as the cap rock of the Wheeler coal, a seam which has not been found in Oklahoma.

Near the top of the Verdigris-Lagonda interval and 1 foot below the base of the Lagonda is a discontinuous bed of coal, 4 to 15 inches thick, which occupies the position of the Bevier coal of Missouri.

Lying above the Bevier coal is a sandy zone called the Lagonda Sandstone (Squirrel sand or Prue sand of subsurface). In southern Craig County the Lagonda is a single unit of brown, well-indurated, fine-grained, cross-bedded sandstone overlain by 5 to 8 feet of gray, silty shale. In northern Craig County, the Lagonda includes two sandstones separated by 6 to 12 feet of shale. The upper sandstone ranges from 4 to 10 feet in thickness, and the lower from 3 to 8 feet. The shale is tan, silty, and micaceous, grading laterally into fine-grained sandstone.

The Lagonda "zone" is overlain by the Iron Post coal (fig. 24), which ranges in thickness from 10 to 18 inches. It has been mined extensively throughout its area of exposure. The unit between the Lagonda and the Iron Post coal is 5 to 10 feet thick and is composed of shale and underclay.

The Iron Post coal is succeeded by the Kinnison Shale (fig. 24), a sequence of 3 to 5 feet of dark-gray to yellow, calcareous shale named from exposures near the former settlement of Kinnison in sec. 36, T. 28 N., R. 19 E.

In the area of the type locality the basal bed of the Kinnison is an impure limestone which forms the cap rock of the Iron Post coal. The cap rock of the Iron Post coal is well developed locally in southwestern Craig County. There the Kinnison is but 2 to 3 feet thick and is a clay shale, and in Rogers County the unit thins to 10 inches.

The Breezy Hill Limestone (fig. 24) succeeds the Kinnison Shale. It is gray to light-brown, dense, fine- to medium-crystalline,

Figure 23. Verdigris Limestone, west side of sec. 36, T. 26 N., R. 18 E.

Figure 24. Iron Post coal, Kinnison Shale, and overlying Breezy Hill Limestone exposed in the north wall of the Patch Coal Company pit in SE¼ sec. 28, T. 26 N., R. 18 E.

silty, fossiliferous limestone, 2 to 10 feet thick. A thin algal limestone overlain by a fusulinid bed is common near the base of some sections. The upper 2 feet of the Breezy Hill is gray, medium crystalline, and relatively free of silt.

The Breezy Hill Limestone carries an abundant fauna. Chrisman (1951, p. 47) listed the following forms from an abandoned strip pit in NW¼ sec. 36, T. 26 N., R. 18 E.; *Caninia torquia* (Owen), *Cleiothyridina orbicularis* (McChesney), *Antiquatonia* sp., *Lophophyllidium* sp., *Desmoinesia muricatina* (Dunbar and Condra), *Mesolobus mesolobus* (Norwood and Pratten), and *Condrathyris perplexa* (McChesney).

Claxton (1952, p. 21-23) listed the following forms from the vicinity of Welch in northeastern Craig County: *Wilkingia* sp., *Astartella* sp., *Chonetinella flemingi* (Norwood and Pratten), *Cleiothyridina orbicularis* (McChesney), *Composita subtilita* (Hall), *Antiquatonia portlockiana* (Norwood and Pratten), *Echinaria moorei* (Dunbar and Condra), *Echinaria semipunctata* (Shepard), *Linoproductus prattenianus* (Norwood and Pratten), *Desmoinesia muricatina* (Dunbar and Condra), *Meekospira* sp., *Neospirifer cameratus* (Morton), and *Spirifer rockymontanus* Marcou. Alexander (1954, p. 27; pl. 2, figs. 5-8) described *Fusulina expedita* Alexander from the Breezy Hill Limestone in SW¼ sec. 24, T. 28 N., R. 19 E.

The Excello Shale separates the Breezy Hill Limestone from the overlying Fort Scott Formation. The Excello consists of 4 to 8 feet of black, phosphatic shale, which has been used locally for road metal.

Marmaton Group

The Marmaton Group is defined as including all beds between the base of the Fort Scott Limestone and the disconformity at the base of the Missourian, which is marked in southern Kansas by the Hepler Sandstone (Jewett, 1940, p. 8-9). The Hepler rests disconformably upon the Holdenville Shale, the Lenapah Limestone, the Nowata Shale, and the Altamont Limestone. In Oklahoma the Seminole Formation similarly rests disconformably upon Marmaton strata.

The Marmaton Group includes, in ascending order, the following formations: (1) Fort Scott Limestone, (2) Labette Shale, (3) Pawnee Limestone, (4) Bandera Shale, (5) Altamont Limestone,

(6) Nowata Shale, (7) Lenapah Limestone, and (8) Holdenville Shale. Strata from the Fort Scott through the Altamont are present in the Craig County section.

Fort Scott Formation.—The Fort Scott Formation of southern Kansas (Jewett, 1941, p. 304) is divisible into three members. In ascending order these are (1) Blackjack Creek Limestone Member (5.2 feet), (2) Little Osage Shale Member (7.7 feet), and (3) Higginsville Limestone Member (14 feet), with a total thickness of nearly 27 feet. These units can be traced from Kansas into Craig County, Oklahoma.

The Blackjack Creek Limestone Member is a light-gray, finely crystalline limestone with vugs and fossil cavities filled with coarse-crystalline calcite. Locally thin beds of light-gray, fine-textured limestone occur in the upper part of the member. Thickness in Craig, Nowata, and northern Rogers Counties ranges from 20 to 30 feet, with a maximum of 40 feet in the subsurface in sec. 22, T. 29 N., R. 19 E. (Warren, 1952). *Fusulina girtyi* (Dunbar and Condra) and *Fusulina haworthi* (Beede) were collected and identified by Alexander (1954, p. 29-30; pl. 2, figs. 9-12) from the Blackjack Creek Limestone in NW¼ sec. 13, T. 28 N., R. 19 E.

The Little Osage Member, a sequence of black, fissile shale with phosphatic concretions, is 5 to 10 feet thick. The Summit (?) coal and the Houx Limestone of the Kansas section have not been recognized in the Craig County exposures.

The Higginsville Limestone Member of the Fort Scott is a light-gray to brown, thin-bedded, finely crystalline limestone. Thickness is variable, ranging from 0 to approximately 40 feet. The member caps a broad dip slope.

Labette Formation.—The Labette Shale occupies the interval between the Higginsville Limestone Member of the Fort Scott Formation and the base of the Pawnee Limestone. It is composed of two major rock types: a lower blue shale and an upper silty to sandy shale. Lenticular sandstones, thin limestones, and one coal mark the upper portion. Total thickness ranges from 110 to 175 feet, and the outcrop belt is from ½ mile to more than 3 miles wide.

The basal blue shale of the Labette is irregularly bedded and blocky. Although the unit is poorly exposed, a thickness of 40 feet has been observed.

Middle and upper portions of the Labette are silty and sandy. The "Peru sand" of the subsurface, a cross-bedded, tan, fine-grained, lenticular sandstone, 20 feet thick, occurs in the upper part of the Labette.

Above the "Peru sand" is a thin, persistent limestone, the Wimer School Limestone Member (Cade, 1952, p. 25). It is a compact, massive, fossiliferous, gray to yellow-brown, lithographic limestone, 2 feet thick, and is underlain by 2 feet of greenish-yellow, calcareous shale. Fossils from the Wimer School include *Caninia torquia* (Owen), *Reticulatia* sp., *Echinaria semipunctata* (Shepard), and *Fusulina megista* Thompson.

The Lexington coal lies near the top of the Labette Shale. The coal ranges from 0.1 foot to 1.4 feet in thickness but is absent south of Childers in Nowata County. It is overlain by a bed of sandy shale and is underlain by an underclay and thin stringers. A limestone cap rock is present over the Lexington coal in adjacent Nowata County.

The Anna Shale Member, here placed in the Labette Formation, is composed primarily of black, fissile, carbonaceous shale containing spherical phosphatic concretions and dark-gray, calcareous shale that grades laterally into yellow, silty shale. Large fossiliferous limestone concretions lie directly upon the black, fissile shale facies (Faucette, 1954, p. 39). Dark gray-green, nodular, earthy limestone; light-gray, massive limestone; and sandy limestone characterize the base. Thickness is approximately 7.5 feet.

The Labette Shale has yielded *Composita subtilita* (Hall), *Derbyia crassa* (Meek and Hayden), and *Lophophyllidium* sp.

Pawnee Formation.—The Pawnee forms a conspicuous outcrop across northwestern Craig County, a belt which ranges from 1 to 6 miles in width. The Pawnee has a relatively uniform thickness of 37 to 40 feet and forms a prominent escarpment. Three members are recognied. In ascending order these are: Myrick Station Limestone, Mine Creek Shale, and Coal City Limestone. Because the Myrick Station Limestone is the cap rock of the Lexington coal in Missouri, Kansas geologists place the Anna Shale in the Pawnee. That assignment is not followed here.

The Myrick Station Member, a massive, coarsely crystalline, crinoidal limestone, 6 to 8 feet thick, ranges in color from gray to pink. Alexander (1954, p. 43; pl. 4, figs. 9-12) described *Fusulina tumida* from the member. A thin bed of black, fissile shale directly above the Myrick Station Limestone may respresent the Mine Creek Shale Member of Missouri and Kansas.

The Coal City Member is a gray, massive to irregularly bedded, coarsely crystalline limestone with a brecciated appearance. Thickness ranges from 20 to 26 feet with southward thickening to 35 feet. Jewett (1959) called this limestone the Laberdie Limestone.

The Pawnee Formation is fossiliferous and the following forms are diagnostic: *Aviculopecten interlineatus* Meek and Worthen, *Composita subtilita* (Hall), *Condrathyris perplexa* (McChesney), *Reticulatia* sp., *Derbyia crassa* (Meek and Hayden), *Echinaria semipunctata* (Shepard), *Hustedia mormoni* (Marcou), *Pulchratia ovalis* (Dunbar and Condra), *Leiorhynchus rockymontanum* (Marcou), and *Desmoinesia muricatina* (Dunbar and Condra).

Bandera Shale.—The Bandera is a dark-gray to yellow-brown, micaceous, limonitic, sandy shale. Limestone concretions mark the upper part. Near the top is a 7- to 11-foot development of thick-bedded, medium-grained, gray to yellow, micaceous, limonitic sandstone referred to as the Bandera Quarry Sandstone. The uppermost 4 feet of the Bandera is a black, platy shale which lies in contact with the overlying Altamont.

The Bandera reaches a maximum thickness of 120 feet in Craig County and thins southward to 3 feet in southern Nowata County. Outside this area, the Altamont Formation and the Pawnee merge to form the Oologah Limestone. The Mulberry coal, which occurs within the Bandera Shale of Kansas and Missouri, has not been observed in Craig County.

Altamont Formation.—The Altamont Formation is composed of three members: the Amoret Limestone, the Lake Neosho Shale, and the Worland Limestone. The Altamont ranges in thickness from 26 to 43 feet and is limited in distribution in the county to secs. 16-21, 29, 30, T. 29 N., R. 18 E.

The Amoret Member, 9 to 10 feet thick, consists of two limestone beds separated by shale. The upper 2 feet is a black, shaly limestone underlain by 4 feet of dark-gray shale. The lower limestone is a light-gray, coarsely crystalline limestone 3 feet thick. The Amoret forms a well-defined escarpment, with the Bandera Shale forming a steep slope below.

The Lake Neosho, 6 to 10 feet thick, is a black, carbonaceous, fissile shale with flattened phosphatic concretions.

The Worland is gray, irregularly bedded, coarsely crystalline, cherty limestone. Its thickness is relatively uniform and ranges from 20 to 23 feet.

The Altamont is abundantly fossiliferous and is characterized by brachiopods, corals, pelecypods, and bryozoans of typical Middle Pennsylvanian forms. Corals include *Caninia torquia* (Owen), *Chaetetes milleporaceus* Edwards and Haime, *Lophophyllidium* sp., and *Syringopora multattenuata* McChesney. Brachiopods are *Reticulatia* sp., *Neochonetes granulifer* (Owen), *Composita trilobata* Dunbar and Condra, *Composita subtilita* (Hall), *Crurithyris planoconvexa* (Shumard), *Echinaria semipunctata* (Shepard), *Hustedia mormoni* (Marcou), *Linoproductus* sp., and *Pulchratia ovalis* (Dunbar and Condra).

STRUCTURE

General discussion.—Craig County is on the northwestern edge of the Ozark uplift, a broad, domal, northeastward-trending structure occupying portions of Missouri, Arkansas, and Oklahoma. Here rocks of Mississippian age pass beneath the gently dipping beds of the Prairie Plains homocline, with westward dips ranging from 15 to 50 feet per mile. Regional dip is interrupted by normal faulting and by local folding.

Horse Creek anticline.—The Horse Creek anticline is an asymmetrical fold extending from about 5 miles southeast of Big Cabin northeastward across southern Craig County. The average dip on the north side is approximately 2 degrees, that on the south ranges from 5 to 18 degrees. The Horse Creek anticline is faulted locally along its crest, as in the roadway along State Highway 82 in secs. 21, 22, T. 24 N., R. 21 E. (fig. 25).

Whiteoak Creek fault.—The Whiteoak Creek fault extends from about 4 miles southwest of Vinita along the course of White-

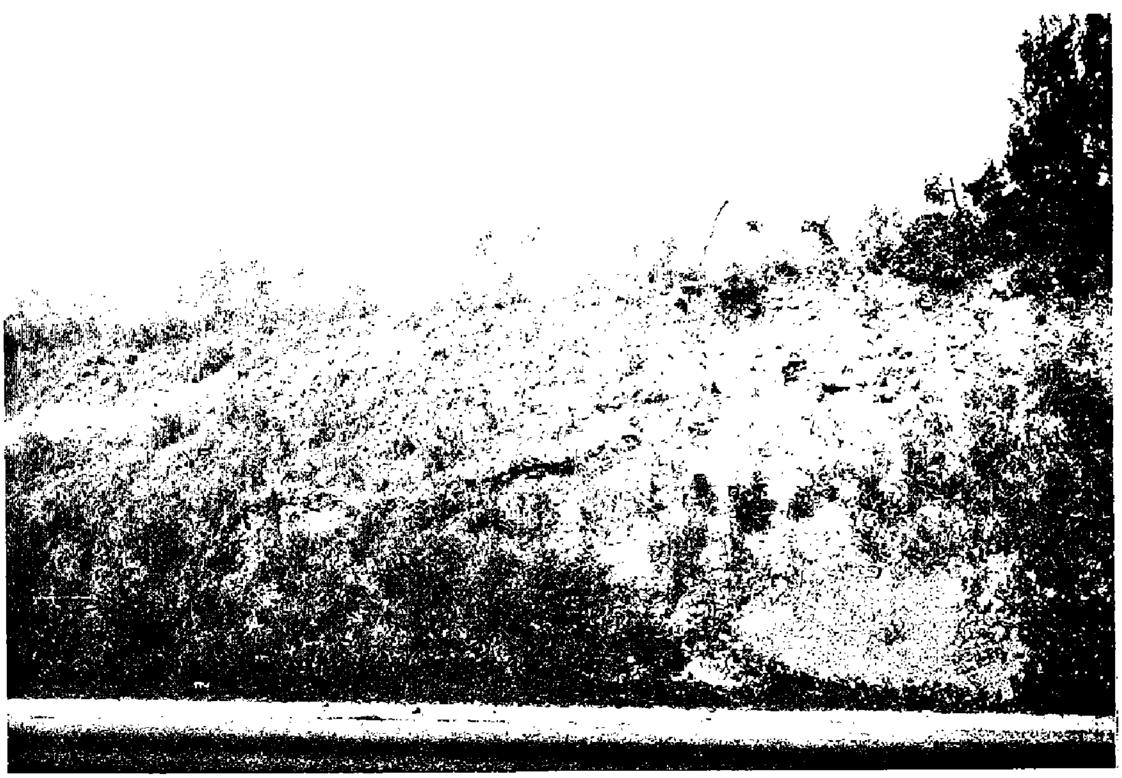

Figure 25. Small fault cutting the Horse Creek anticline along State Highway 82, sec. 21, T. 24 N., R. 21 E.

oak Creek, a tributary of Big Cabin Creek. It runs east-west from U. S. Highway 69 to State Highway 82, thence northeastward, disappearing in the Keokuk chert in sec. 36, T. 25 N., R. 21 E. It is a normal fault which brings the McAlester, Atoka, and Fayetteville in contact with the Keokuk with an estimated throw of more than 100 feet.

Miami syncline.—The Miami syncline passes through western Ottawa County and enters Craig County in sec. 36, T. 26 N., R. 21 E., where it continues into sec. 12, T. 25 N., R. 21 E. The structure is well exposed in the "Frisco" railroad cut in sec. 1, T. 25 N., R. 21 E., where the rocks dip 23 degrees on the west limb and 6 degrees on the east limb.

Dupree fault.—The Dupree fault begins in sec. 7, T. 25 N., R. 20 E., and cuts across the northwestern part of that township into T. 26 N., R. 20 E. The fault is downthrown to the southeast, is normal, and has a calculated displacement of 90 feet (Lohman, 1952, p. 51).

Big Cabin fault.—The Big Cabin fault enters Craig County just south of Big Cabin and trends northeastward through the town. It is a normal fault, downthrown to the northwest, bringing the *Taonurus* siltstone bed of the Hartshorne Formation to lie against the Fayetteville Shale with a stratigraphic throw of 25 feet or more.

Little Pryor Creek fault.—The Little Pryor Creek fault trends northeastward paralleling Little Pryor Creek in T. 24 N., R. 18 E. It extends into extreme western Craig County in sec. 7, T. 24 N., R. 19 E. It is downthrown to the northwest with a throw of 75 to 100 feet (Lohman, 1952, p. 52-53).

Condry School fault.—The Condry School fault originates in the southeast corner of T. 24 N., R. 18 E., and extends 1.5 miles northeastward, entering western Craig County in sec. 30, T. 24 N., R. 19 E. It is downthrown to the southeast, with the basal part of the Chelsea faulted against the upper part of the Bluejacket, giving a displacement of 35 feet.

Booker School fault.—The Booker School fault begins in sec. 6, T. 24 N., R. 18 E., and trends northeastward across T. 25 N., R. 18 E. It is 4 miles long and is downthrown to the northwest, with an estimated displacement of 65 feet (Lohman, 1952, p. 54).

Welch fault.—The Welch fault is a northeastward-trending fault, downthrown to the northwest, with a displacement of 25 to

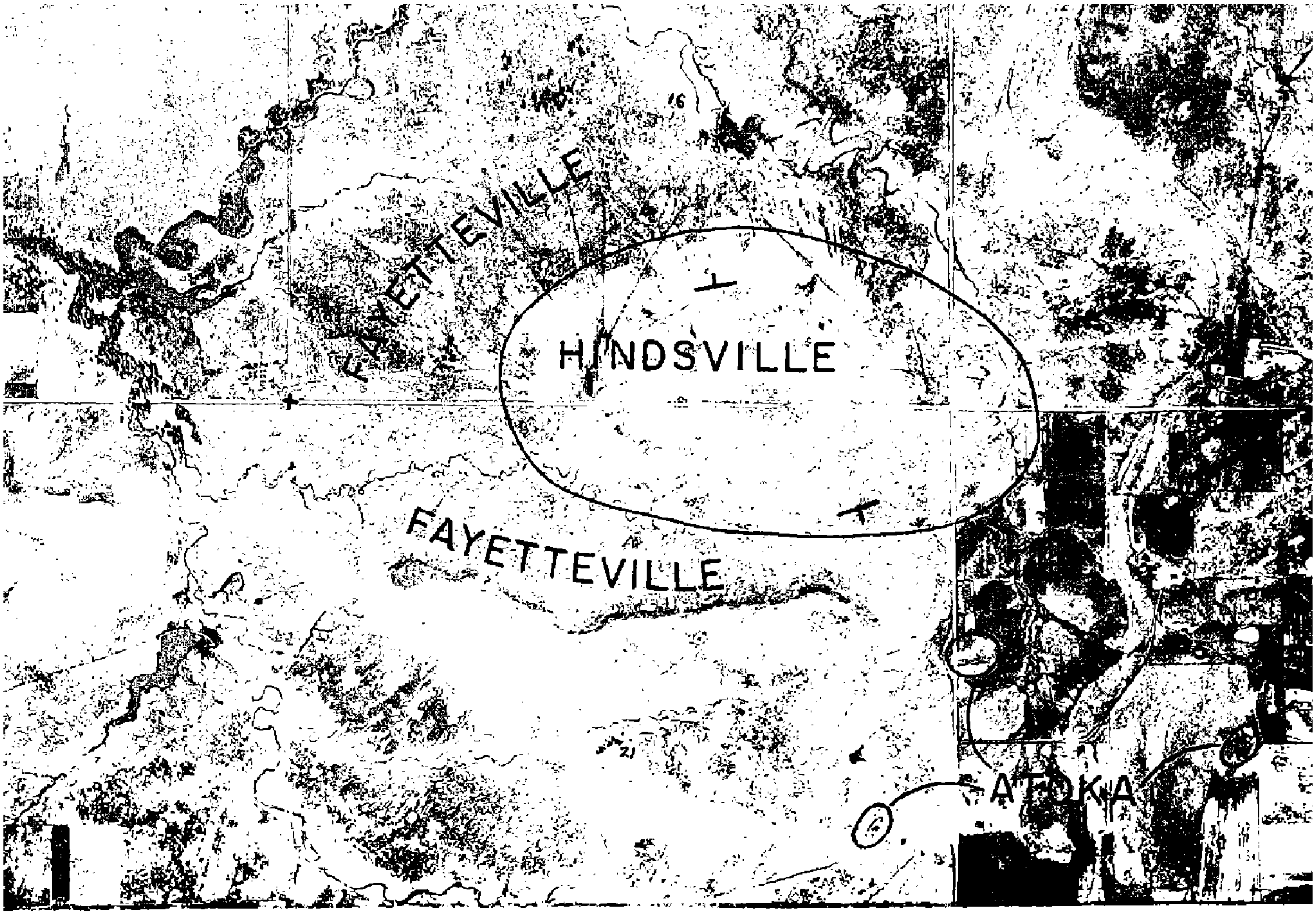

Figure 26. Airplane photograph showing small dome exposing the Hindsville Limestone and surrounding Fayetteville Formation, secs. 15, 16, 21, 22, T. 25 N., R. 21 E.

50 feet. It extends from sec. 22, T. 27 N., R. 20 E., to sec. 18, T. 28 N., R. 20 E., a distance of 7½ miles.

Miscellaneous folds.—Anticlinal uplifts and several small domes characterize parts of Craig County as follows:

1) Anticlinal uplift, north one-half of T. 28 N., R. 19 E.
2) Small anticline, W½ sec. 6, T. 27 N., R. 18 E.
3) Domal uplift, secs. 3, 4, T. 25 N., R. 21 E., bringing Hindsville Limestone to the surface.
4) Small dome, sec. 7, T. 25 N., R. 21 E., exposing Hindsville surrounded by Fayetteville.
5) Domal uplift, secs. 15, 16, 21, 22, T. 25 N., R. 21 E., 1 mile north of intersection of U. S. Highway 66 and State Highway 82 east of Vinita (fig. 26).
6) Sharp uplift on Little Cabin Creek, SW cor. sec. 28, T. 26 N., R. 21 E.

GEOLOGIC AND TECTONIC HISTORY

The geologic and tectonic history of Craig County and northeastern Oklahoma is closely associated with that of the Ozark geanticline, which persisted as a positive feature through the Paleozoic Era with frequent oscillations both to the north and south and with numerous inundations by shallow seas. During much of its history, portions of the Ozark uplift were sufficiently high to serve as a source (Ozarkia) for many of the clastics which accumulated around its flanks.

Sedimentary history of northeastern Oklahoma began with the advance of Late Cambrian seas across the irregular surface of the Precambrian rocks. In Late Cambrian-Early Ordovician seas, nearly 1,000 feet of "Arbuckle" limestone and dolomite were deposited across the Ozark area, with marked thinning across Precambrian "highs." Near Spavinaw, in Mayes County, uppermost Arbuckle-Cotter Dolomite rests unconformably upon Precambrian granite and contains weathered granite fragments. The dolomitic, sandy, and algal nature of the Cotter suggests nearshore deposition, with "Ozarkia" to the east supplying the detritus.

In Chazyan and Blackriveran time, the Simpson sea advanced across the Ozark area with the deposition of the Burgen Sandstone, the shales and dolomites of the Tyner Formation, and the lithographic Fite Limestone. Trentonian units are missing in the Oklahoma Ozarks, and the Cincinnatian is represented by the "Fernvale" limestone and the Sylvan Shale.

Submergence in Early Silurian time was followed by deposition of the high-purity Middle Silurian limestones of the Marble City area. During Early Devonian Oriskanian time the Frisco was deposited upon the eroded surface of the Silurian. Middle Devonian Sallisaw Formation lies unconformably upon the Frisco Limestone.

Ozarkia was uplifted and tilted to the south in post-Sallisaw time, and the upturned strata of Devonian, Silurian, and Ordovician age were stripped from much of the Ozark area, including Craig County. In Late Devonian time, the Chattanooga sea invaded the area, depositing the basal Sylamore (Misener) Sandstone and overlying black, pyritic, carbonaceous Noel Shale, which rests upon Arbuckle dolomite in Craig County.

Clear, warm, shallow seas prevailed during Early Mississippian (Kinderhookian and Osagean Epochs) depositing the shales, limestones, and cherts of the St. Joe, Reeds Spring, and Keokuk Formations. Uplift in post-Osagean time and northward tilting removed the Keokuk from the southern Ozarks and produced an irregular, knobby surface on the Osagean strata.

Meramecian seas advanced northward around the flanks of the Ozarks, depositing limestones and siltstones of the Moorefield Formation. The overlying Hindsville was deposited unconformably upon the eroded Keokuk and Warsaw cherts in Craig and Ottawa Counties. Fayetteville deposition represents the return of the black shale environment (euxinic) to the Ozark area. Eastern exposures of the Fayetteville contain a nearshore deposit, the Wedington Sandstone, which does not extend into Craig County. The final event in Mississippian time was the deposition of the Pitkin Limestone in warm, shallow seas. The Pitkin is not represented in Craig County.

Northeastern Oklahoma was uplifted and tilted southward in post-Pitkin time (Early Pennsylvanian). Morrowan seas advanced across the truncated Mississippian, depositing the Hale and Bloyd Formations. Port-Morrowan uplift and southward tilting occurred, and subsequent erosion removed the Morrowan north of T. 20 N., including the Craig County area.

Middle Pennsylvanian Atoka sandstones, shales, and thin limestones lie with marked unconformity upon the Morrowan and older beds. Progressive northward spread of Atoka seas is indicated by overlap of younger members from south to north. The Atoka is overlain by a thin development of shales, underclays, coal, and siltstone assigned to the Hartshorne; these are cyclic and demonstrate the beginning of platform conditions of Middle Pennsylvanian time.

Clastic deposition continued during McAlester time with development of the basal Warner Sandstone and overlying shales and coal. The succeeding Savanna and Boggy Formations are cyclic in nature and are a reflection of fluctuation of sea level on the platform area of northern Oklahoma.

The Hartshorne, McAlester, Savanna, and Boggy thicken rapidly into the Arkoma basin, where the Krebs Group reaches a thickness of 6,000 to 8,000 feet.

Movements in the Ouachita area, accompanied by downwarp in the Arkoma (McAlester) basin, led to the exclusion of the early Cabaniss seas from the Oklahoma platform. The Thurman Formation was deposited in the Arkoma basin, overlapped by the Stuart Formation, which in turn was overlapped by the Senora Formation. Deposition in Craig County was resumed by the advance of the Senora sea across the platform area. Senora sedimentation was cyclic, producing a series of sandstones, underclays, coals, shales, and thin limestones.

Epeirogenic movement in post-Boggy, pre-Senora time uplifted the Ozark area and produced a series of large, normal faults which parallel the elongation of the Ozark uplift. The trend of faulting suggests that it is the result of tension created by downwarping and loading in the Arkoma basin, accompanied by positive movement in the Ozarks, thus causing a stretching of the basement rocks and associated adjustment along basement fractures.

Greater stability of the platform was attained in Marmaton time during the deposition of thick shales and limestones of the shelf type, with only local development of coals.

Post-Marmaton time saw deposition of the Missourian and Virgilian sediments in Oklahoma and surrounding states, deposition of Permian sediments, post-Permian tilting toward the west from the Ozark uplift, peneplanation, and deposition of Pleistocene and Recent terrace gravels and alluvium.

MINERAL RESOURCES

Craig County produces a limited amount of coal, stone, sand, gravel, oil, and gas. In 1957, the total value of these products was $439,820, and the products in order of their value were coal, stone, sand and gravel, petroleum, and natural gas. The 1958 value of total production of minerals was $373,065; in order of their value these were coal, petroleum, natural gas, and sand and gravel (Grandone and Ham, 1959). By 1963, the value increased to $1,018,863; in order of value, the products were coal, oil, gas, and stone (McDougal and Ham, 1964).

Coal.—Craig County has seven coal beds of minable thickness. Most of the mining has been and all of the current operations are by stripping. Two shafts once operated, and several small drifts were in operation more than 20 years ago. Craig County was second among Oklahoma counties in coal production in 1963 (Padgett, 1964, p. 6), and probably was first in 1964. In 1963, seven companies operated eleven strip pits. In 1965, four companies were operating six pits in March.

The Rowe coal in the Savanna Formation has been produced only in small wagon pits. The Drywood coal at the top of the Savanna Formation has yielded much coal on Timbered Hill (west of Bluejacket) and in drifts and shafts in secs. 13, 14, 23, T. 26 N., R. 19 E. The Bluejacket coal, in the Boggy Formation at the top of the Bluejacket Sandstone, is and was produced in quantity from pits west of Estella operated by McNabb Coal Company.

The Weir-Pittsburg coal, lowest bed of the Senora Formation, was stripped west of Welch until ten years ago, and was an important source of tonnage. The abandoned pits are in secs. 27, 28, 32, 33, T. 28 N., R. 20 E.

The Mineral coal of the Senora Formation was produced near the Kansas-Oklahoma state line (secs. 13, 14, 23, 24, T. 29 N., R. 20 E.) where one pit is currently operating, and from many small pits west and northwest of Welch in T. 28 N., R. 20 E. The Croweburg coal is important in several Oklahoma counties and in Craig County has been produced in sec. 30, T. 25 N., R. 18 E., in sec. 29, T. 28 N., R. 19 E., and in sec. 33, T. 25 N., R. 18 E. A pit opened in

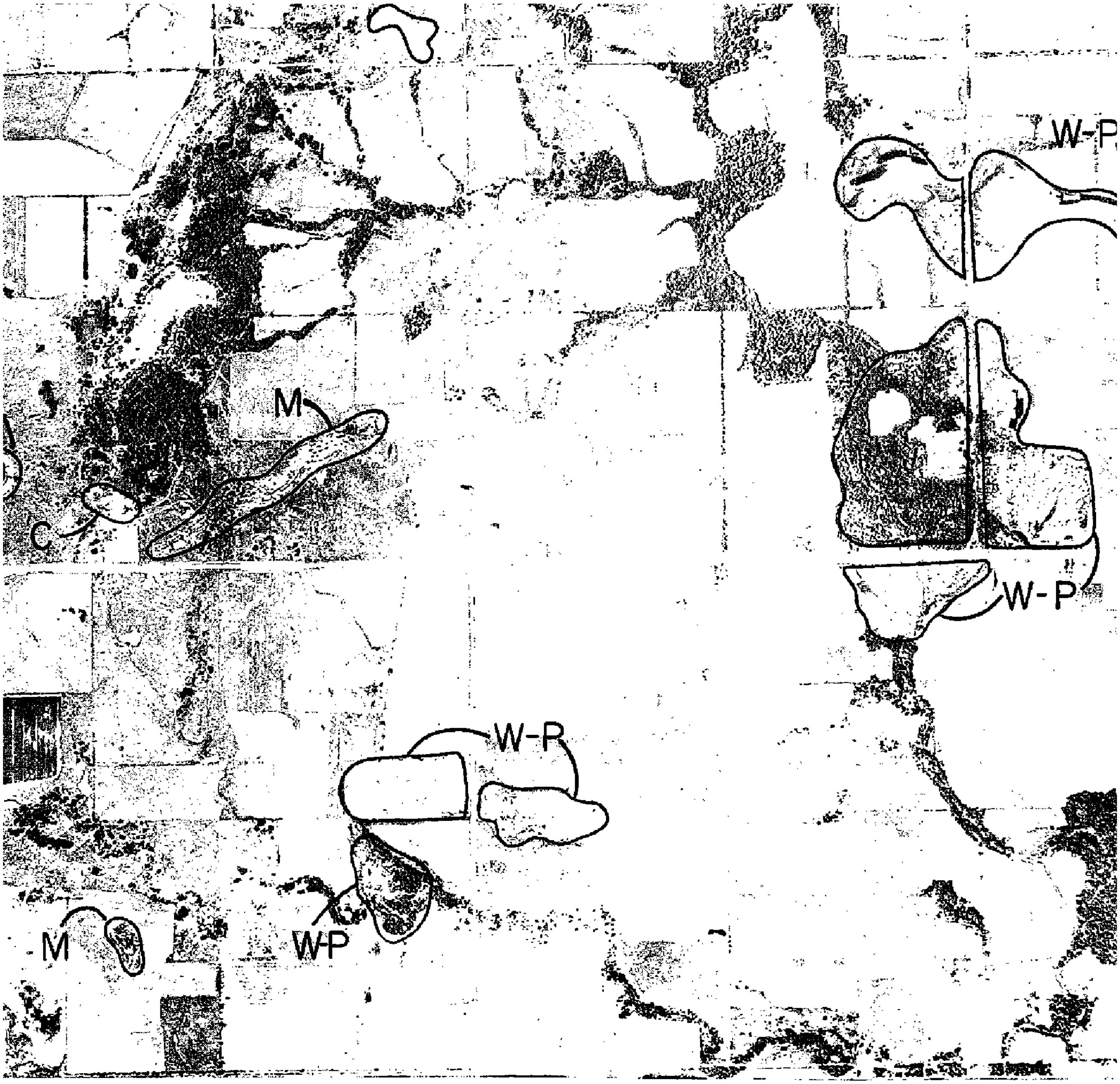

Figure 27. Airplane photograph showing strip pits about 4 miles west of Welch in secs. 20, 27, 28, 29, 32, 33, T. 28 N., R. 20 E. The Croweburg (C), Mineral (M), and Weir-Pittsburg (W-P) coals are being mined as indicated.

1957 or 1958 stripped the bed in secs. 8, 9, 16, 17, T. 27 N., R. 19 E. The pit is not shown on the geologic map.

The Iron Post coal is 10 to 16 inches thick, has a limestone cap rock of 0 to 2 feet, and lies a few feet below the Breezy Hill Limestone. Older pits were linear and along the rim of the Fort Scott escarpment. Current operations involve lifting of blocks outlined by solution-widened joints and blasting of the cap rock where it is

Figure 28. Airplane photograph of the large strip pit 0.5 mile west of Estella as it appeared in 1958. The coal being mined here is the Bluejacket. Today the pit is much larger and occupies portions of secs. 31, 32, T. 26 N., R. 19 E., and secs. 6, 7, T. 25 N., R. 19 E.

thick. The larger present and recent operations are in secs. 28, 29, 32, 33, T. 25 N., R. 18 E.

Coal 4 to 6 feet thick underlies northwestern Craig County at a depth of 300 to 400 feet.

Oil and gas.—Numerous tests have been drilled in Craig County, but the results have been disappointing. Several large fields have been discovered in Nowata and Rogers Counties to the west, and one or more of these extend across the line into Craig County. Gas and oil occur in limited quantities in the Arbuckle dolomite, the "Mississippi lime," the Burgess sand, the Bartlesville sand, and the Squirrel (Prue) sand.

The history of oil and gas production and description of the fields are given in Part II of this bulletin (p. 59-72).

Figure 29. Airplane photograph showing strip pits in the Iron Post coal in western Craig County, T. 26 N., R. 18 E. Photograph was taken in 1958.

Stone.—Stone for concrete aggregate, road metal, and building purposes is readily available in Craig County. Several limestone quarries have been in operation in recent years in the Hindsville Limestone east of Vinita. Specifically these are: (1) sec. 4, T. 25 N., R. 21 E., (2) secs. 15, 16, 22, T. 25 N., R. 21 E., (3) sec. 7, T. 25 N., R. 21 E., secs. 31, 32, T. 25 N., R. 21 E., and sec. 10, T. 24 N., R. 20 E.

Material suitable for flagstone occurs in the Bandera Quarry Member of the Bandera Formation in T. 29 N., R. 18 E. The Peru and Warner could be used for this purpose. Several of the limestones, such as the Breezy Hill and Fort Scott, have been used in construction of farm buildings.

Phosphate.—Phosphatic material is associated with several of the units in Craig County, especially in the Anna Shale Member of the Labette Formation. When combined with $CaCO_3$, commercial fertilizer results. The availability of phosphate in the Anna Shale, together with limestone from the Pawnee, makes northwestern Craig County a potential site for a fertilizer plant (Cade, 1952, p. 35). The Excello Shale and the Little Osage Shale are similarly phosphatic.

Shale for road metal.—Black, fissile shales are used for road surfacing in some localities. Near Welch, in secs. 19, 20, 21, T. 29 N., R. 20 E., and in sec. 8, T. 28 N., R. 20 E., the Excello Shale has been strip mined for road-building purposes.

Clay.—Several of the underclays, as well as the shales in this area, could be used for the making of brick, tile, and other clay products. These have been investigated by Sheerar and Redfield (1932, p. 117-123).

A 6-foot clay beneath the Weir-Pittsburg coal in SE¼ sec. 27, T. 28 N., R. 20 E., and a 2-foot clay below the Bluejacket Sandstone in SE¼ sec. 30, T. 28 N., R. 21 E., are of possible significance. The Fayetteville Shale in SE¼ sec. 8, T. 25 N., R. 21 E., is 10 feet thick and burns buff. It is suitable for brick manufacture. The McAlester Shale in SE¼ sec. 16, T. 25 N., R. 20 E., was utilized by the Vinita Brick Company to make common brick. Shale above the Weir-Pittsburg coal in the pits west of Welch has medium plasticity and is suitable for brick and pottery. Shale in the upper part of the Boggy Formation in NW¼ sec. 16, T. 24 N., R. 19 E., has good qualities, but the section tested is too thin to be classed as commercial. The Labette Shale in NE¼ NW¼ sec. 9, T. 27 N., R. 18 E., is thick and is a potential raw material for brick.

Sand and gravel.—Sand and gravel are available along the streams, and angular chert is available from the upper weathered portion of the Keokuk. High-level terrace gravels, found extensively in portions of Mayes County, are not known to exist in Craig County.

Tripoli.—Tripoli results from the weathering of chert. It is produced commercially from the upper weathered Keokuk Chert in Ottawa County. No production is known from Craig County, although in the southeastern portion the Keokuk Chert is deeply weathered and is tripolitic at places.

Part II.—Oil and Gas in Craig County

Daniel M. Strong and George G. Huffman

INTRODUCTION

Craig County lies to the west and northwest of the Ozark uplift. Although it is not an important producer of oil and gas, several small fields have been discovered within the county. The principal producing horizons are the so-called "Burgess" sand and the "Mississippi chat." Actually these probably represent in most instances the Hindsville and Warsaw Formations of Late Mississippian age. Upper Mississippian production has been established at depths ranging from 160 to 730 feet below the surface. Other producing horizons include the Arbuckle dolomite, the Bartlesville sand, and, locally, the Oswego lime. The shallow depth and limited distribution of the Bartlesville and Oswego tend to restrict their potentialities as producing horizons. The Arbuckle remains relatively untested and is the most promising horizon for future development.

SUBSURFACE STRATIGRAPHY

Precambrian Rocks

Basement rocks encountered in the subsurface of Craig County are in general composed of pink to red coarse-grained granite of the Spavinaw type. Recent investigations (Ham, 1961, p. 139-149), based upon well cuttings from central and northern Craig County, have revealed the presence of a basement-rock complex consisting of andesite tuff and dacite. This discovery has led to the postulation of a widespread volcanic flow covering much of the area of Craig and Nowata Counties.

The Frankfort Oil Company 1 Van Ausdel well (SE¼ NE¼ NW¼ sec. 31, T. 28 N., R. 20 E.) penetrated 322 feet of dark-gray to reddish-brown, welded andesite tuff. Andesite tuff also occurs beneath the Arbuckle dolomite in the Wackerle Oil Company 4

Hood well (SE¼ SW¼ SE¼ sec. 19, T. 28 N., R. 20 E.), where 97 feet was penetrated. The Frankfort Oil Company 1 Bluejacket well (NW¼ NW¼ NW¼ sec. 4, T. 26 N., R. 19 E.) penetrated 26 feet of flesh-pink dacite, overlain unconformably by the Cambrian Lamotte Sandstone.

According to Ham (1961, p. 149), the andesite and dacite rocks of Craig County are probably related to the same magma and are essentially contemporaneous.

Cambrian and Ordovician Rocks

Lamotte Sandstone.—Precambrian basement rocks are succeeded unconformably by the Upper Cambrian Lamotte Sandstone, a time-transgressive unit which may be homotaxial in part with the Reagan Sandstone of the Arbuckle Mountains. Thickness of the Lamotte in Craig County ranges from 0 to 100 feet and averages 50 feet.

Arbuckle Group.—The Arbuckle Group includes the post-Lamotte dolomitic and sandy beds of Late Cambrian and Early Ordovician age. Upon the basis of insoluble residues, Ireland (1944) divided the Arbuckle of northeastern Oklahoma into the Bonneterre Dolomite, Eminence Dolomite, Gasconade Dolomite with basal Gunter Sandstone Member, the Roubidoux Formation, Jefferson City Dolomite, Cotter Dolomite, and Powell Dolomite, using terminology already established in the Ozark uplift in Missouri and Arkansas. The Cotter Dolomite appears to be the uppermost unit present in Craig County and crops out a few miles to the south at Spavinaw, Oklahoma.

In general the Arbuckle Group is composed of brown to gray, massive-bedded, cherty, vuggy dolomite with interbeds of white, fine-grained, well-sorted, dolomitic sandstone. Associated cherts are white and oölitic. Lowermost sandstones and sandy dolomites are characterized by large, rounded, frosted quartz grains.

Thickness of the Arbuckle Group ranges from approximately 750 feet to more than 1,500 feet, with a general southward and westward thickening (fig. 30). Arbuckle rocks dip uniformly westward at the rate of approximately 30 feet per mile (fig. 31).

The Arbuckle is succeeded unconformably by the Chattanooga Formation or, in its absence, by rocks of Mississippian age. Simpson equivalents are absent owing to pre-Chattanooga uplift and erosion.

Late Devonian-Early Mississippian Rocks

Chattanooga Formation.—The Chattanooga Formation in subsurface includes the basal Sylamore Sandstone Member and the

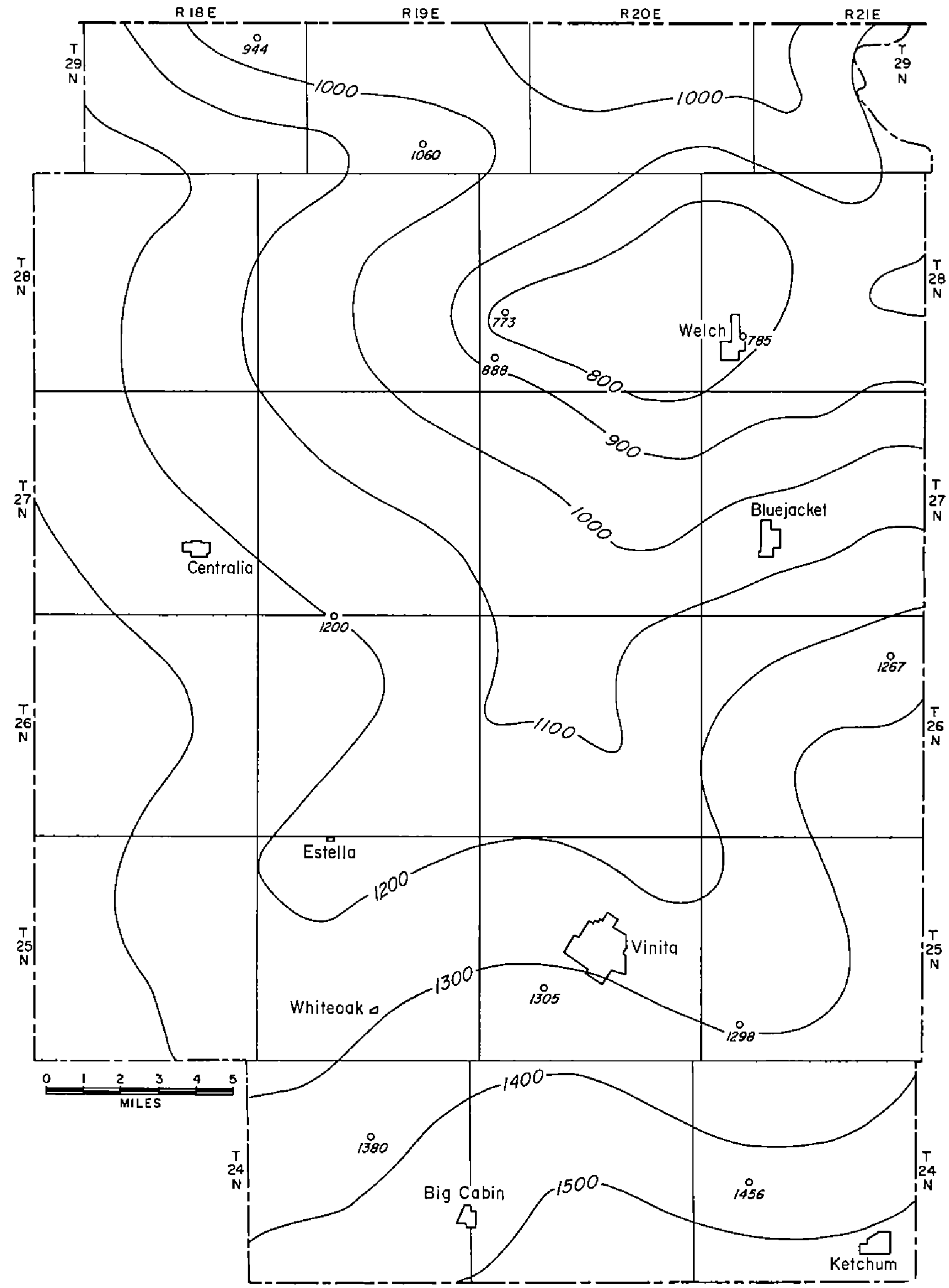

Figure 30. Isopach map of "Arbuckle" Group including Lamotte Sandstone. Contour interval: 100 feet. Redrawn from Strong (1961).

overlying black shale member, the Noel. The Sylamore Member is erratic in distribution and at few places exceeds a foot or two in thickness. A maximum thickness of 10 feet occurs in one well in

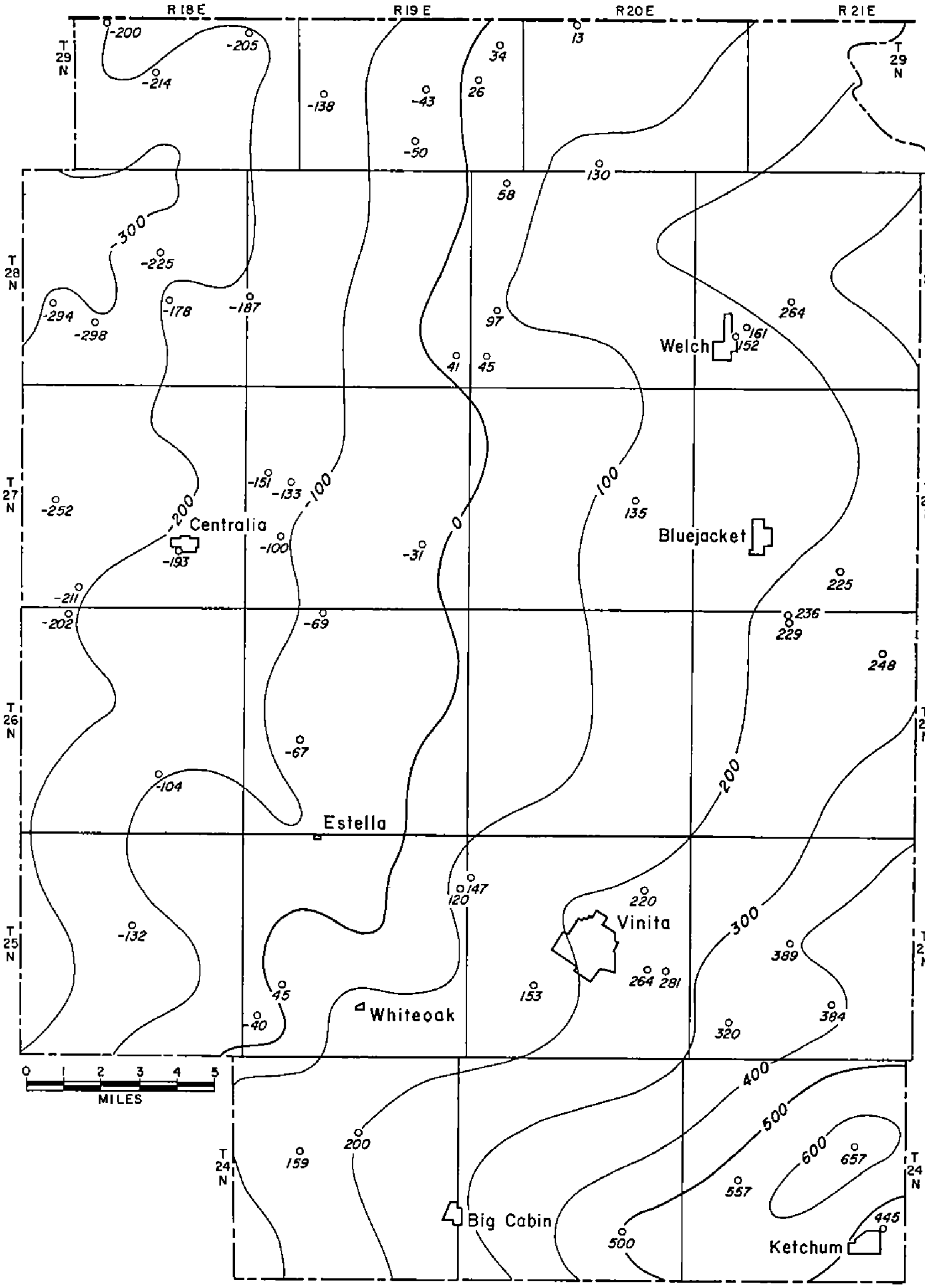

Figure 31. Structure map of top of Arbuckle Group. Contour interval: 100 feet. Redrawn from Strong (1961).

northern Craig County. The sand grains are fine to medium, subangular to rounded, and poorly sorted.

The overlying Noel Shale Member is black to brownish black,

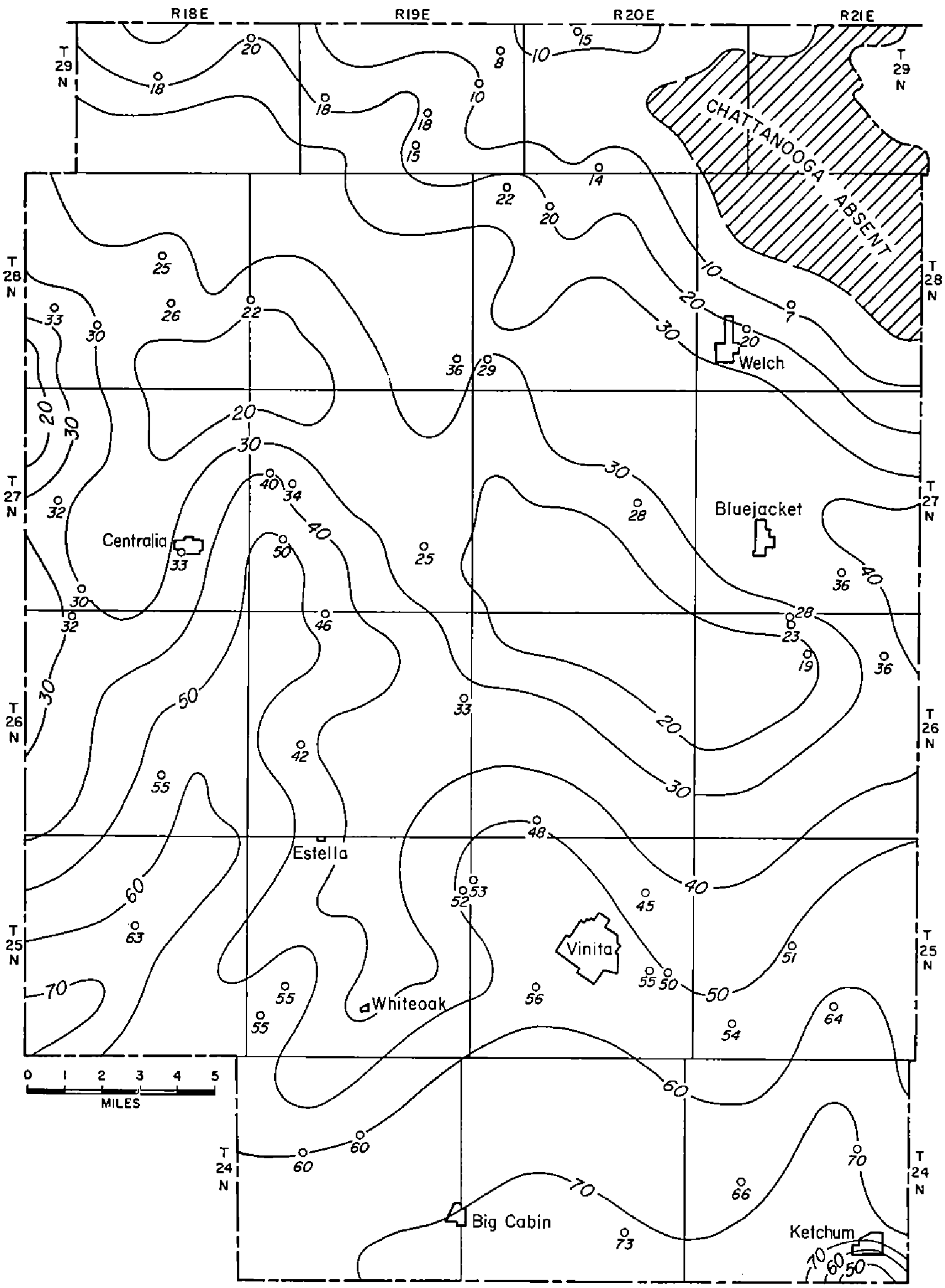

Figure 32. Isopach map of Chattanooga Formation (Sylamore and Noel facies). Contour interval: 10 feet. Redrawn from Strong (1961).

platy to fissile, pyritic, and *Tasmanites* bearing. Thickness of the Noel facies ranges from 0 to 40 feet in northern Craig County; it thickens southward to more than 70 feet along the Craig-Mayes county line (fig. 32).

Kinderhookian green shale.—In northern Craig County, the Chattanooga Formation (Noel facies) is succeeded by gray and gray-green, dolomitic and silty shale with local beds of thin, impure dolomite. *Tasmanites* is characteristically associated with the gray-green shale facies. The shale ranges in thickness from 0 in T. 26 N. to 35 feet in T. 28 N. It thickens northward as the Noel Member thins and it disappears southward as the Noel facies thickens so that the aggregate thickness of the two facies remains a relatively constant 50 to 60 feet throughout the county.

The age and stratigraphic assignment of this gray-green shale unit are not clearly understood. Lee and Girty (1940, p. 22) reported similar shales in southeastern Kansas and considered them to be a lateral variation of the Chattanooga. In northeastern Kansas, a greenish-gray, "spore-bearing," silty, and dolomitic shale resting above the Chattanooga has been named the Boice Shale (Moore and others, 1951, p. 111).

The presence of *Tasmanites* (Strong, 1961, p. 28) in both the gray-green shale and the underlying black Noel Shale and their inverse thickness relationships across the area suggest that this gray-green shale is a northern facies of the Chattanooga Formation rather than a correlative of some part of the overlying St. Joe Group.

Mississippian Rocks

The post-Chattanooga Mississippian rocks in Craig County are represented by the St. Joe Group and the Reeds Spring, Keokuk, Warsaw, Hindsville, and Fayetteville Formations. Thickness ranges from 0 to 350 feet in southeastern Craig County, where the section is truncated by post-Pennsylvanian erosion. Beneath the Pennsylvanian cover, thickness ranges from 300 to 400 feet (fig. 33).

St. Joe Group.—The St. Joe Group in subsurface resembles that at the surface where a three-fold subdivision has been recognized (Huffman, 1958, p. 41-43). The basal limestone (Compton equivalent) is cream to gray, finely crystalline, pyritic, argillaceous, and fossiliferous. The middle shale (Northview equivalent) is pale green, pyritic, calcareous, or dolomitic. The upper limestone (Pierson equivalent) is cream to gray, finely crystalline, noncherty, crinoidal limestone. Locally the upper limestone grades laterally into bio-

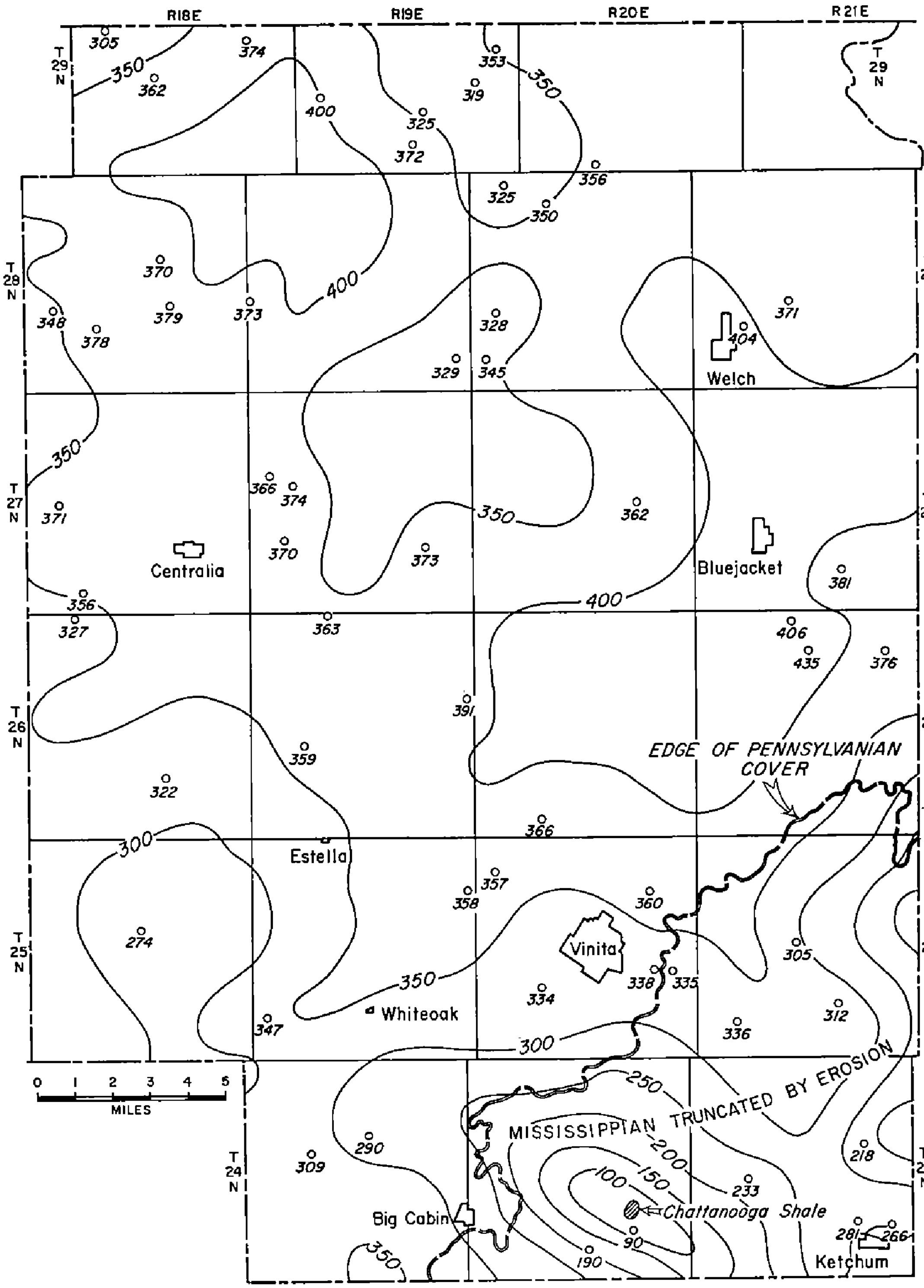

Figure 33. Isopach map of Mississippian System (post-Chattanooga). Contour interval: 50 feet. Redrawn from Strong (1961).

hermal reefs. The "nonreef phase" of the St. Joe maintains a uniform thickness of 15 to 20 feet in Craig County. In the "reef phase" thicknesses of 40 to 100 feet have been reported. A good example of the "reef phase" is present in the Mesker Drilling Company 1 Sheffield well, sec. 21, T. 28 N., R. 21 E., where 87 feet of crinoidal limestone was penetrated (Strong, 1961, p. 31).

Reeds Spring and Keokuk Formations.—The Reeds Spring consists of tan to gray, finely crystalline, siliceous limestone and blue-gray to dark-gray and brown, vitreous chert. The Keokuk is a massive, white, tripolitic chert and gray, siliceous, finely crystalline limestone. The Keokuk-Reeds Spring sequence is thickest in northeastern Craig County, where 260 feet has been recognized, and it thins southwestward.

Warsaw Formation.—The Keokuk is succeeded unconformably by the Warsaw Formation in the Tri-State mining district, as in Ottawa County, Oklahoma. The Warsaw can be traced into the subsurface of Craig County, where it maintains a relatively uniform thickness of 120 feet until it reaches the Craig-Mayes county line, where it thins to extinction.

The Warsaw is characterized at the base by the so-called "J" bed, a brownish to dark-gray, glauconitic limestone, which ranges in thickness from 5 to 50 feet. The Osage-Meramec contact was placed by Moore, Fowler, and Lyden (1939, p. 3) at the base of the "J" bed. This boundary generally occurs 30 to 40 feet above the Short Creek oölite, a prominent marker bed in the upper part of the Keokuk.

Warsaw strata above the "J" bed consist of siliceous, tan to gray, finely crystalline limestone and gray to white, microfossiliferous chert. The chert seems to represent various stages of replacement of the original limestone. Locally the upper portion of the Warsaw is tripolitic and weathered to form "cotton rock."

The Warsaw is believed to occupy the stratigraphic position of the Moorefield Formation of the south and west flanks of the Ozark uplift. The glauconitic "J" bed is thought to correspond to the glauconite development at the base of the Moorefield in Mayes, Wagoner, and Cherokee Counties.

Hindsville Formation.—In subsurface, the Hindsville is a gray, fine- to coarse-crystalline, oölitic, fossiliferous, bioclastic limestone. The lower part is argillaceous, and green shales are present at many places. Locally the Hindsville becomes silty and sandy, and the upper part becomes the Batesville Sandstone of Ottawa County.

The Hindsville rests unconformably upon the eroded surface of the Warsaw and Keokuk Formations. Thickness ranges from 0 to 64 feet and averages 40 feet. The Hindsville is petroliferous and accounts for much of the "Burgess sand" production in Craig County.

Fayetteville Formation.—The Fayetteville Formation consists primarily of dark-gray to gray-green, calcareous shale with local beds of gray, medium-crystalline, fossiliferous limestone. It is truncated and overlapped northward by Pennsylvanian shales and sandstones; it thickens southward into Mayes County, where it grades into a lower limestone and shale sequence overlain by black, fissile shale.

Pennsylvanian Rocks

Krebs Group.—The Krebs Group includes, in ascending order, the Hartshorne, McAlester, Savanna, and Boggy Formations. The beds are cyclic and include alternating sandstones, shales, thin limestone, and coal.

In subsurface the lower part of the Krebs Group consists of dark-gray to black shale with thin beds of clay-ironstone, impure limestone, coal, sandstones, and green, waxy shale. The upper portion is composed of dark shales and massive sandstones, which grade laterally and vertically into siltstones and silty shale. Locally at the base of the Krebs is a thin conglomerate which C. C. Branson (1954b, p. 11) correlated with the "Burgess sand" of the subsurface.

The Krebs Group is present throughout the subsurface extent of Craig County west and north of the Mississippian outcrop. Thickness ranges from 0 along the updip edge to approximately 520 feet (fig. 34). The more prominent and persistent marker beds are the Warner (Booch) Sandstone, Bluejacket (Bartlesville) Sandstone, and the Taft (Red Fork) Sandstone.

Cabaniss Group.—The Cabaniss Group in Craig County includes only the Senora Formation, a cyclic sequence of shale, sandstone, limestone, and thin coals. Paleobotanical evidence places the base of the Senora Formation at the base of the Weir-Pittsburg coal (L. R. Wilson, oral communication, October 1961).

Important subsurface marker beds within the Senora Formation, in ascending order, are the Tiawah (Pink) Limestone, Chelsea (Skinner) Sandstone, Verdigris Limestone, Lagonda (Prue or Squirrel) Sandstone, and the Breezy Hill Limestone.

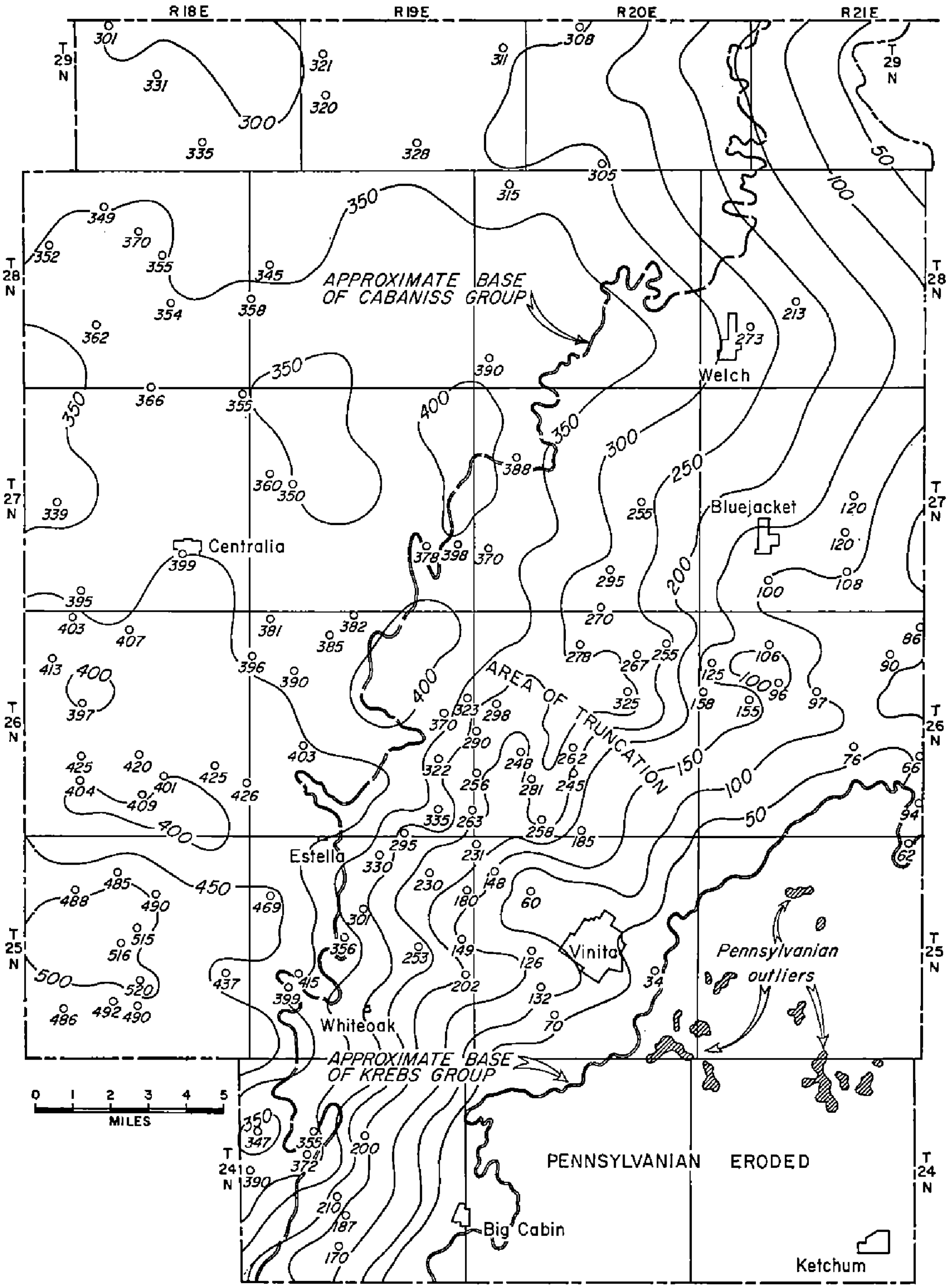

Figure 34. Isopach map of Krebs Group. Contour interval: 100 feet. Redrawn from Strong (1961).

Thickness of the Cabaniss Group (fig. 35) ranges from 0 at the updip edge to a maximum of 222 feet.

Marmaton Group.—The Marmaton Group includes, in ascending order, the Fort Scott Formation, Labette Shale, Pawnee Lime-

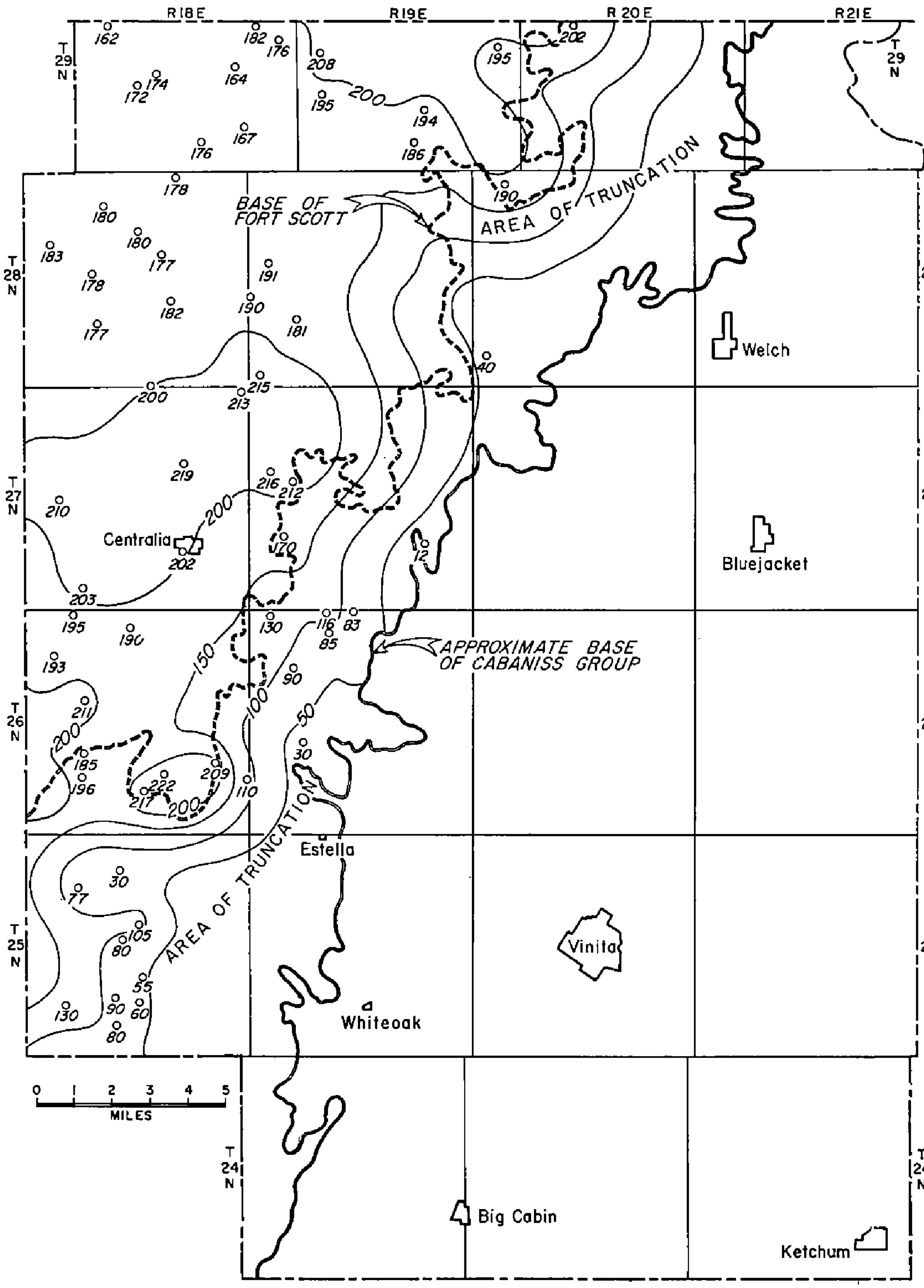

Figure 35. Isopach map of Cabaniss Group. Contour interval: 50 feet. Redrawn from Strong (1961).

stone, Bandera Shale, and Altamont Limestone. The limestones serve as excellent marker beds both at the surface and in subsurface, although few wells in Craig County have encountered beds younger than the Pawnee.

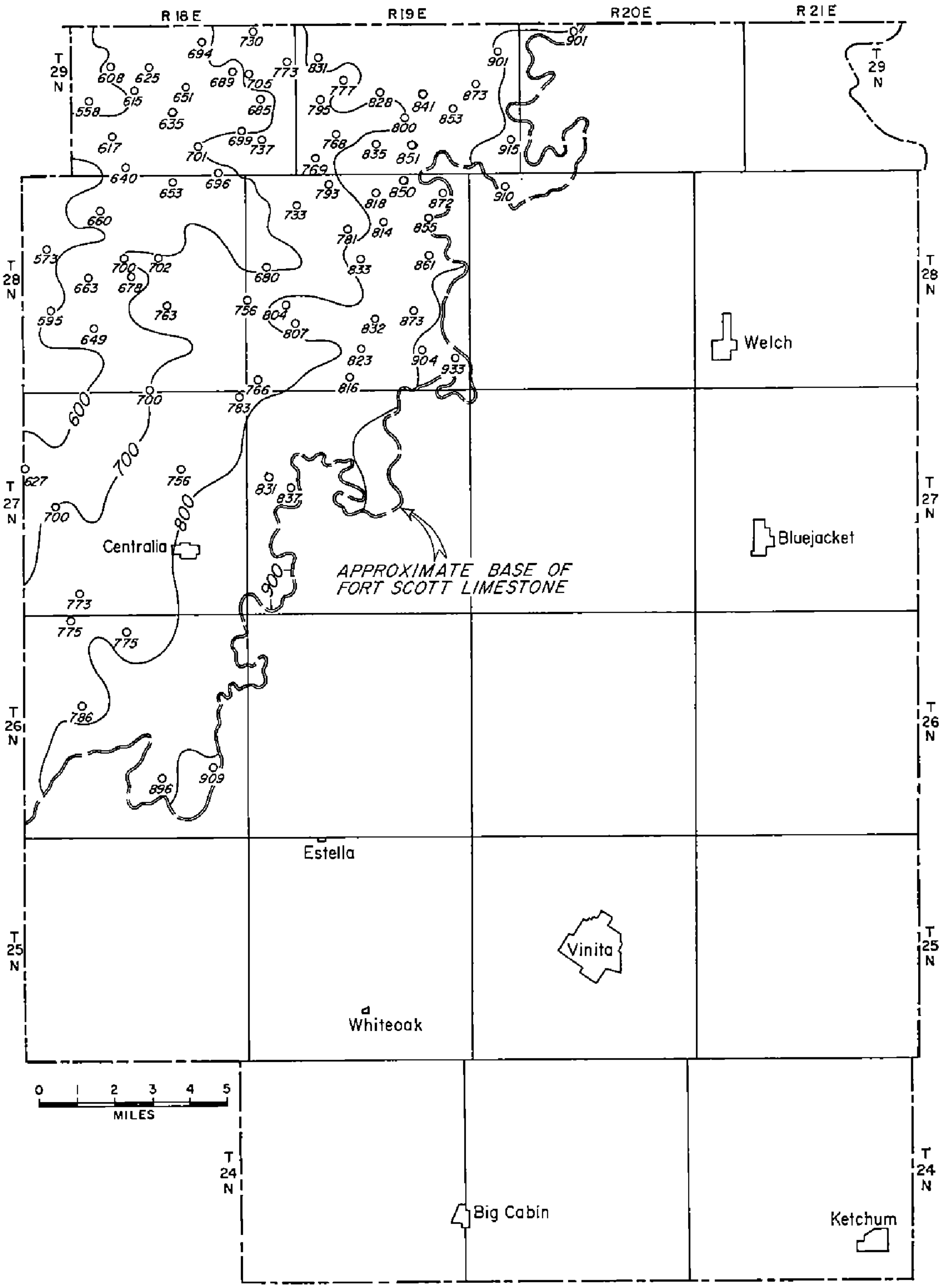

Figure 36. Structure map of base of Fort Scott Limestone. Contour interval: 100 feet. Redrawn from Strong (1961).

The most important subsurface marker bed of the Marmaton Group is the Fort Scott. It consists of a lower limestone member, the Blackjack Creek, and an upper limestone member, the Higginsville, separated by a black shale unit known as the Little Osage Member. The Blackjack Creek Member is 30 to 40 feet thick; the Little Osage Shale is 4 to 10 feet thick; and the Higginsville Member averages nearly 40 feet in thickness.

The base of the Fort Scott is an excellent subsurface datum plane and is used in subsurface mapping, in which the unit is called the Oswego lime. Regional westward dip on the base of the Fort Scott (Oswego) is about 30 feet per mile (fig. 36).

OIL AND GAS PRODUCTION

1) The East Catale field (T. 24 N., R. 19 E.), formerly called the Vinita pool, was discovered in 1910. Production was from the "Burgess" at a depth of 400 feet. Initial production ranged from 3 to 10 barrels of oil and 1,000 to 2,000 cubic feet of gas per day (Mills-Bullard, 1928, p. 260-261).

2) The Wimer pool (T. 28 N., R. 18 E.) was discovered by the Kansas-Oklahoma Oil Company in 1914. Production from the "Burgess" at a depth of 700 feet included 20 barrels of oil and 1,000 to 3,000 cubic feet of gas per day (Mills-Bullard, 1928, p. 267).

3) According to Bloesch (1928), a small pool was opened in sec. 20, T. 26 N., R. 18 E., in 1916 with minor production from the Bartlesville and "Burgess" sands.

4) The "Vinita" field (T. 26 N., R. 20 E.) produces oil from the "Burgess" and gas from the "chat" at depths of 210 and 270 feet. Initial production ranged from 0.5 to 25 BPD but averaged less than 5 BPD. Gas yields of more than one million cubic feet per day were reported. These wells were drilled in the 1930's.

5) Several small wells were drilled near Booker School (secs. 28, 32, T. 25 N., R. 18 E.). Production was from the Burgess zone (Bloesch, 1928).

6) Northwest of Vinita in T. 25 N., Rs. 19, 20 E., a small field produces oil and gas from the Hindsville and Warsaw at depths of 160 to 240 feet. Initial gas production ranged as high as six million

cubic feet per day but averaged less than one million. These wells were drilled in the 1930's.

7) East of Vinita, in secs. 16, 21, T. 25 N., R. 21 E., are several wells which produced gas from the top of the Arbuckle at depths of 380 and 360 feet. Initial production averaged a million cubic feet per day. The wells are noncommercial and are shut in.

8) East Centralia pool, T. 27 N., R. 19 E., includes two wells from which oil and gas shows were reported from the top of the Arbuckle, the "Mississippi chat," and the Bartlesville.

9) Southeast of Centralia (T. 26 N., R. 19 E.) is a small field which produces gas from the upper part of the Warsaw or "chat" at a depth of 460 to 490 feet. These wells were drilled in the late 1930's and early 1940's.

10) Four wells reportedly found oil in the top of the Arbuckle in sec. 21, T. 29 N., R. 18 E. One of these is supposed to have yielded 50 barrels of oil per day (Bloesch, 1938).

11) Miscellaneous reports: (a) sec. 9, T. 28 N., R. 20 E., gas production from the "Burgess" at 514 feet; (b) sec. 1, T. 25 N., R. 19 E., abandoned production from "Mississippi lime"; (c) sec. 1, T. 27 N., R. 18 E., with minor gas production from a Pennsylvanian sand; (d) sec. 25, T. 27 N., R. 18 E., producing gas from the Upper Mississippian at 574 feet; (e) sec. 4, T. 26 N, R. 21 E., and sec. 32, T. 27 N., R. 21 E., with minor production from the Upper Mississippian at 105 to 120 feet; and (f) isolated wells in Tps. 28, 29 N., R. 18 E., producing small amounts of gas at depths of 645 to 760 feet.

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APPENDIX

Measured Sections

	Feet
1. *Sec. 3, T. 24 N., R. 19 E. Measured in high bluff on south bank of Whiteoak Creek on west side of tributary stream in NE¼ NW¼ (Lohman, 1952, p. 79).*	
Boggy Formation	
Sandstone (Bluejacket), light grayish-yellow, fine-grained, massive-bedded, cross-laminated; not measured	
Savanna Formation	
Coal (Drywood)	0.1
Underclay	1.0
Shale, dark-gray	13.3
Claystone; weathers light grayish yellow	3.3
Shale, gray, fissile	9.8
Coal (Rowe)	0.5
Shale, light yellowish-gray	5.3
Base of exposure at water level in creek	

2. *Sec. 3, T. 24 N., R. 19 E. Measured along road up hill in southwest corner SE¼ (Lohman, 1952, p. 80).*	
Boggy Formation	
Bluejacket Member	
Sandstone, light-yellow, massive, cross-bedded, medium-grained, silty. Basal beds contain limonitic concretions and a few pieces of shale, giving conglomeratic appearance; not measured	
Savanna Formation	
Coal (Drywood)	0.2
Underclay; approximately	1.5
Shale, dark-gray to black, hard, platy; upper beds lighter gray and softer	9.9
Shale, gray; containing concretionary clay, ironstone beds, and dikelike structures	8.2
Coal (Rowe)	0.3
Shale, light-gray; not measured	

3. *Sec. 9, T. 24 N., R. 19 E. Measured in south bank of creek near southeast corner (Lohman, 1952, p. 80).*

Boggy Formation

Bluejacket Member

Sandstone, light grayish-yellow to light-yellow,

	Feet
massive, fine-grained; mottled and streaked with brown; not measured	
Savanna Formation	
Clay, gray	1.0
Shale, gray; weathers fissile; contains two thin clay-ironstone beds and one 6-inch bed of silty, ferruginous clay	26.2
Coal (Rowe)	0.6
Underclay; about	1.0
Shale, dark-gray; irregularly stratified and containing concretionary masses of hard siltstone ...	11.0
Base of section at water level in creek	

4. *Sec. 9, T. 24 N., R. 19 E. Measured west along the south line of section from creek bottom 0.25 mile west of the southeast corner to top of hill 0.25 mile east of the southwest corner (Lohman, 1952, p. 83).*

	Feet
Senora Formation	
Sandstone (Chelsea), brown, ferruginous, medium-grained; angular grains. Basal beds are dark purple and brown, conglomeratic, with chips of shale and phosphatic nodules; not measured	
Shale, sandy, poorly exposed	31.0
Boggy Formation	
Sandstone (Taft), light grayish-yellow, fine-grained, micaceous, thin-bedded	5.8
Shale, light-gray, soft, shaly	12.6
Sandstone, light grayish-yellow, thin-bedded, very fine-grained, silty	1.0
Covered interval; probably gray shale	10.6
Sandstone, tan with dark-brown streaks, very fine-grained, well-indurated	2.0
Shale, gray	12.3
Bluejacket Member	
Heterogeneous sequence of yellow shale, siltstone, fine-grained sandstone, and clay-ironstone, all thin-bedded	21.4
Sandstone, light grayish-yellow, fine-grained, micaceous, massive-bedded, cross-laminated	20.0
Savanna Formation	
Coal (Drywood)	0.1
Underclay; not measured	

5. *Sec. 15, T. 24 N., R. 19 E. Measured westward up hill along road near the southwest corner (Lohman, 1952, p. 80-81).*

Boggy Formation

	Feet
Bluejacket Member	
Sandstone, light grayish-yellow, fine-grained, micaceous, ferruginous; with 6-inch lenticular shale bed near base; not measured	
Savanna Formation	
Shale, gray, silty	2.0
Coal (Drywood)	0.2
Shale, gray; contains concretionary clay-ironstone beds	22.4
Coal (Rowe)	0.5
Shale, gray, poorly exposed	10.1
Mudstone, mottled gray and purple; noncalcareous with gray shale chips	0.5
Shale, light-olive, platy; containing a few clay-ironstone concretions; gradational into underlying beds; about	6.8
Shale, gray, fissile; containing clay-ironstone concretions	5.8
Limestone (Sam Creek), dark, silty, fossiliferous; clay-ironstone	0.3
Shale, yellow, fossiliferous; contains calcareous, fossiliferous clay-ironstone bed 1.5 feet below the top; approximately	3.0

6. *Secs. 16, 17, T. 24 N., R. 19 E. Measured along south line of sections from creek bottom, 0.2 mile east of southwest corner sec. 16, to top of hill, 0.3 mile west of southeast corner of sec. 17 (Lohman, 1952, p. 84).*

	Feet
Senora Formation	
Sandstone (Chelsea), red, highly ferruginous, medium- to fine-grained; not measured	
Shale, gray, poorly exposed; contains a few sandy beds; about	53.0
Boggy Formation	
Sandstone (Taft), white, yellow, and brown mottled, very fine-grained, well-indurated	5.0
Shale, gray, poorly exposed; probably contains a few thin sandstones	30.3
Bluejacket Member	
Sandstone, yellow, ferruginous, medium- to fine-grained, micaceous, friable, cross-laminated	7.8
Heterogeneous sequence of brownish-yellow, very fine-grained sandstone, siltstone, and silty shale, all thin-bedded	14.1
Sandstone, light brownish-yellow to grayish-yellow, ferruginous, micaceous, fine-grained, massive-bedded, cross-laminated	30.0

	Feet
7. *Sec. 19, T. 24 N., R. 19 E. Measured northward along road from creek bottom about 0.25 mile north of the southwest corner (Lohman, 1952, p. 83).*	
Boggy Formation	
Sandstone (Taft) micaceous, friable; gray to brown on fresh surface; weathering light red. Basal beds are slightly conglomeratic; *Stigmaria* present; not measured	
Shale, gray; containing large limonitic concretions	8.1
Bluejacket Member	
Sandstone, light grayish-yellow, fine-grained, thin-bedded, micaceous	4.5
Siltstone, light-gray, laminated	1.0
Sandstone, light grayish-yellow, fine-grained, even-bedded; base not exposed	2.0
8. *Sec. 19, T. 24 N., R. 19 E. Measured east along road up hill, 0.2 mile east of the southwest corner (Lohman, 1952, p. 84).*	
Senora Formation	
Sandstone (Chelsea), highly ferruginous, deep purple and yellow; basal beds, conglomeratic, containing limonitic concretions, phosphatic nodules, and plant remains; top eroded	54.0
Shale, gray	10.6
Coal (Weir-Pittsburg)	0.8
Underclay; not measured	
Shale, gray; not measured	
9. *Sec. 28, T. 24 N., R. 19 E. Measured in escarpment behind farmhouse in NW¼ SE¼ (Lohman, 1952, p. 81).*	
Boggy Formation	
Bluejacket Sandstone Member; not measured	
Savanna Formation	
Shale, gray	27.0
Coal (Rowe)	0.5
Shale, gray	25.0
Limestone (Sam Creek), dense, black, fossiliferous; clay-ironstone	0.3
Shale, gray, fossiliferous	2.5
Coal	0.3
Shale, gray; not measured	
10. *Sec. 32, T. 24 N., R. 19 E. Measured westward along road in southeast corner of SW¼ (Lohman, 1952, p. 81).*	
Boggy Formation	
Bluejacket Sandstone Member; not measured	

	Feet
Savanna Formation	
Shale, gray; estimated thickness	25.0
Limestone (Doneley), gray, silty, sparingly fossiliferous	0.5
Shale, dark-gray	0.3
Coal (Rowe)	0.4
Underclay	1.0
Shale; largely covered	27.0
Limestone (Sam Creek), dense, black, fossiliferous; clay-ironstone	0.2
Shale, yellow; not measured	

11. *Sec. 36, T. 24 N., R. 19 E. Measured west up hill, 0.2 mile east of the northwest corner (Lohman, 1952, p. 76).*

	Feet
McAlester Formation	
Shale; not measured	
Warner Member	
Sandstone, brown, medium-grained, thin-bedded, cross-laminated	3.0
Sandstone, brown, medium-grained, massive, cross-bedded	5.8
Sandstone, black, tar-stained, medium-grained, well-sorted	8.8
Sandstone, brown to purple, medium-grained, conglomeratic, highly ferruginous, slightly calcareous; tar-stained in part; contains shale chips	5.8
Hartshorne Formation	
Shale, poorly exposed; not measured	

12. *Sec. 3, T. 25 N., R. 18 E. Measured east along road up hill, 0.2 mile west of the northeast corner (Lohman, 1952, p. 88).*

	Feet
Fort Scott Formation	
Limestone (Blackjack Creek), light-gray, finely crystalline, fossiliferous; weathers white; top eroded	8.8
Senora Formation	
Shale (Excello), black; containing phosphatic nodules	5.1
Breezy Hill Member	
Limestone, light-gray to white, fine-crystalline, fossiliferous	2.0
Limestone, light-brown, silty, dense, fossiliferous	3.0
Shale (Kinnison), poorly exposed	4.0
Coal (Iron Post)	0.5
Shale, gray	11.9

	Feet
Sandstone (Lagonda), brown; with a few calcareous streaks	0.5
Shale, gray; weathers yellow	9.8
Limestone (Verdigris); not measured	

13. *Sec. 6, T. 25 N., R. 18 E. Measured west, up hill along road, 0.25 mile north of the southwest corner (Lohman, 1952, p. 87).*

Fort Scott Formation	
Limestone (Blackjack Creek), light-gray, crystalline, fossiliferous; not measured	
Senora Formation	
Shale (Excello), black; containing phosphatic nodules	5.0
Limestone (Breezy Hill); upper beds thin-bedded	10.4
Shale (Kinnison), dark-gray; upper one-foot yellow	2.5
Coal (Iron Post)	1.5
Shale, gray, silty	1.0
Sandstone (Lagonda), gray, fossiliferous, calcareous; weathers brown	1.0
Shale, weathered	1.0
Limestone (Verdigris); not measured	

14. *Sec. 12. T. 25 N., R. 18 E. Measured in bank of creek near the southwest corner NE¼ NE¼ (Lohman, 1952, p. 85).*

Senora Formation	
Sandstone (Chelsea), poorly exposed; not measured	
Covered interval: about	30.0
Limestone (Tiawah), brown; weathered clay-ironstone containing *Mesolobus* and *Desmoinesia muricatina*	0.2
Siltstone, yellow	1.0
Shale, dark-gray to black, fissile; containing clay-ironstone concretions	12.5
Shale, black, blocky; containing phosphatic nodules	0.8
Shale, gray, fissile	0.8
Coal (Tebo)	0.3
Underclay; not measured	

15. *Sec. 28, T. 25 N., R. 18 E. Measured in east slope of hill about 0.6 mile west of northeast corner (Lohman, 1952, p. 87-88).*

Senora Formation	
Limestone (Breezy Hill), light-gray to brown, finely crystalline, silty, fossiliferous	4.3
Shale (Kinnison), largely covered	1.0
Coal (Iron Post)	1.0

	Feet
Shale	1.0
Sandstone (Lagonda), brown, calcareous, fossiliferous	1.5
Shale; weathers light grayish yellow	1.0
Coal (Bevier)	0.3
Underclay	0.4
Shale, gray, silty	0.6
Sandstone, light blue-gray, silty, very fine-grained, micaceous	1.5
Shale, gray; weathers light grayish yellow	19.4
Limestone, dark-gray, dense, silty	0.5
Limestone (Verdigris), light-gray, dense, massive, fossiliferous	6.1
Shale, black; containing phosphatic nodules	0.7
Shale, gray, silty	4.8
Sandstone, tan, very fine-grained, silty, micaceous; containing abundant *Stigmaria*	5.0
Shale; weathers grayish yellow; not measured	

16. *Sec. 36, T. 25 N., R. 18 E. Measured south from creek bed, 0.2 mile south of northwest corner up gulch just east of road and along road to top of hill (Lohman, 1952, p. 86).*

Senora Formation	
Sandstone (Chelsea), variously colored red, orange, and purple, massive-bedded, cross-laminated, micaceous, medium-grained; top eroded	58.0
Covered interval; presumably gray shale, containing a 2-inch coal and underclay somewhere near the middle; about	12.0
Shale, dark-gray to black	6.0
Limestone (Tiawah), brown; clay-ironstone; concentric structures; with a gastropod-pelecypod fauna	0.2
Shale, black	1.0
Shale, black; paper-thin bedding	0.5
Shale, black, blocky; containing phosphatic nodules	0.6
Coal (Tebo)	0.3
Underclay; not measured	

17. *Sec. 3, T. 25 N., R. 19 E. Measured westward along road up bluff, about 0.3 mile west of southeast corner (Lohman, 1952, p. 77).*

Savanna Formation	
Shale, gray; not measured	
Shale, black, soft, carbonaceous; with small phosphatic nodules	0.7

	Feet
Shale, light-gray, silty, fossiliferous; weathering tan	0.7
Shale, dark-gray to black, silty, carbonaceous	1.0
Sandstone, well-indurated, calcareous	0.4
Shale, gray; containing clay-ironstone concretions	6.6
Limestone, dark-gray, dense, silty, sparingly fossiliferous; typical cap-rock lithology	0.5
Shale, black, carbonaceous, deeply weathered	0.5
Coal	0.6
Underclay	1.0

18. *Sec. 10, T. 25 N., R. 19 E. Measured in south bank of creek near center SE¼ NW¼ (Lohman, 1952, p. 77).*

Boggy Formation	
Bluejacket Member	
Sandstone, massive; weathers brown; not measured	
Savanna Formation	
Covered interval; about	10.0
Limestone, gray, dense, silty; weathers dull reddish; sparingly fossiliferous	0.3
Shale; weathers yellow	2.0
Coal (Drywood)	1.0
Underclay; about	1.0
Shale, dark-gray; with black clay-ironstone concretions	6.3
Limestone (Doneley), black, dense, fossiliferous; clay-ironstone	0.4
Shale, dark-gray, fissile, fossiliferous	0.4
Coal (Rowe)	0.2
Siltstone, lead-gray, thin-bedded, crudely stratified; with nodular masses of hard, gray, unstratified siltstone	4.0
Base of section at water level in creek	

19. *Sec. 10, T. 25 N., R. 19 E. Measured in gulch in south bank of creek in SW¼ NE¼ (Lohman, 1952, p. 78).*

Boggy Formation	
Bluejacket Sandstone Member; not measured	
Savanna Formation	
Covered interval; probably shale	14.0
Limestone, gray, silty, sparingly fossiliferous	0.3
Shale, black, carbonaceous; paper-thin bedding	1.5
Coal	0.6
Covered interval; uppermost beds are light-gray shale; lowermost beds are dark-gray shale. Between these lie beds of light grayish-yellow, silty, fine-grained sandstone. Thickness of these beds above and below sandstone cannot be determined	33.0

	Feet
Limestone, dark-gray, dense, silty, nonfossiliferous	0.3
Shale, black, fissile	2.5
Coal	0.5
Shale, gray, silty	2.0
Base of section at water level in creek	

20. *Sec. 22, T. 25 N., R. 19 E. Measured southeast along U. S. Highway 60 from bottom of valley to top of hill in NE¼ (Lohman, 1952, p. 78).*

	Feet
Boggy Formation	
Bluejacket Sandstone Member	
Sandstone, yellow and brown to reddish, laminated, cross-bedded, soft, micaceous; bleached white in spots; not measured	
Savanna Formation	
Clay, soft, black, carbonaceous	0.2
Shale, light-gray	8.8
Sandstone, light-yellow to brown, very fine-grained to fine-grained, siliceous; white in spots	3.5
Shale, gray	11.6
Shale, yellowish-gray to gray, laminated; intercalated beds of silty shale, siltstone, and silty sandstone; containing ironstone concretions	17.4
Sandstone, light yellowish-gray, fine-grained, laminated	1.5
Shale, grayish-yellow, silty; with thin beds of very fine-grained sandstone	10.4

21. *Sec. 26, T. 25 N., R. 19 E. Measured on long hill trending northeast across the southern end of NW¼ SW¼ (Lohman, 1952, p. 79).*

	Feet
Boggy Formation	
Sandstone (Bluejacket); not measured	
Savanna Formation	
Shale, covered; about	27.0
Sandstone (Dickson), partially covered; top not exposed	3.0
Shale, gray	6.0
Limestone (Doneley), dense, black, fossiliferous; ironstone	0.3
Shale, grayish-yellow, fossiliferous	0.5
Coal (Rowe)	0.1
Shale, yellowish-weathering	30.0
Sandstone	3.0
Shale; not measured	

		Feet
22.	*Sec. 35, T. 25 N., R. 19 E. Measured westward up hill in southwest corner (Lohman, 1952, p. 79).*	
	Savanna Formation	
	Sandstone (Dickson Member), well-indurated, thin-bedded, micaceous	2.5
	Shale, light-olive	0.8
	Clay-ironstone, weathered	0.5
	Shale; weathers grayish yellow	10.6
	Limestone (Doneley), fossiliferous; clay-ironstone	0.3
	Shale, yellow, fossiliferous; with abundant *Mesolobus* and crinoid stems	4.0
	Coal (Rowe)	0.3
	Shale, gray; weathers light-yellowish gray; base unexposed	27.2
23.	*Sec. 5, T. 25 N., R. 20 E. Measured on west slope of hill on township line east of the northeast corner (Lohman, 1952, p. 76-77).*	
	Boggy Formation	
	Bluejacket Member	
	Sandstone, light grayish-yellow, hard, fine-grained, massive; contains a few shale chips, plant fossils, and limonitic concretions; not measured	
	Savanna Formation	
	Shale; weathers dull yellow	24.7
	Dickson Member	
	Sandstone, light-brown, very fine-grained, compact, even-bedded	3.8
	Siltstone, light grayish-yellow, laminated; interbedded silty sandstone	4.8
	Shale, gray; weathers light yellow	14.6
	Limestone (Doneley), black, dense, fossiliferous; clay-ironstone	0.5
	Shale, gray	0.5
	Coal (Rowe)	0.1
	Shale; not measured	
24.	*Sec. 23, T. 25 N., R. 20 E. Measured on east face of hill, 3 miles east of Vinita on U. S. Highway 66 in southeast corner (modified from Wilson and Newell, 1937, p. 184).*	
	McAlester Formation	
	Warner Member	
	Sandstone, shaly	3.0
	Shale, whitish, sandy	3.0
	Sandstone, shaly; with limonite concretions or pebbles	2.0

	Feet
Hartshorne Formation	
Shale, gray, sandy; with ironstone near the top; upper layer of shale, whitish	21.0
Limestone, reddish, granular, crinoidal	0.8
Shale, gray; contains ironstone concretions	11.0
Shale, dark-gray, silty	5.5
Sandstone, greenish, irregular, platy; filled with *Taonurus*	4.0
Shale, sandy	0.2
Underclay	3.0
Fayetteville Formation	
Shale, greenish-gray	3.0
Limestone, shaly, fossiliferous; with abundant Bryozoa, Productidae, and *Archimedes*	4.0
Shale, greenish, argillaceous; base covered	6.0

25. *Sec. 11, T. 25 N., R. 21 E. Measured on hillside in northeast quarter (Huffman, 1958, p. 271).*

	Feet
Fayetteville Formation	
Limestone, buff, platy, abundantly fossiliferous; with *Archimedes* and other bryozoans	2.3
Shale, dark-gray to black, calcareous, fissile, soft	11.4
Limestone, buff, shaly, platy	0.6
Shale, varicolored, calcareous, fissile. Three thin (0.2 feet) fossiliferous zones	16.4
Covered; probably shale	17.1
Limestone, reddish-brown, lithographic; weathers into distinct cubical blocks; forms base of exposure	0.6

26. *Sec. 16, T. 25 N., R. 21 E. Measured on south quarry wall, southeast quarter (Huffman, 1958, p. 270).*

	Feet
Hindsville Formation	
Limestone, gray, medium to coarse, calcarenitic, irregularly bedded; with thin shale interbeds	2.0
Shale, green, weathered; nodules of dense limestone	0.7
Limestone, dark-gray, calcarenitic, medium-crystalline; with abundant *Agassizocrinus*	1.0
Limestone, gray, medium-crystalline, calcarenitic; thin shale interbeds	1.6
Limestone, gray, medium-crystalline, calcarenitic	0.5
Limestone, gray, medium-crystalline; with thin shale interbeds	0.9
Limestone, gray, medium-crystalline, flaggy, irregularly bedded; with abundant *Agassizocrinus*	1.0
Siltstone, gray, calcareous, cross-laminated, fossiliferous	3.0

	Feet
Limestone, gray to white, medium- to coarse-crystalline, calcarenitic; interbeds of fine-grained limestone; nodules of shale and limestone "conglomerate" near top; black chert near base	10.6
Limestone, gray, even-textured, medium-crystalline; microscopic chert fragments; interbedded green shale laminae	1.4
Keokuk Formation	
Limestone, blue-gray, massive, saccharoidal, cherty	8.0

27. *Sec. 32, T. 25 N., R. 21 E. Measured on southern slope of hill in northeast quarter (Huffman, 1958, p. 270).*

	Feet
Fayetteville Formation	
Limestone, brown to tan, thin-bedded, abundantly fossiliferous; gray on fresh surface	2.0
Shale, varicolored, calcareous, fissile and jointed. Several fossiliferous, shaly limestone beds (0.2 feet thick) are interbedded with the shale	45.2
Base of formation concealed	

28. *Sec. 13, T. 26 N., R. 18 E. Measured from creek, 0.4 mile east and 0.1 mile north of southwest corner, westward along road up the hill (Chrisman, 1951, p. 56-57).*

	Feet
Fort Scott Formation	
Limestone (Blackjack Creek), tan to gray, fine-crystalline, fossiliferous; weathers brown	5.0
Senora Formation	
Shale (Excello), black; phosphatic nodules	4.5
Limestone (Breezy Hill), gray, fine-crystalline, fossiliferous; weathers brown	7.7
Shale, gray, calcareous	2.2
Coal (Iron Post)	0.4
Shale, tan, silty, micaceous	4.8
Sandstone (Lagonda), tan, fine-grained, micaceous	6.2
Coal (Bevier)	0.4
Underclay	0.8
Shale, tan, micaceous	12.5
Covered	17.0

29. *Sec. 25, T. 26 N., R. 18 E. Measured from creek, 0.4 mile east of northwest corner, west up the hill (Chrisman, 1951, p. 55).*

	Feet
Senora Formation	
Limestone (Breezy Hill), gray to brown, fine-crystalline, fossiliferous	2.7

	Feet
Shale, gray	2.5
Coal (Iron Post)	1.5
Underclay	0.5
Sandstone (Lagonda), brown, calcareous, fossiliferous	2.8
Shale, gray	2.3
Coal (Bevier)	0.9
Underclay	0.5
Shale, gray, silty	25.3
Limestone (Verdigris), steel-gray, fine-crystalline, fossiliferous; weathers brown	4.3

30. *Sec. 36, T. 26 N., R. 18 E. Measured from creek, 0.5 mile north of southwest corner, north up the hill (Chrisman, 1951, p. 55).*

Senora Formation	
Limestone (Breezy Hill), gray to brown, fine-crystalline, fossiliferous	2.5
Shale, gray	2.0
Coal (Iron Post)	0.8
Underclay	2.5
Shale, gray; contains concretions	11.2
Shale, gray	4.2
Sandstone (Lagonda), gray, calcareous, medium-grained	0.7
Siltstone, gray, thin-bedded	1.6
Shale, dark-gray, thin-bedded	10.6
Limestone (Verdigris), steel-gray, fine-crystalline, massive, fossiliferous; weathers brown	4.2
Shale, black; phosphatic nodules	2.0
Underclay; not measured	

31. *Sec. 36, T. 26 N., R. 18 E. Measured westward along road from hill, 0.3 mile east of northeast corner (Lohman, 1952, p. 88-89).*

Fort Scott Formation	
Limestone (Blackjack School); white-weathered blocks on surface; not measured	
Senora Formation	
Shale (Excello), black; containing phosphatic nodules	6.0
Breezy Hill Member	
Limestone, gray, finely crystalline, fossiliferous; weathers white	2.0
Limestone, light-brown, dense, silty, fossiliferous	3.0
Shale (Kinnison); yellow at top; grading into dark gray at base	2.5
Coal (Iron Post)	1.5

	Feet
Shale, gray	1.4
Sandstone (Lagonda), brown, calcareous, fossiliferous; grading into silty shale at base	2.5
Shale, gray	2.4
Coal (Bevier)	1.0
Shale, gray; grading into sandy to silty shale at top	25.6
Limestone (Verdigris); not measured	

32. *Sec. 15, T. 26 N., R. 19 E. Measured from creek 0.3 mile south of northeast corner, south along road up hill (Chrisman, 1951, p. 62).*

Boggy Formation

Covered interval with some weathered silty shale	16.2
Siltstone, tan, micaceous	2.0
Shale, tan, silty, micaceous	6.3
Sandstone (Bluejacket), tan, medium-grained, micaceous; weathers tan to brown	7.0
Covered	5.0

33. *Sec. 21, T. 26 N., R. 19 E. Measured 0.2 mile south of northwest corner in the creek, northwestward into section 17 (Chrisman, 1951, p. 58).*

Senora Formation

Sandstone (Chelsea); exposed thickness	2.0
Shale, tan, weathered; contains concretions	35.3
Ironstone, black, fossiliferous; weathers brown	0.4
Shale, black, fissile	3.3
Ironstone, black; weathers red brown	0.4
Shale, black, fissile	3.6
Limestone (Tiawah), black, finely crystalline, fossiliferous; weathers red brown	0.5
Shale, black, blocky; contains phosphatic nodules	1.6
Shale, dark-gray	1.9
Coal (Tebo)	0.4

34. *Sec. 24, T. 26 N., R. 19 E. Measured from base of sandstone, 0.3 mile east of southwest corner NW¼ westward along creek (Chrisman, 1951, p. 63).*

Boggy Formation

Bluejacket Member

Sandstone, fine-grained, micaceous; weathers tan; conglomeratic in basal portion	46.0
Conglomerate	2.0

35. *Sec. 25, T. 26 N., R. 19 E. Measured from northeast corner, west along road up the hill (Chrisman, 1951, p. 64).*

Savanna Formation

Covered	7.5

	Feet
Sandstone (Dickson), tan, medium-grained, micaceous; weathers gray	10.0
Shale, gray; contains concretions	12.0
Limestone (Doneley)	0.3
Shale, tan	0.7
Coal (Rowe)	0.1
Underclay	0.5
Covered	19.0

36. *Sec. 29, T. 26 N., R. 19 E. Measured 0.1 mile south of northwest corner, in creek (Chrisman, 1951, p. 58).*

Senora Formation	
Shale, dark-gray; concretionary; not measured	
Ironstone, black, fossiliferous	0.5
Shale, black	3.3
Ironstone, black	0.4
Shale, black	3.5
Limestone (Tiawah), black, finely crystalline, fossiliferous; weathers reddish brown	0.4
Shale, black, blocky; phosphatic nodules; pyritized fossils	1.5
Shale, dark-gray	2.0
Coal (Tebo)	0.4
Underclay; exposed thickness	3.0

37. *Sec. 34, T. 26 N., R. 19 E. Measured from southeast corner, west along road up the hill (Chrisman, 1951, p. 62).*

Boggy Formation	
Sandstone (Bluejacket), buff, fine-grained micaceous; platy near top; weathers tan	10.0
Savanna Formation	
Shale, tan, concretionary	6.8
Shale, dark-gray; contains concretions	8.8

38. *Sec. 34, T. 26 N., R. 19 E. Measured 0.4 mile west of southeast corner, east along road up the hill (Chrisman, 1951, p. 62).*

Boggy Formation	
Sandstone (Bluejacket), buff, fine-grained, micaceous; platy near top; weathers tan	10.0
Savanna Formation	
Shale, tan to gray; contains thin ironstone layers; dark shale zones	29.8

39. *Sec. 1, T. 26 N., R. 20 E. Measured from creek 0.1 mile south of northwest corner, south along road up the hill (Chrisman, 1951, p. 63-64).*

Savanna Formation	
Covered interval; probably gray shale	7.5

	Feet
Dickson Member	
Sandstone, gray, medium-grained, micaceous	4.2
Siltstone, gray, micaceous	0.5
Sandstone, gray, medium-grained, micaceous	3.8
Shale, gray; contains concretions	5.6

40. *Sec. 1, T. 26 N., R. 20 E. Measured 0.2 mile from northwest corner, west along road up the hill (Chrisman, 1951, p. 63).*

	Feet
Savanna Formation	
Sandstone (Dickson Member), gray, medium-grained, micaceous	8.6
Shale, dark-gray	6.2
Shale, gray	2.2
Limestone (Doneley), black, compact, finely crystalline, fossiliferous; weathers reddish brown	0.5
Shale, dark-gray	0.5
Coal (Rowe)	0.1
Underclay	0.7

41. *Sec. 14, T. 26 N., R. 20 E. Measured 0.2 mile west of northeast corner, along road up the hill (Chrisman, 1951, p. 61).*

	Feet
Boggy Formation	
Sandstone (Bluejacket), buff, medium-grained, micaceous; weathers tan	10.5
Savanna Formation	
Coal (Drywood)	0.4
Underclay	1.0
Covered	11.2
Coal (Rowe)	0.4
Underclay	2.4
Sandstone, gray, medium-grained, micaceous	4.4
Covered	15.0

42. *Sec. 16, T. 26 N., R. 20 E. Measured in creek, 0.2 mile south of northwest corner, west to road (Chrisman, 1951, p. 64).*

	Feet
Savanna Formation	
Covered	3.0
Shale, tan, silty, micaceous	2.8
Sandstone (Dickson Member), tan to gray, fine-grained, slightly calcareous; weathers gray	0.8
Shale, tan, micaceous	7.5
Limestone (Doneley), black, compact, finely crystalline; weathers red	0.3
Shale, gray, fossiliferous	0.7
Coal (Rowe)	0.2
Underclay; exposed thickness	1.0

	Feet
43. *Sec. 21, T. 26 N., R. 20 E. Measured from road intersection, 0.25 mile south of northwest corner, south along road up the hill (Chrisman, 1951, p. 61).*	
Boggy Formation	
Sandstone (Bluejacket), buff, fine- to medium-grained, micaceous; conglomeratic at base; weathers tan	48.8
Savanna Formation	
Shale, tan	4.9
44. *Sec. 28, T. 26 N., R. 20 E. Measured from 0.1 mile east of northwest corner, west along road to top of hill between secs. 20 and 29 (Chrisman, 1951, p. 61).*	
Boggy Formation	
Sandstone (Bluejacket), tan, fine-grained, micaceous; weathers gray; exposed thickness	9.5
Savanna Formation	
Coal (Drywood)	0.3
Covered; possibly gray, silty shale	28.8
Sandstone (Dickson), tan to gray, fine-grained, micaceous; weathers tan	4.8
Ironstone	0.3
Shale, tan to gray	1.5
45. *Sec. 32, T. 26 N., R. 20 E. Measured from base of hill 0.1 mile from southwest corner, eastward up the hill (Chrisman, 1951, p. 61-62).*	
Boggy Formation	
Sandstone (Bluejacket), tan, fine-grained, micaceous, conglomeratic	19.5
Savanna Formation	
Shale, gray, silty, weathered	23.8
Sandstone (Dickson), brown, fine-grained, massive	1.8
Shale, tan to gray, silty, micaceous	13.2
Shale, dark-gray	4.3
Limestone (Doneley), black, finely crystalline, fossiliferous; weathers brown	0.6
Shale, gray	0.3
Coal (Rowe)	0.1
Underclay	0.5
Shale, tan to gray, silty, micaceous	23.4
Sandstone, tan, micaceous, fine-grained	4.3
Shale, tan, silty, micaceous	42.6
46. *Sec. 7, T. 26 N., R. 21 E. Measured from bend in stream, 0.25 mile southwest of northwest corner, west along stream (Chrisman, 1951, p. 64-65).*	
Savanna Formation	
Siltstone, tan, micaceous	1.0

	Feet
Shale, dark-gray, micaceous	2.5
Sandstone, gray, fine-grained, micaceous	0.3
Shale, gray, silty, micaceous	5.8
Sandstone, gray, fine-grained, micaceous; contains *Taonurus*	1.5
Shale, black, blocky; exposed thickness	4.0

47. Sec. 28, T. 26 N., R. 21 E. Measured from creek, 0.3 mile east of southwest corner, west along road to the intersection (Chrisman, 1951, p. 65).

McAlester Formation	
Sandstone (Warner), red-brown, medium-grained	8.0
Hartshorne Formation	
Shale, tan to gray	25.5
Shale, black	10.5
Covered interval (soil and alluvium)	24.7
Fayetteville Formation	
Limestone, black, fine-crystalline, fossiliferous; weathers brown	0.7
Covered	7.5
Limestone, buff, fine-crystalline, fossiliferous	3.5

48. Sec. 25, T. 26 N., R. 21 E. Measured 0.1 mile east of southwest corner, from road up the hill (Chrisman, 1951, p. 66).

McAlester Formation	
Sandstone (Warner), red-brown, medium-grained	2.0
Hartshorne Formation	
Covered	47.2
Fayetteville Formation	
Limestone, buff, fine-crystalline; exposed thickness	1.0

49. Sec. 13, T. 27 N., R. 19 E. Measured from northeast corner, westward along road up the hill (Chrisman, 1951, p. 56).

Senora Formation	
Limestone (Breezy Hill), gray, fine-crystalline, fossiliferous; weathers brown	3.0
Shale, gray, calcareous	2.0
Coal (Iron Post)	1.8
Underclay	0.5
Shale, buff, micaceous	3.3
Lagonda Member	
Sandstone, tan to gray, fine-grained, micaceous	3.3
Shale, tan, silty, micaceous	9.0
Sandstone, tan to gray, fine-grainel, micaceous	1.0
Shale, tan, silty, micaceous	14.2
Limestone (Verdigris), steel-gray, fine-crystalline, fossiliferous; weathers brown	3.7

	Feet
Shale, black; phosphatic nodules	1.6
Shale, tan, silty, micaceous	53.9

50. *Sec. 21, T. 27 N., R. 19 E. Measured from 0.2 mile south of northeast corner, northward along road up the hill (Chrisman, 1951, p. 56).*

Fort Scott Formation	
Limestone (Blackjack Creek); not measured	
Senora Formation	
Shale (Excello), black; phosphatic nodules	5.0
Limestone (Breezy Hill), gray, fine-crystalline, fossiliferous; weathers brown	8.0
Shale, gray, weathered	1.5
Coal (Iron Post)	1.4
Shale, buff, weathered	1.9
Shale, tan, slightly silty, micaceous	9.0
Sandstone (Lagonda), tan, fine-grained, micaceous	0.9
Shale, tan, silty, micaceous	16.9
Limestone (Verdigris), steel-gray, fine-crystalline, fossiliferous; weathers brown; not measured	

51. *Sec. 25, T. 27 N., R. 19 E. Measured in creek bank, 100 feet south of northwest corner (Chrisman, 1951, p. 59).*

Senora Formation	
Sandstone, brown, fine-grained, slightly calcareous	2.5
Shale, tan, silty, micaceous	21.5
Conglomerate	1.0
Ironstone, black, finely crystalline, fossiliferous	0.3
Shale, black	0.1
Limestone (Tiawah), black, finely crystalline, fossiliferous; weathers red brown	0.3
Shale, blocky, black; phosphatic nodules	2.0
Coal (Tebo)	2.5
Underclay; exposed thickness	2.0

52. *Sec. 29, T. 27 N., R. 19 E. Measured from northwest corner of NW¼, east along road up the hill (Chrisman, 1951, p. 57).*

Senora Formation	
Siltstone, tan, micaceous	8.0
Lagonda Member	
Sandstone, tan to brown, fine-grained, micaceous	7.8
Sandstone, tan, medium-grained, micaceous; grades upward into siltstone	4.5
Coal (Bevier)	0.3
Underclay	0.3

	Feet
Sandstone, tan, fine-grained, micaceous	3.5
Shale, tan, silty, micaceous	6.0

53. *Sec. 9, T. 27 N., R. 20 E. Measured along stream, 0.25 mile from the northwest corner (Chrisman, 1951, p. 60).*

Boggy Formation	
Bluejacket Member	
Sandstone, tan, fine- to medium-grained, micaceous, massive; weathers brown	8.6
Sandstone, tan, fine- to medium-grained, micaceous, thin-bedded; weathers tan	6.0

54. *Sec. 13, T. 27 N., R. 20 E. Measured from northeast corner of the SE¼, south along road up the hill (Chrisman, 1951, p. 60).*

Boggy Formation	
Bluejacket Member; not measured	
Savanna Formation	
Covered	22.0
Sandstone (Dickson), gray, fine-grained, micaceous	6.0
Shale, gray, silty, micaceous	7.0
Limestone (Doneley), black, finely crystalline, compact, fossiliferous; weathers reddish brown	0.6
Shale, gray; contains concretions	1.9
Coal (Rowe)	0.2
Underclay	2.0
Shale, gray; contains concretions	7.6

55. *Sec. 25, T. 27 N., R. 20 E. Measured 0.25 mile from the northwest corner in road cut (Chrisman, 1951, p. 58).*

Senora Formation	
Sandstone (Chelsea), red-brown, medium- to coarse-grained; cross-bedded in upper part; phosphatic nodules at base	21.0
Boggy Formation	
Coal (Bluejacket)	0.3
Underclay	1.0
Shale, gray	4.0
Sandstone (Bluejacket), tan, fine-grained; not measured	

56. *Sec. 25, T. 27 N., R. 20 E. Measured from the NE¼ NE¼, west along road up the hill (Chrisman, 1951, p. 59-60).*

Boggy Formation

Bluejacket Member

	Feet
Sandstone, tan, fine- to medium-grained, massively cross-bedded, micaceous	48.7
Savanna Formation	
Shale, black	3.0
Coal (Drywood)	0.2
Underclay	2.5
Covered	6.8
Sandstone, gray, medium-grained, micaceous	8.8
Covered interval; probably gray shale	13.2
Sandstone (Dickson), gray, medium-grained, micaceous	2.0

57. *Sec. 11, T. 27 N., R. 21 E. Measured from southwest corner NW¼ NW¼, north along road up the hill (Chrisman, 1951, p. 63).*

Savanna Formation	
Sandstone (Dickson), gray, fine-grained, micaceous; weathers gray	3.0
Shale, gray, micaceous; contains concretions	20.9
Coal (Rowe)	0.6
Underclay	1.0
Shale, tan	13.5

58. *Sec. 19, T. 27 N., R. 21 E. Measured from 0.4 mile south of northeast corner, north along road up the hill (Chrisman, 1951, p. 60-61).*

Boggy Formation	
Bluejacket Member	
Covered interval; probably weathered top of Bluejacket Sandstone	15.2
Sandstone, brown, fine-grained, micaceous; weathers tan	26.3
Sandstone, red to brown, medium- to coarse-grained, conglomeratic	2.0
Savanna Formation	
Shale, gray	0.9
Coal (Drywood)	1.3

59. *Sec. 28, T. 27 N., R. 21 E. Measured from 0.4 mile west of northeast corner, in the creek bank (Chrisman, 1951, p. 65).*

Savanna Formation	
Shale, black, fossiliferous	4.0
Limestone (Spaniard), black, finely crystalline, fossiliferous, compact; weathers brown	0.7
McAlester Formation	
Shale, black; exposed thickness	2.0

	Feet
60. *Sec. 30, T. 27 N., R. 21 E. Measured from creek, 0.4 mile west of northeast corner, west up the hill (Chrisman, 1951, p. 63).*	
Savanna Formation	
Dickson Member	
Sandstone, gray, medium-grained, micaceous, massive	3.5
Shale, gray, micaceous	2.0
Sandstone, gray, fine-grained, micaceous	1.0
Shale, gray, silty, micaceous	3.2
Shale, dark-gray, silty, micaceous	6.4
Limestone (Doneley), black, finely crystalline, compact, fossiliferous; weathers reddish brown	0.6
Shale, black, fossiliferous	1.0
Coal (Rowe)	0.3
Underclay	0.8
Shale, tan, silty	13.0
61. *Sec. 7, T. 28 N., R. 18 E. Measured 0.25 mile south of northeast corner (Cade, 1952, p. 47).*	
Pawnee Formation	
Myrick Station Member	
Limestone, massive, dense, light-gray to pink	8.0
Clay	0.3
Shale, soft, crumbly, yellowish-gray	1.7
Labette Formation	
Anna Member	
Shale, black, fissile; phosphatic concretions	3.0
Shale, blocky, light-gray to blue, calcareous	5.0
Shale, crumbly, sandy, greenish-gray	6.0
Siltstone, micaceous, soft, greenish	1.2
Sandstone, fine-grained, micaceous, buff	1.9
Shale, blue-gray; base covered	3.5
62. *Sec. 9, T. 28 N., R. 18 E. Measured 0.7 mile east of northwest corner in road bank (Cade, 1952, p. 47-48).*	
Pawnee Formation	
Myrick Station Member	
Limestone, massive- to irregular-bedded, coarsely crystalline, light-gray	6.4
Shale, light-gray, crumbly, calcareous	4.0
Labette Formation	
Anna Member	
Shale, black, fissile; phosphatic concretions	4.0
Limestone, dark-gray, very fine-grained to lithographic	1.1
Shale, blocky, blue-gray to maroon	5.6
Shale, yellow, calcareous; abundant fossil fragments	4.0

	Feet
Shale, blocky, calcareous; dark-gray on fresh exposure	11.2
Wimer School Member	
Limestone, compact, dark-brown to black, finely crystalline, fossiliferous; weathers dull yellow	0.9
Limestone, compact, massive, medium dark-gray; weathers to light gray; fusulinid zone 2 feet above base	3.0

63. *Sec. 12, T. 28 N., R. 18 E. Measured 0.1 mile south of northwest corner (Cade, 1952, p. 48).*

Pawnee Formation	
Myrick Station Member	
Limestone, compact, light-gray; top eroded	2.0
Shale, light-gray, calcareous	1.0
Labette Formation	
Anna Member	
Shale, black, fissile	3.5
Shale, light-gray to yellow, thin-bedded, sandy	30.7
Wimer School Member	
Limestone, dense, dark-gray to blue; abundant fossils; basal 0.8 foot massive; top thin-bedded and slabby	3.0
Shale, yellowish, platy, calcareous; more than	10.0

64. *Sec. 19, T. 28 N., R. 18 E. Measured on north side State Highway 10, 0.25 mile west of southeast corner (Cade, 1952, p. 48).*

Pawnee Formation	
Myrick Station Member	
Limestone, light-gray, coarsely crystalline	3.0
Limestone, massive, medium-gray to pinkish	2.0
Limestone, massive, fine-grained, fossiliferous	0.3
Shale, yellowish, crumbly, calcareous	2.3
Labette Formation	
Anna Member	
Shale, black, fissile; phosphatic concretions	7.5
Limestone, dark-gray, shaly	0.6
Shale, bluish-gray; limonitic concretions	1.6
Wimer School Member (type section)	
Limestone, compact, dark-gray to yellow-brown, lithographic; abundant large brachiopods; weathers light yellow	2.0
Shale, greenish-yellow, calcareous; abundant brachiopods; limonitic concretions	1.8
Shale, blocky, sandy, yellow-gray; more than	3.0

65\. *Sec. 24, T. 28 N., R. 18 E. Measured from 0.6 mile north of southeast corner, northwest up hill (Cade, 1952, p. 48-49).*

	Feet
Labette Formation	
Shale, silty, yellowish	4.0
Sandstone, soft, coarse-grained, micaceous	1.0
Shale; largely covered	4.0
Sandstone, yellow-brown, medium-grained, micaceous	1.0
Shale, yellow, poorly exposed	5.6
Sandstone, massive, soft, micaceous, yellow-brown	8.0
Shale, sandy; mostly covered	62.0

66\. *Sec. 36, T. 28 N., R. 19 E. Measured east on hill in northeast corner (Claxton, 1952, p. 39).*

	Feet
Fort Scott Formation	
Limestone (Blackjack Creek); not measured	
Senora Formation	
Shale (Excello), black, platy; with phosphatic nodules	5.0
Limestone (Breezy Hill), brown, medium-crystalline, fossiliferous	2.5
Shale (Kinnison), black	2.0
Limestone, black, impure, fossiliferous; cap rock	1.5
Coal (Iron Post), hard, bright	1.0
Sandstone (Lagonda), gray-brown, medium-grained, limonitic	10.3
Shale, drab-gray	12.0
Limestone (Verdigris), gray, fine-crystalline, fossiliferous	3.0
Shale, black, fissile; with phosphatic nodules	2.0
Shale, gray, platy	12.0

67\. *Sec. 3, T. 28 N., R. 20 E. Measured on hill in northwest corner (Claxton, 1952, p. 36).*

	Feet
Fort Scott Formation	
Limestone (Blackjack Creek); not measured	
Senora Formation	
Shale (Excello), black, fissile; with phosphatic nodules	5.0
Limestone (Breezy Hill), brown, medium-crystalline, fossiliferous	2.5
Shale (Kinnison), light-gray	5.0
Sandstone (Lagonda), brown, medium-grained	4.0
Shale, light-gray	12.5
Shale, gray, laminated	6.0

	Feet
68. *Sec. 19, T. 28 N., R. 20 E. Measured on hill, NW¼ (Claxton, 1952, p. 40).*	
Senora Formation	
Sandstone (Lagonda), brown-red, medium-grained	4.0
Shale, dark, platy	4.1
Coal (Bevier)	0.8
Shale, gray	2.0
Sandstone, brown-gray, micaceous	5.0
Shale, gray, platy	13.0
Limestone (Verdigris), dark-gray; weathers brown-buff	2.0
Shale, black, fissile; phosphatic nodules	5.0
Shale, gray	6.0
69. *Sec. 13, T. 28 N., R. 21 E. Measured 300 feet east of northwest corner (Claxton, 1952, p. 38).*	
Boggy Formation	
Sandstone (Bluejacket), brown, medium-grained	5.6
Savanna Formation	
Clay, light-gray	1.9
Shale, green, platy; with ironstone concretions	12.3
Sandstone (Dickson); not measured	
70. *Sec. 18, T. 28 N., R. 21 E. Measured in south half, in abandoned coal pit (Claxton, 1952, p. 38).*	
Senora Formation	
Sandstone (Goldenrod), brown-mottled; buff when fresh	20.0
Shale, black, platy; phosphate nodules; limonitic concretions and septarian concretions	2.0
Shale; covered by water	
71. *Sec. 25, T. 28 N., R. 21 E. Measured south from base of hill (Claxton, 1952, p. 37).*	
Boggy Formation	
Sandstone (Bluejacket), brown, medium-grained	4.0
Savanna Formation	
Clay, gray	6.0
Shale, greenish-gray	6.0
Sandstone (Dickson), brown, medium-grained; lower part shaly	5.0
72. *Sec. 16, T. 29 N., R. 18 E. Measured from 0.3 mile west of northeast corner, west along road (Cade, 1952, p. 42).*	
Altamont Formation; not measured	
Bandera Formation	
Shale, bluish, platy	4.0

	Feet
Shale, sandy, crumbly, yellowish to light-gray	7.6
Sandstone, soft, massive, brownish	1.6
Shale, sandy, thin-bedded, platy	4.0
Sandstone, massive, brownish, micaceous, fine-grained	5.6
Shale, thin-bedded, micaceous, sandy	11.2
Sandstone, thin-bedded, micaceous, light-tan	3.0
Shale, crumbly, silty, yellowish; base covered; more than	8.0

73. *Sec. 21, T. 29 N., R. 18 E. Measured on west side of road in southeast corner (Cade, 1952, p. 42-43).*

	Feet
Pawnee Formation	
Coal City Member	
Limestone, irregularly bedded, dense, jointed	26.0
Myrick Station Member	
Limestone, massive, light-gray to pink	5.0
Shale, clayey, light-gray to bluish, crumbly	0.6
Limestone, thin-bedded; with yellowish, clayey shale	0.7
Shale, blocky, silty, light-gray	1.2
Labette Formation	
Anna Member	
Shale, black, fissile; phosphatic concretions	1.9
Shale, blocky, gray to black	1.9
Shale, yellowish, clayey	2.0

74. *Sec. 22, T. 29 N., R. 18 E. Measured 0.6 mile east of northwest corner (Cade, 1952, p. 43).*

	Feet
Pawnee Formation	
Coal City Member	
Limestone, irregularly bedded, light-gray; more than	10.0
Myrick Station Member	
Limestone, massive; pinkish at base; abundant large crinoid stems; light gray near top	5.7
Shale, light-blue to gray, crumbly	0.4
Limestone, thin-bedded; with yellow, clayey shale	0.7
Labette Formation	
Anna Member	
Shale, black, fissile, carbonaceous	1.4
Shale, blocky, black to gray	1.2
Shale, black, fissile; phosphatic concretions	1.9
Shale, blocky, gray	1.4
Limestone, nodular, fine-grained (cap rock of Lexington coal)	0.2
Coal (Lexington)	0.1
Shale, sandy, yellowish; more than	20.0

	Feet
75. *Sec. 27, T. 29 N., R. 18 E. Measured one-eighth mile north of southwest corner, on east side of road (Cade, 1952, p. 44).*	
Pawnee Formation	
Myrick Station Member	
Limestone, dense, light-gray; large crinoid stems and *Chaetetes*	6.0
Shale, yellow, crumbly	1.0
Labette Formation	
Anna Member	
Shale, black, platy; abundant phosphatic concretions	3.0
Shale, black, platy, calcareous	0.3
Shale, calcareous, light-gray; small limestone nodules	0.8
Coal (Lexington)	0.1
Shale, black, clayey	0.5
Shale, light-gray, calcareous; numerous shaly limestone nodules and fossil fragments; base covered	2.0
76. *Sec. 27, T. 29 N., R. 18 E. Measured on west side of road, 0.4 mile south of northwest corner (Cade, 1952, p. 43).*	
Pawnee Formation	
Coal City Member	
Limestone, massive, irregularly bedded; more than	10.0
Myrick Station Member	
Limestone, massive, light-gray to pink, crinoidal	6.0
Shale, blue, crumbly	0.6
Limestone, thin; irregularly bedded with yellow shale	0.7
Shale, blocky, bluish-gray	2.0
Labette Formation	
Anna Member	
Shale, black, fissile; phosphatic concretions	6.0
Shale, blocky, brownish-gray	1.8
Limestone, nodular, fine-grained (cap rock of Lexington coal)	0.2
Coal (Lexington)	0.1
77. *Sec. 31, T. 29 N., R. 18 E. Measured from southwest corner, northeastward up hill (Cade, 1952, p. 44).*	
Bandera Formation	
Shale, sandy, thin-bedded	2.0
Sandstone, massive, fine-grained	5.6
Shale, sandy, thin-bedded	1.1
Sandstone, massive, yellowish-brown	1.5

	Feet
Shale, sandy, blue-gray to yellow	1.4
Sandstone, massive, fine-grained, calcareous	3.1
Limestone, sandy, nonfossiliferous, finely crystalline	2.0
Sandstone, massive, regularly bedded, micaceous	2.5
Shale, blue, calcareous	3.2
Shale, platy, yellowish to light-gray; sandy at top	6.6
Sandstone, massive, light-brown, very fine-grained	1.0
Shale, platy, bluish-gray; sandy at top	14.2
Shale, sandy, yellow; mostly covered	56.8

78. *Sec. 34, T. 29 N., R. 18 E. Measured in extreme northeast corner (Cade, 1952, p. 44-45).*

	Feet
Pawnee Formation	
Myrick Station Member	
Limestone, massive, hard, light-gray, fossiliferous	6.0
Shale, yellow to light-gray, soft, crumbly	1.8
Labette Formation	
Anna Member	
Shale, black, platy; fissile in part; phosphatic concretions	3.0
Shale, black, calcareous; limestone nodules	0.3
Shale, light-gray, calcareous; limestone nodules	3.2
Coal (Lexington)	0.1
Shale, black, crumbly	0.5
Shale, greenish-yellow, limonitic	0.4
Shale, light-gray, calcareous; limestone nodules	5.5
Shale, light-gray to yellow, jointed, blocky; more than	20.0

79. *Sec. 36, T. 29 N., R. 18 E. Measured in southwest corner (Cade, 1952, p. 49).*

	Feet
Pawnee Formation	
Myrick Station Member	
Limestone, light-gray to pinkish, crystalline	1.0
Limestone, very fine-grained, yellow, fossiliferous	0.3
Labette Formation	
Anna Member	
Shale, black, fissile	0.1
Shale, light-gray, calcareous, blocky	0.3
Shale, black, platy; phosphatic nodules	0.3
Shale, yellow, crumbly, clayey	0.5
Shale, black, platy to fissile; phosphatic nodules	3.4
Shale, sandy; covered	2.0
Wimer School Member	
Limestone, dense, jointed, irregularly bedded, dark-gray to brown	3.4

	Feet
80. *Sec. 26, T. 29 N., R. 20 E. Measured in southeast corner, up hill to east (Claxton, 1952, p. 38).*	
Senora Formation	
Sandstone (Goldenrod), brown, conglomeratic; with ferruginous streaks	6.0
Coal	0.1
Underclay, gray-blue	3.0
Shale, gray	3.0
Sandstone, medium-grained, brown; shale streaks	23.0
Shale, gray; not measured	
81. *Sec. 16, T. 29 N., R. 21 E. Measured from north-center northward along river road (Claxton, 1952, p. 37).*	
Boggy Formation	
Sandstone (Bluejacket), fine- to medium-grained, gray to brown; upper part micaceous and massive	48.1
Savanna Formation	
Clay, gray, sticky	9.5
Sandstone, red-brown, ferruginous	0.2
Sandstone (Dickson), light-gray, fine-grained; to water level	5.0
82. *Sec. 18, T. 29 N., R. 21 E. Measured north of creek in SW¼ (Claxton, 1952, p. 38).*	
Boggy Formation	
Bluejacket Member	
Sandstone, medium-grained, massive, brown	12.0
Sandstone, argillaceous, fine-grained, gray	3.0
Sandstone, medium-grained, gray-brown, micaceous, thin-bedded	5.0

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(*Italic number* indicates main reference)