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GEOLOGY AND MINERAL RESOURCES OF MARSHALL COUNTY, OKLAHOMA

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The University of Oklahoma
Norman
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DEDICATION

This bulletin is dedicated to the memory of E. C. "Hap" Parker, pioneer petroleum geologist and charter member of the AAPG, who died in Ardmore, Oklahoma, on October 17, 1983. He attended the University of Oklahoma and graduated in 1914. In 1916, he accepted a position with Marland Oil Company. He later worked for Empire Gas and Fuel Company at Eldorado, Kansas. His career was interrupted by World War I, in which he served as a lieutenant in the U.S. Army. Upon return from military service, he joined Marland Oil Company, which later merged with Continental Oil Company. He held this position for 38 years until retirement in 1956. During his career he established the Parker scholarship fund for students in geology at the University of Oklahoma. Following retirement, he maintained an office in Ardmore, Oklahoma, as a consultant.

Publication of this bulletin was made possible by a $5,000 grant from The Continental Oil Company (Conoco Inc.) in memory of E. C. Parker.

ERRATA

OGS Bulletin 142

Contents, Part II -- "Surface Structure" should read *Subsurface Structure* (p. 62)

Page 46, Figure 27 -- "Brian basin rocks" should read *Bryan basin rocks*

Page 62 -- heading "SURFACE STRUCTURE" should read *SUBSURFACE STRUCTURE*

Pages 62-66 -- running heads "Surface Structure" should read *Subsurface Structure*

Page 77, left column, line 17 -- "(1,994)" should read *(-1,994)*

Page 95, right column, last line -- "Figure 54" should read *Figure 55*

Page 96, left column, line 9 -- "Figure 55" should read *Figure 54*

Photo by Fabian Bachrach

E. C. "Hap" Parker
(1891–1983)

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Title-Page Illustration

Antlers sandstone and Goodland Limestone (capping escarpment). The Walnut Clay is seen at the base of the Goodland. NE¼NE¼NE¼ sec. 9, T7S, R5E. (Photo by K. F. Bridges.)

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TABLES

GEOLOGY AND MINERAL RESOURCES OF MARSHALL COUNTY, OKLAHOMA

Abstract—Marshall County encompasses 421 mi^2 in central southern Oklahoma, of which 64 mi^2 is covered by water. Rocks exposed at the surface range in age from early Paleozoic (Viola Group) to Late Cretaceous (Woodbine Formation). Paleozoic rocks, including the Viola Group, Hunton Group, Woodford Formation, and Sycamore Limestone, are partially exposed around Lake Oteka on the Mannsville anticline. The basal Cretaceous Antlers Formation (Trinity Group) comprises the Baum Limestone Member, a probable lagoonal deposit which lies unconformably on eroded Paleozoic rocks, and the Antlers sandstone, a nearshore deposit of a transgressive sea. The overlying Fredericksburg Group is represented by the Goodland Limestone and the Kiamichi Formation. The Washita Group includes the Caddo Formation (Duck Creek and Fort Worth Members), the Bokchito Formation (Denton Clay, Soper Limestone, Weno Clay, McNutt Limestone, and Pawpaw Sandstone Members), the Bennington Limestone, and the Grayson Marlstone. The Upper Cretaceous Woodbine Formation (Dexter Member) rests disconformably on the Lower Cretaceous beds. Three terrace levels are well developed on unconsolidated Quaternary deposits overlying Cretaceous rocks along the eastern and southern edges of the county.

Surface structure is relatively simple: a gentle SE dip is interrupted by NW-trending folds, including the Cumberland syncline, the Mannsville–Madill–Aylesworth anticline, the Kingston syncline, and the Preston anticline.

Subsurface rocks in Marshall County include the Precambrian Tishomingo Granite and the Colbert Porphyry (Carlton Rhyolite) of Middle Cambrian age. Overlying Paleozoic rocks (Arbuckle facies) include the Reagan Sandstone and Honey Creek Limestone, Arbuckle Group, Simpson Group (Joins, Oil Creek, McLish, Tulip Creek, and Bromide Formations), Viola Group, Sylvan Shale, Hunton Group, Woodford Formation, Sycamore Limestone, "Caney" Shale, "Goddard–Springer" Shale, Dornick Hills Group, Deese Group, and Hoxbar Group. The Ouachita facies includes the Mazarn Shale, Womble Shale, Bigfork Chert, and Polk Creek Shale (Ordovician); Missouri Mountain Shale and Arkansas Novaculite (Silurian–Devonian); and Stanley Shale (probably Upper Mississippian) in the subsurface of southeastern Marshall County, where these rocks have been thrust-faulted northwestward onto rocks of the Arbuckle facies. Both the Arbuckle and Ouachita facies are truncated by erosion and disconformably overlain by Cretaceous rocks.

Tectonic elements of significance to an understanding of the subsurface geology of Marshall County include, from northeast to southwest, the Ravia fault block and associated Ravia and Sand Canyon nappes, Cumberland fault, Cumberland anticline, Cumberland syncline, Mannsville–Madill–Aylesworth fault system, Mannsville anticline, Madill anticline, Aylesworth anticline, Bryan fault, Kingston fault, Kingston syncline, Preston anticline, Overbrook thrust fault, Criner fault block, and Bryan salient of the Ouachita thrust system.

Numerous oil and gas fields associated with these structures include the Cumberland, Aylesworth, Southeast Aylesworth, North Madill, Madill and East Madill, Southeast Mannsville (abandoned), Enos, Isom Springs, Southwest Isom Springs, Kingston (abandoned), Handy and Southeast Handy (Texas), and South Powell. New discoveries in the Ouachita facies in the Isom Springs area and deep Ordovician production in the South Powell field highlight recent developments.

Nonmetallic-mineral production includes petroleum, natural gas, stone, sand, and gravel. Water is abundant, especially in surface lakes.

The geologic and tectonic history of Marshall County includes (1) faulting of the Precambrian basement and formation of the southern Oklahoma geosyncline, part of the Ouachita aulacogen; (2) filling of the southern Oklahoma geosyncline with early Paleozoic carbonates and late Paleozoic clastic rocks; (3) deposition of the Ouachita facies in the Bryan and Atoka basins (Ouachita geosyncline); (4) several episodes of tectonic activity, especially in post-Hunton, pre-Woodford time and during the Pennsylvanian (Wichita, Arbuckle, and Marathon–Ouachita orogenies); (5) post-Pennsylvanian, pre-Cretaceous erosion and peneplanation; (6) inundation by Cretaceous seas and deposition of Cretaceous sediments; (7) post-Cretaceous erosion; and (8) formation of extensive Pleistocene terraces and development of modern drainage systems.

Oil and gas accumulation and entrapment in Marshall County occurred in Late Pennsylvanian time, shortly after the folds and faults of the Arbuckle and Ouachita systems had been formed. Oil and gas trapped in isolated Pennsylvanian sands enclosed in Pennsylvanian shales accumulated during Pennsylvanian time. Shallow accumulations of hydrocarbons in basal Cretaceous sands may be the result of upward leakage from underlying structures, migration having occurred along fractures and faults which cut pre-Cretaceous beds.

Manuscript submitted November 3, 1982.

Part I

Areal Geology

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PART I. AREAL GEOLOGY

GEORGE G. HUFFMAN[1], KENNETH F. BRIDGES[2], ROBERT W. GANSER[3], ALAN M. HOLTZMAN, JR.[4], AND MICHAEL L. MERRITT[5]

INTRODUCTION

Purpose and Methods of Investigation

The primary purpose of this investigation has been the detailed mapping of the sedimentary rocks that crop out in Marshall County. Special attention was given to mapping and differentiation of Pleistocene terraces adjacent to Lake Texoma, and their correlation with levels established by Frye and Leonard (1963). These deposits have been mapped on the Sherman and Texarkana Quadrangles (Geologic Atlas of Texas) by Barnes and others (1966,1967) and in Choctaw and Bryan Counties, Oklahoma, by Huffman and others (1975,1978). A second part of this report deals with oil and gas in Marshall County and describes the pre-Cretaceous stratigraphy and structure related to accumulation of hydrocarbons.

Graduate students from the University of Oklahoma, working under the direction of the senior author, mapped parts of the area. The northeastern part was mapped by Ganser (1968) and restudied by Merritt (1978). The northwestern part was mapped by Holtzman (1978), and the southern by Bridges (1979). Subsurface studies were made by Merritt (1978) and Huffman.

Most of the mapping was done on 7.5′-quadrangle maps at a scale of 1:24,000. The southern part was covered by 15′-quadrangle maps; these were photographically enlarged to the same scale (1:24,000). Aerial photographs taken by the U.S. Department of Agriculture in 1963 at a scale of 1:20,000 (~3.2 in./mi) were used in the field and laboratory to confirm the mapping. Geologic data were plotted on the topographic base, which was photographically reduced to 1 in./mi. Final drafting and scribing were done by members of the cartographic section of the Oklahoma Geological Survey.

During the course of the field work, representative sections were measured and described (Appendix). Fossils were collected from various stratigraphic units, and rock samples were taken. Fossil identifications and sample descriptions were made in laboratories at the University of Oklahoma.

Acknowledgments

The project was financed and supported by the Oklahoma Geological Survey and by a grant from Herbert E. Ware, Jr., of Midland, Texas. A generous gift from Conoco Inc. helped defray drafting and publication costs.

Elliott W. Wiltse helped to compile information for the section on geography, and Robert O. Fay gave generously of his knowledge concerning the history of the area. The manuscript was reviewed by L. F. Brown, Jr., Keith Young, Jerome Westheimer, B. K. Reed, and R. O. Fay.

Previous Investigations

According to Thoburn (1916, p. 17–35), many well-known explorers visited Oklahoma and studied the southeastern part of the State during the 18th and early 19th centuries. These explorers include Bernard de La Harpe (1719–22), Pierre and Paul Mallett (1739), Fabry de La Bruyere (1741), John Sibley (1805), Capt. Richard Sparks (1806), Capt. Zebulon M. Pike (1806–11), Maj. Stephen H. Long (1817–20), Thomas Nuttall (1819–21), and Thomas Say (1823).

Many early geographic and geologic investigations were made along the Red River, which served as a boundary between (1) French and Spanish possessions in America; (2) colonial Spain and the United States; and (3) the United States and Mexico (Texas). These investigations have been summarized by many authors, including Hill (1887a,1901), Larkin (1909), Bullard (1928), Adkins (1933), and others. According to these sources, mapping of the Texas side of the Red

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River of New Spain was compiled from 1799 to 1804 by Baron Friedrich Heinrich Alexander von Humboldt, who did not visit southern Oklahoma. An early map of Texas was done in 1836 by William Kennedy, an English diplomat to Texas, and in 1841 by a German emigrant agent named G. A. Scherf. Other European investigators were Carl Solms-Braunfels in 1846 and Victor Bracht in 1848.

Early paleontological work was done by S. G. Morton of Philadelphia, who in 1834 named and described specimens of *Gryphaea pitcheri* and *Ammonites vespertinus* collected near Fort Towson (Choctaw County, Oklahoma). Problems concerning the taxonomy of these specimens have been reviewed by Hill and Vaughn (1898), Adkins (1944), Branson (1965), Stenzel (1959,1971), and Fay (1975).

Early work on the Cretaceous of the Texas region was done by Roemer, who published several papers, the most important being *Die Kreidebildungen von Texas und ihre organischen Einschlüsse* (1852). Also in 1852, a party under Capt. R. B. Marcy traveled from Fort Smith, Arkansas, into what is now Oklahoma. In 1853, Dr. G. G. Shumard, a physician attached to that expedition, applied the term "Washita Limestone" to beds exposed near old Fort Washita (Bryan County, Oklahoma) and collected fossils that were identified by Dr. B. F. Shumard and Prof. Jules Marcou. Marcou later accompanied a federal expedition to locate a suitable route for a railroad to the Pacific Coast. He described Cretaceous rocks in western Oklahoma and near Tucumcari, New Mexico, and attempted to relate them to rocks in the Red River region (1856). G. G. Shumard (1886) published his 1855 study of Grayson County, Texas, in which he included information concerning the Cretaceous of southern Oklahoma.

Three early state geological surveys were established in Texas. These include (1) the Shumard Survey (1857–61), (2) the Glenn–Buckley Survey (1870–75), and (3) the Dumble Survey (1888–93). Only the Dumble Survey accomplished important work on the Cretaceous, this being in the form of reports by J. A. Taff (1892) and F. W. Cragin (1893). The present Texas survey, the Bureau of Economic Geology at the University of Texas, was established in 1909, and since about 1918 a vast amount of work on the Cretaceous has been accomplished. The Oklahoma Geological Survey was established in 1908 under the direction of Charles N. Gould.

The first significant geological work on the Cretaceous of the Red River region following Shumard was by Hill (1887a,b,c), who prepared a careful analysis of the Cretaceous stratigraphic sequence. Hill's monograph (1901) still serves as a standard reference for Cretaceous studies in northern Texas and southern Oklahoma.

J. A. Taff, working with the U.S. Geological Survey, mapped the Atoka and Tishomingo Quadrangles in Oklahoma (1902,1903) and proposed much of the Cretaceous nomenclature used in the area. Stephenson (1918) mapped parts of southern Oklahoma and northeastern Texas. Detailed studies in Love and Marshall Counties, Oklahoma, were done by Bullard (1925,1926). Davis (1960) summarized the Cretaceous stratigraphy and prepared a map of southern McCurtain County, Oklahoma. Curtis mapped parts of Bryan County (1956–61), but his work was not published. In 1965, Frederickson, Redman, and Westheimer reported on the geology and petroleum occurrences of Love County, Oklahoma.

Our understanding of the stratigraphy of the Woodbine Formation of southern Oklahoma was enhanced by the work of Bergquist (1949) in Grayson and Fannin Counties, Texas. Frye and Leonard (1963) studied the terraces along the Red River and Barnes and others (1966,1967) mapped terraces on the Texarkana and Sherman Quadrangles. Paleontological work has been done by Adkins (1928), Stenzel (1959,1971), Stephenson (1952), Young (1957,1959,1963), and Fay (1975).

Recent investigations concerning the Cretaceous of southern Oklahoma have been completed by graduate students from The University of Oklahoma. These students include Heilborn (1949), Skolnick (1949), Gibbs (1950), Prewit (1961), Blau (1961), Hedlund (1962,1966), Redman (1964), Olson (1965), Jeffries (1965), Manley (1965), Dalton (1966), Alfonsi (1968), Duarte-Vivas (1968), Ganser (1968), Currier (1968), Hart (1970), Holtzman (1978), Merritt (1978), and Bridges (1979). Huffman and others (1975,1978) have published reports on Choctaw County and Bryan County, Oklahoma.

GEOGRAPHY

Location and Description of Area

Marshall County, located in central southern Oklahoma (Fig. 1) has an area of 421 mi^2 (Burgess, 1980). This includes ~39,040 acres of water, most of which is in Lake Texoma. The land area includes 357 mi^2. The County is bordered on the west by Love and Carter Counties and on the north by Johnston County. The Washita Arm of Lake Texoma separates it from Bryan County on the east, and the Red River Arm of Lake Texoma forms the southern boundary, separating Marshall County, Oklahoma, from Grayson County, Texas.

Historical Background

Archaeologists have traced the Indian occupation of the Oklahoma region back at least some 10,000 to 11,000 years (Gibson, 1965, p. 13).

Recorded history began with the arrival of the early Spanish explorers in search of gold. Spain

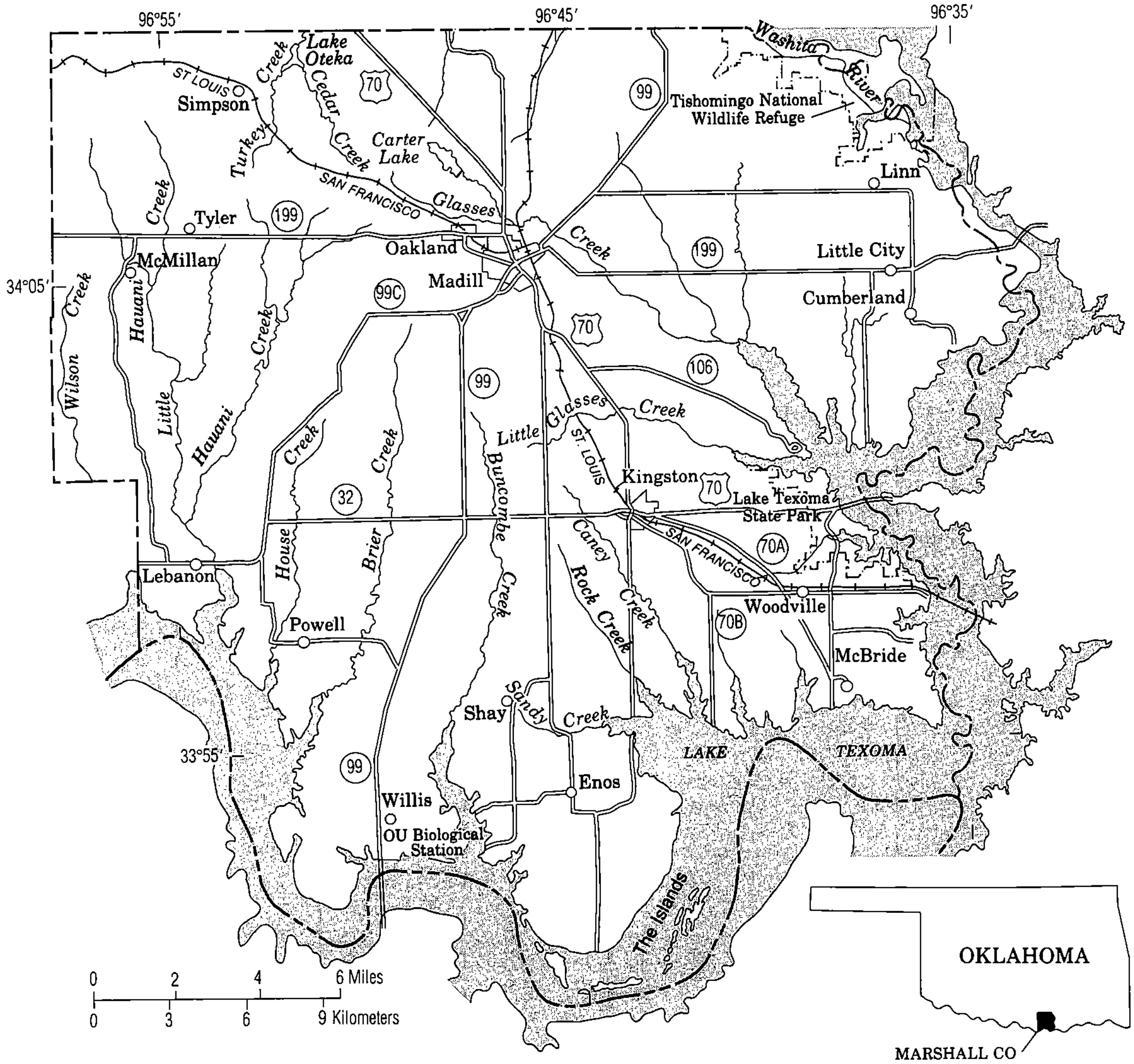

Figure 1. Location and general geography of Marshall County.

laid claim to the southern third of the United States, including what is now Oklahoma, as a result of the explorations of Hernando De Soto and Francisco Vasques de Coronado (ca. 1541). The French claimed much of the interior of North America following the travels of Père Jacques Marquette and Louis Joliet in 1673 and Robert Cavelier Sieur de La Salle, who named and claimed the Louisiana Territory in 1682. La Salle, as he is commonly known, established a colony near the mouth of the Mississippi River in 1684. La Harpe received a grant in 1718 from John Law, president of the French *Compagnie d'Occident* ("company of the west") for a tract of land extending from the upper waters of the Red River to the Arkansas River. He traveled through what is now eastern Oklahoma and Arkansas. During the Seven Years War (1756–63), Spain, France, and England all claimed the territory which is now Oklahoma. The Treaty of Paris (1763) gave the territory west of the Mississippi River to Spain and the area east of the Mississippi to England. Spain recovered Florida from England and retained possession of Louisiana west of the Mississippi River (Morris and McReynolds, 1965, p. 10), and the new United States extended from the Atlantic Ocean west to the Mississippi River.

Following the secret treaty of San Ildefonso in

1800, the Louisiana Territory was transferred to France. In 1803 the Louisiana Territory was sold to the United States for $15 million. This transfer included what is now Louisiana, Arkansas, Missouri, Iowa, Minnesota, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, Montana, Wyoming, and part of Colorado. In 1804 the Province of Louisiana was divided into the Territory of Orleans, with New Orleans as its capital, and the Louisiana Territory (north of the 33rd parallel), with St. Louis as its capital. The State of Louisiana was admitted to the Union in 1812, and the balance of Louisiana Territory became the Territory of Missouri. In 1819 the southern part of Missouri Territory was designated Arkansas Territory, and the northern part was admitted to the Union as the State of Missouri in 1821. In 1828, Indian Territory (later to become Oklahoma) was separated from Arkansas Territory.

The southern and western boundaries of Indian Territory were fixed by the Spanish Treaty of 1819 as the Red River and the 100th meridian, respectively. The northeastern boundary was established by the Enabling Act of 1820, and the eastern boundary (Choctaw line) was settled in 1825. The Osage Treaty of 1825 established the northern boundary, so that by 1825 the United States had acquired title to all of Oklahoma except the Panhandle.

Oklahoma soon became the residence of some 67 Indian tribes, many through the process of removal from areas to the east by the United States Government. Between 1816 and 1840, removal of the Five Great Civilized Tribes from their homes in Georgia, Alabama, Mississippi, Tennessee, South Carolina, and Florida was completed, and the tribes were relocated in what was to become Oklahoma. The five Indian nations in Oklahoma were the Cherokee, Choctaw, Chickasaw, Seminole, and Creek, each with its own capital and representative government (Fig. 2).

The Chickasaws moved to Oklahoma from 1838 to 1844. At first they were part of the Choctaw Nation, but in 1855 a new treaty was drawn up, establishing the Chickasaw Nation in south-central Oklahoma, with the capital at Tishomingo. Marshall County was in the southeastern corner of Pickens County, a subdivision of the Chickasaw Nation.

The Indian Nations of Oklahoma sided with the Confederacy during the Civil War. After the Union victory in 1865, a series of reconstruction treaties led to the ultimate destruction of Oklahoma's five Indian republics. Chartered railroads were given the right to build their routes through the Indian lands, which meant that the white settler would soon follow.

Increased pressure from the white man called for the opening of Indian Territory to white settlement. In 1890 the original Indian Territory was divided into two territories, Oklahoma Territory and Indian Territory. Whites moved into Oklahoma Territory, and 800,000 settlers were living there by 1906. In 1893 the Dawes Commission shifted tribal ownership of the Indian Nations to individual ownership, thus abolishing the Indian republics in preparation for statehood. The Enabling Act of 1906 paved the way for statehood, and in 1907 Oklahoma was admitted to the Union.

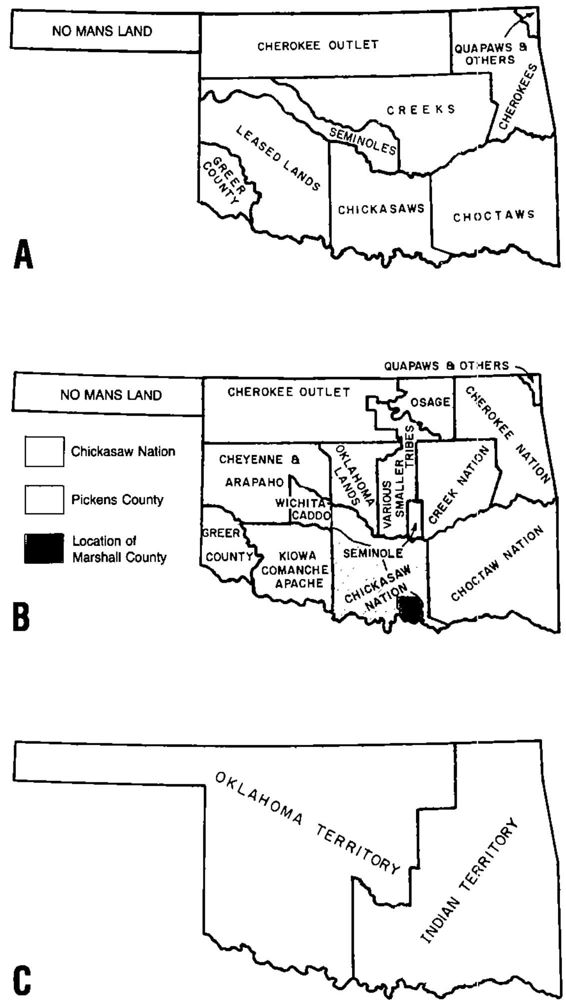

Figure 2. Development from Indian land to State of Oklahoma. (From Huffman and others, 1963; reprinted in Huffman and others, 1978). *A*, Indian Country, 1856–66. *B*, Indian Country, 1855. *C*, Twin Territories, 1890–1905.

Marshall County was named by George A. Henshaw, a delegate to the constitutional convention, in honor of his mother. Marshall County is the smallest county in Oklahoma.

The Chickasaws introduced farming and stockraising into southern Oklahoma, where their slaves tended the fields of cotton and corn. They were aware of the value of education, and in 1857 they appropriated money to build Burney Institute. The first post office was established at Burney Institute in 1860 and remained there until 1866. The town of Madill was established in 1900, and its post office was opened in 1901 (Shirk, 1965, p. 133).

Cities, Towns, and Population Trends

Marshall County had a population of 7,682 in 1970 and a population of 10,550 in 1980. Owing to the presence of Lake Texoma, Texoma Lodge, and other parks and recreation areas, the county is a popular resort area.

Madill, county seat of Marshall County, was established in 1900. Its establishment was a result of the southward extension of the Frisco Railroad into Indian Territory. The town was named in honor of George A. Madill, a St. Louis attorney and an official of the Frisco Railroad, who was associated with the townsite commission. Madill has an elevation of 755 ft; its population in 1970 was 2,875, and its population in 1980 was 3,173. This increase in population seems to be the direct result of its proximity to Lake Texoma.

Smaller towns in Marshall County (and their 1980 population) include Kingston (1,171), Oakland (485), Woodville (94), and McBride (91). The population of Little City was not recorded in the 1980 census. Odell, Taliaferro, and Willis Townships, listed in the census for 1940 through 1960, were not listed in the 1970 or 1980 censuses, having been incorporated into nearby towns.

Small communities include Lebanon, Linn, Powell, McMillan, Shay, Simpson, Enos, and Cumberland. These rural centers serve as support for nearby resorts.

Madill is in the heart of a ranching area and is a center for oil production. It also serves as a resort center for the Lake Texoma region.

Population trends for the county and various towns and communities are shown in Table 1.

Industries and Material Resources

Revenue-producing activities in Marshall County fall into four general categories: (1) mineral production, (2) agriculture, (3) manufacturing, and (4) tourism.

Mineral Production

According to the U.S. Bureau of Mines, the minerals produced in Marshall County, in order of their importance, are petroleum, natural-gas liquids, natural gas, sand, and gravel (Table 2).

Oil seeps were known near Madill from the time of initial settlement, and oil seeping into water wells and springs was thought to have medicinal

TABLE 1.—POPULATION TRENDS IN MARSHALL COUNTY

Area or town	1940	1950	1960	1970	1980	Percent change, 1940–80
Marshall County	12,384	8,177	7,263	7,682	10,550	−15
Holford Township	2,318	1,250	985	—	—	—
Kingston (town)[a]	481	677	639	710	1,171	+143
Little City (town)	—	101	102	80	—	—
McBride (town)[b]	—	—	14	44	91	—
Madill (town)[c]	2,594	2,791	3,084	2,875	3,173	+22
New Woodville (town)[d]	364	78	98	118	94	−74
Oakland (town)	311	293	288	317	485	+56
Odell Township[b]	1,929	805	563	—	—	—
Taliaferro Township[c]	1,892	1,054	650	—	—	—
Willis Township[a]	2,495	1,128	840	—	—	—

Source: U.S. Population, 1960, v. 38-A, tables 2,7; 1970, v. 38-A, table 10; 1980 Census Enumerations, Oklahoma Employment Security Commission, Special Studies, April 1, 1980.
[a]Part of Willis Township annexed to Kingston.
[b]McBride town incorporated from Odell Township.
[c]Part of Taliaferro Township annexed to Madill.
[d]Original town of Woodville inundated by Lake Texoma.

TABLE 2.—VALUE OF MINERAL PRODUCTION IN MARSHALL COUNTY

Year	Total value (dollars)
1964	5,195,243
1965	4,965,961
1966	6,298,004
1967	5,877,969
1968	6,600,000
1969	6,599,000
1970	6,808,000
1971	6,543,000
1972	5,919,000
1973	5,671,000
1974	8,944,000
1975	8,865,000

Source: U.S. Bureau of Mines *Minerals Yearbook* for respective years.

Note: Petroleum, natural-gas liquids, and natural gas have been the most valuable products in every year; sand and gravel and/or stone also have had significant production.

value. The first oil well was dug in Marshall County in 1909, leading to development of the Arbuckle field, which was later incorporated in the Madill field. Gas was discovered in the Enos field south of Kingston in 1918. Deep drilling began in 1939 and led to the discovery of such major fields as the Cumberland, Aylesworth, North Madill, and Mannsville. Other fields include the Isom Springs, Southeast Handy, and South Powell. Several fields have been abandoned. Recent production statistics are summarized in Table 3. Table 4 summarizes production from various fields before consolidation.

Sulfur has been refined by the Pioneer Gas Producing Co. from sour gas produced from the Oil Creek Formation in the Cumberland field. Limestone has been produced from at least four quarries in the Goodland Limestone, a chemically pure carbonate rock 15–25 ft thick. Gravels found in terrace deposits and in alluvium along some of the creeks are a source of construction material and road metal.

Agriculture

When the Indian Territories were opened for white settlement, the new Oklahomans rushed to stake claims on the vast expanse of fertile farmland. The Indians also had done considerable farming, raising mostly cotton and corn. Marshall County remained primarily an agricultural area until the time of the big oil strikes, which provided great wealth to the county.

The principal crops are peanuts, hay, cotton, grain sorghum, oats, soybeans, rye, corn, wheat, and barley. Much of the land today has been converted back to grass, as the size of the average farm increased from 173 acres in 1936 to 428 acres in 1975. Many large ranches have been established.

Manufacturing

With the general decline in population and the movement of population to larger centers, the Madill Chamber of Commerce and the citizens of Madill have worked to attract industry to their area, and manufacturing has contributed considerably to the economy of the county.

TABLE 3.—OIL AND GAS PRODUCTION IN MARSHALL COUNTY FOR VARIOUS FIELDS, 1983–1984

Field	Producing wells, 1983	Oil production, 1983 (bbl)	Producing wells, 1984	Oil production, 1984 (bbl)	Cumulative oil production, 1/1/85 (bbl)	Natural-gas production, 1983 (Mcf)	Natural-gas production, 1984 (Mcf)
Aylesworth	92	66,686	82	62,270	10,800,678	800,770	829,840
Aylesworth SE	22	29,281	23	31,604	2,202,726	1,451,820	1,270,114
Cumberland	144	155,015	81	166,849	72,042,054	1,995,318	3,424,965
Isom Springs	98	126,031	100	109,024	3,725,130	487,124	435,866
Isom Springs SW	5	8,127	4	8,727	416,845	0	0
Madill	164	91,718	108	81,048	15,298,335	1,557,617	1,595,973
Powell South	20	39,611	22	33,753	840,360	935,165	1,102,684

Sources: Data on natural-gas production from Oklahoma Corporation Commission, Oil and Gas Conservation Division; other data from Petroleum Information Corp. report for 1983, 1984.

TABLE 4.—OIL AND GAS PRODUCTION IN MARSHALL COUNTY FOR VARIOUS FIELDS (TO JANUARY 1, 1977)

Field	Producing unit	Cumulative oil production (bbl)	Cumulative gas production (Mcf)
Aylesworth	Trinity Simpson "Misener" Woodford Tulip Creek	9,962,910	3,378,909
Aylesworth North[a]	"Misener"	4,152	
Aylesworth NW[b]	Simpson	368,332	
Cumberland	Hunton Bromide McLish Oil Creek	70,605,452	1,463,303
Duffy[c]		1,000	
Enos[d]	Preston–"Arbuckle"	310,000	
Handy SE	Handy	59,637	
Isom Springs	Preston–"Arbuckle," "stray"	1,266,595	
Isom Springs SW	Desmoinesian	350,842	
Kingston[e]	Trinity	27,000	
Madill	"Bilbo sand" Trinity "Springer" Woodford Hunton Bromide McLish Oil Creek (gas)	5,356,204	33,020,187
Madill North	Bromide McLish (gas) Oil Creek (gas)	9,259,209	662,160
Mannsville SE[f]	McLish	347,523	
Powell	Deese "Handy sand" "P sand"	500,007	

Source: International Oil Scouts Association (1978).
[a]Combined with Aylesworth in 1957.
[b]Combined with Aylesworth in 1952.
[c]Abandoned.
[d]Combined with Isom Springs in 1962.
[e]Abandoned in 1962.
[f]Abandoned in 1963.

Tourism

Lake Texoma is one of the Southwest's leading playgrounds, attracting more than 10 million visitors per year. Camping facilities and resort areas are available on both the Texas and Oklahoma sides of the lake, and a 580-mi shoreline provides swimming, boating, and fishing facilities.

Topography and Drainage

Marshall County lies in the dissected Gulf Coast province. Elevations range from 850 ft in the central part of the county to 550 ft at the junction of the Washita and Red Rivers at the southeastern corner of the county. However, this area is now well below the waters of Lake Texoma, where the shoreline elevation at power-pool level is 617 ft. Thus, the effective relief in the county is only ~240 ft.

The area can be divided in general into three contrasting terranes: (1) the area of outcrop of the Antlers sandstone ("Western Cross Timbers" of previous reports); (2) the "Grand Prairie" of previous reports, an area underlain by limestones, marls, and shaly clays overlying the Antlers sandstone; and (3) the Woodbine terrane ("Eastern Cross Timbers" of older reports).

The Antlers terrane is represented by a broad belt extending across northern and western parts of the county. It is characterized by rolling to hilly topography covered with blackjack oak and scrub oak. The shales and carbonates above the Antlers sandstone form a gently rolling upland prairie (Grand Prairie). In Eastern and central parts of Marshall County, the more-resistant limestones (Goodland, lower Duck Creek, Fort Worth, McNutt, and Bennington) form cuestas with moderately steep escarpments and long, gentle dip slopes. The Woodbine sandstone has two outliers in the eastern part of the county, where 4–5 mi^2 of rugged, hilly, sandy terrain is covered by a dense growth of blackjack oak and scrub oak (Eastern Cross Timbers).

Marshall County is drained on the south by the Red River and on the east by its principal tributary, the Washita River. Lake Texoma, formed by impoundment of these rivers, occupies a deep valley some 200–300 ft below the general level of the surrounding country. Two or more high-level terraces are preserved above the lake level. The old flood plain and the lower terrace level (like those below Denison Dam in Bryan County, Oklahoma) are inundated by the waters of Lake Texoma, which at Denison Dam is >100 ft deep.

The principal creeks that drain Marshall County are shown in Figure 1 and on Plate 1.

Soils

Soil has been defined as earth material that has been so modified and acted upon by physical, chemical, and biologic agents that it will support rooted plants. The term is also loosely applied to all unconsolidated material above bedrock that has been in any way altered or weathered. Some soils are said to be residual, that is, formed in place from the underlying bedrock. Other soils are described as transported, owing their position to some agent of transportation, such as streams, which have deposited materials such as floodplain alluvium and terrace gravels. The type of soil in any area is determined by the parent material and the nature of the climate, especially the amount of rainfall. Numerous schemes for the classification of soils, both on the regional and local level, have been devised.

A survey of the types of soil in Marshall County (Burgess, 1980) recognized seven general associations and rated them according to crops, pastures, woodlands, and urban uses. Each association is further subdivided into several types with local development.

The classification and description of the general soil types that follow have been taken from Burgess (1980); the general soils map from this publication has been reproduced as Figure 3.

Bastrop–Konawa Association

The Bastrop–Konawa association consists of nearly level to sloping soils on terraces along the Red River, the Washita River, and some major streams within the county. The Bastrop soils are on high terraces. They are deep and well drained and form on nearly level to gently sloping surfaces. They have a brownish, loamy surficial layer and a brownish and reddish, loamy subsoil. The Konawa soils are on the lower terraces, are gently sloping, and are well drained. They have a brownish, loamy surficial layer and a brownish and reddish, loamy subsoil; the underlying material is yellowish and loamy.

Soils of the Bastrop–Konawa association have a high potential for small grains, row crops, tame pastures, and native grasses. They have a low potential for woodlands and a high potential for urban development. This association makes up 10% of the county's soil.

Dougherty–Konawa Association

The Dougherty–Konawa association consists of nearly level to sloping soils on terraces along the Red River and some major streams. The Dougherty soils are restricted to terraces. The deep soils are nearly level to gently sloping and well drained. They have a brownish, sandy surficial layer; a brownish and yellowish, loamy subsoil; and yellowish, sandy underlying material. Konawa soils are on terraces slightly lower than the Dougherty soils. These deep soils are very gently sloping to sloping and well drained. They have a brownish, loamy surficial layer; a brownish and reddish subsoil; and yellowish, loamy underlying material.

The soils in the Dougherty–Konawa association have medium potential for crops, native grasses, and tame pasture. They have low potential for woodlands and high potential for urban uses. Soil blowing is a major problem during the spring unless there is a cover crop. This association makes up 8% of the county's soil.

Durant–Collinsville Association

The Durant–Collinsville association occurs on hills and ridges that are drained by small streams. This association occupies 17% of the county's soils.

Durant soils occur on hillsides. The soils are

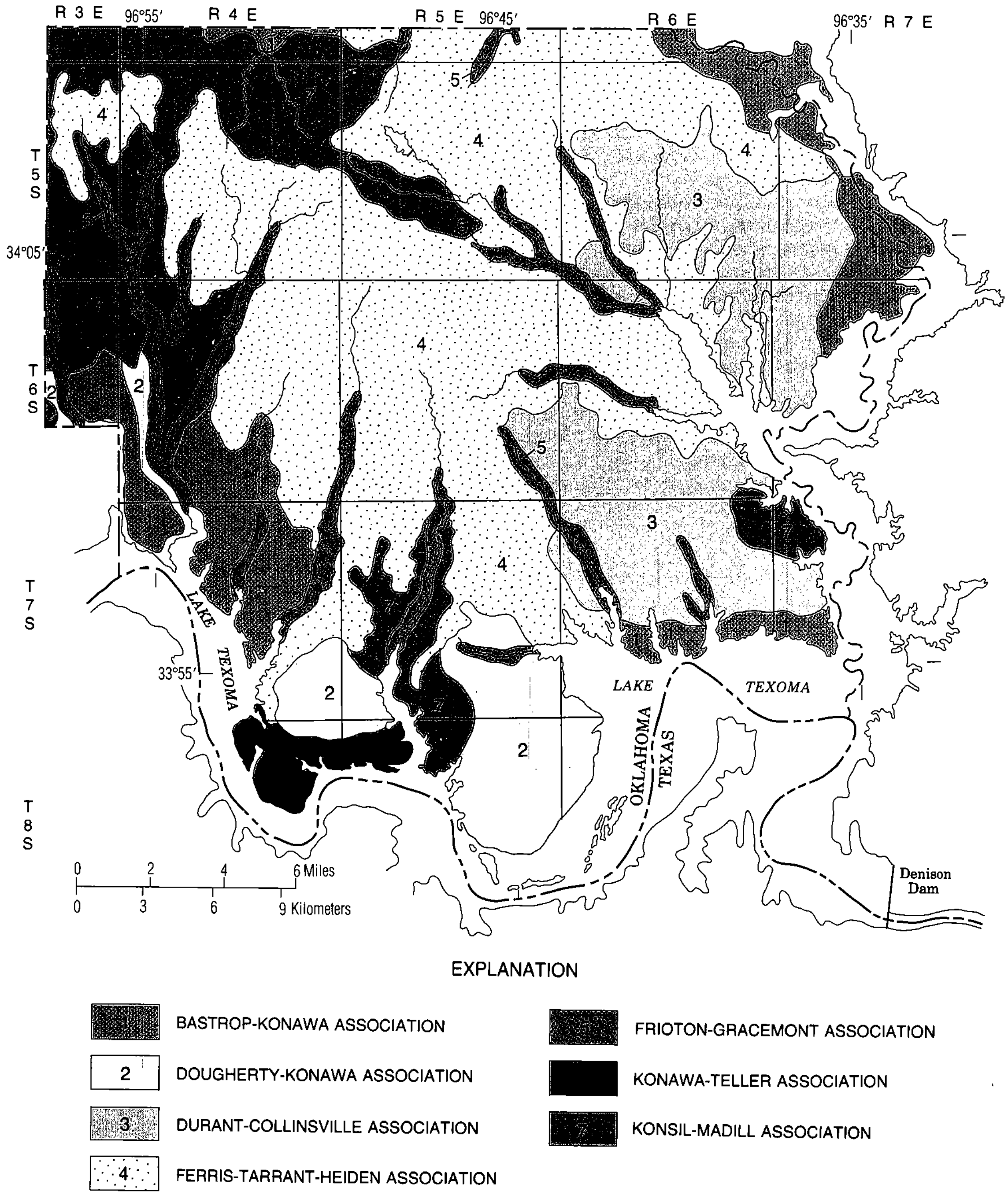

Figure 3. Generalized soils map of Marshall County. (Redrawn from Burgess, 1980).

deep, very gently to gently sloping, and moderately well drained. They have a brownish, loamy surficial layer and a brownish, clayey subsoil. Collinsville soils are on ridge crests and on slopes. These shallow soils are gently sloping to strongly sloping and well drained. They have a brownish, loamy surficial layer and a brownish, loamy subsoil. The underlying rock is sandstone.

The Durant–Collinsville association occurs in the Cumberland syncline and in the Kingston syncline, where they have formed on the shales, siltstones, and sandstones of the Bokchito Formation. The soils have medium potential for crops, high potential for tame pastures and native grasses, and low potential for woodlands and urban uses. The shallow depth of the Collinsville soil and the high shrink–swell potential in subsoils of the Durant make these units unfit for building sites and sanitary systems.

Ferris–Tarrant–Heiden Association

The Ferris–Tarrant–Heiden association occurs on hills and ridges drained by small streams. It occupies 42% of the county. Ferris soils lie on hillsides. They are deep, gently to strongly sloping, and well drained. They have a brownish, clayey surficial layer and a mottled, brownish, olive, and grayish, clayey underlying subsoil. The Tarrant soils are on hillcrests. They are shallow, well drained, and form on very gently sloping to moderately steep surfaces. They have a brownish, cobbly, clayey surficial layer over hard limestone. Heiden soils are on the slopes of hills. These deep soils are well drained and form on very gently sloping surfaces. They have a brownish, clayey surficial layer; a brownish and grayish, clayey layer below the surficial layer; and an underlying mottled (grayish and yellowish), shaley clay.

The deep, very gently to gently sloping Ferris and Heiden soils have low potential for farm crops, medium potential for tame pasture, high potential for native grasses, and low potential for woodlands and urban uses. The shallow Tarrant soils are best suited for grass.

The Ferris–Tarrant–Heiden association is developed throughout the central part of the county, having formed on the shale and limestone beds of the Goodland Limestone, Kiamichi Formation, and Caddo Formation.

Frioton–Gracemont Association

The Frioton–Gracemont association occurs on flood plains along the major streams, making up ~3% of the soils of the county. Frioton soils are on broad, smooth flood plains. The soils are deep, smooth to slightly undulating, and well drained. They have a grayish, loamy surficial layer; a brownish, loamy layer below the surficial layer; and brownish, gravelly, loamy underlying material. Gracemont soils occupy lower positions on slightly undulating flood plains. These deep soils are nearly level and poorly drained. They have a brownish, loamy surficial layer; a brownish, loamy layer below the surficial layer; and brownish, loamy subsoil.

The Frioton soils have high potential for crops, pastures, and tame grasses, medium potential for woodland, and low potential for urban uses. Because of flooding, the Gracemont soils have low potential for crops and urban uses.

Konawa–Teller Association

The Konawa–Teller association makes up only 2% of the county's soil. Konawa soils occur on terraces, where they are deep, well drained, and very gently to gently sloping. They have a brownish, loamy, surficial layer; a brownish and reddish, loamy subsoil; and yellowish, loamy underlying material. Teller soils are on slightly lower terraces. Their deep, well-drained soils are nearly level. They have a grayish, loamy surficial layer and a brownish, loamy subsoil.

The Konawa–Teller association has medium potential for crops, high potential for native grasses and tame pastures, low potential for woodlands, and high potential for urban development. Soils of this association have been identified primarily with a low terrace south of Willis, Oklahoma.

Konsil–Madill Association

The Konsil–Madill association is present on hills, ridges, and flood plains of small streams, making up 18% of the county's soil. Konsil soils are on hillsides and ridge tops. They are deep, well drained, and very gently to steeply sloping. They have a grayish, loamy surficial layer; a reddish, loamy upper subsoil; and a yellowish, loamy lower subsoil. Madill soils are on smooth flood plains of small streams. The deep, well-drained soils are nearly level to slightly undulating. They have a brownish, loamy surficial layer; a brownish, loamy layer below the surficial layer; and underlying subsoil of brownish, loamy clay.

The soils in this association have medium potential for crops, high potential for native grasses and tame pastures, medium potential for woodlands on Madill soils, high potential for urban uses on Konsil soils, and low potential for buildings on the Madill soil.

Soils of the Konsil–Madill association occur in the western and northwestern parts of the county, where they have formed on the Antlers sandstone. They are also developed along Buncombe Creek where the Antlers sandstone is at or near the surface, and in the southeastern part of the county where the Woodbine Sandstone is exposed.

Dams, Reservoirs, and Game Preserves

To make more effective use of our water, to prevent flooding, to control erosion, to generate hydroelectric power, to provide recreational areas, and to stimulate tourism, the State of Oklahoma and the federal government have completed more than 30 major dams and reservoirs on Oklahoma rivers. Hundreds of small, upstream dams have been built for flood control, and thousands of farm ponds dot the Oklahoma landscape. Lake Texoma in southern Oklahoma ranks among the largest of these major lakes.

Denison Dam

Denison Dam, constructed in 1944 on the Red River 16 mi southwest of Durant and 30 mi southeast of Madill, creates Lake Texoma. The dam is a multipurpose structure built for flood control and hydroelectric power. The first hydroelectric turbine was installed in March 1945, and a second unit was installed in September 1949. The power-intake structure will permit the installation of three additional 35,000-kW generators as demand increases. The two generators currently in operation are generating >270 million kWh/yr of electrical energy, which is enough to serve ~100,000 homes (data from U.S. Army Corps of Engineers, Southwestern Division, 1977).

The dam that creates Lake Texoma is of the earth-fill type, with a length of 15,200 ft, a height of 165 ft above the stream bed, a basal width of 1,145 ft, a top width of 40 ft, and a 2,000-ft-wide spillway. The elevation of the top of the dam is 670 ft.

Lake Texoma

Denison Dam creates a body of water that covers 91,200 acres and has a shoreline of 580 mi at the power-pool level of 617 ft. The storage capacity is 5,382,000 acre-ft of water, of which 2,660,000 acre-ft is for flood control, 1,673,000 acre-ft for power drawdown, and 1,049,000 acre-ft for power head and sediment reserve. The flood-control pool is at an elevation of 640.0 ft, giving the lake an area of 143,300 acres and a shoreline of 1,180 mi.

Lake Texoma is a popular recreational area with some 30 resorts and more than 300 private cottages on government land adjacent to the lake. Marshall County has 17 private resorts and 43 public facilities, encompassing some 10,310 acres maintained by the U.S. Army Corps of Engineers. Texoma State Park, with its lodge, golf course, landing field, and other facilities, covers 2,300 acres on the Oklahoma side in eastern Marshall County, and the 405-acre Eisenhower State Park is on the Texas side near Denison Dam.

Marshall County, the surrounding counties, and Oklahoma as a whole have reaped abundant benefits from the construction of Denison Dam and Lake Texoma. Flood control has prevented tens of millions of dollars in damages. A total of 312 million kWh of electrical energy was generated and sold during fiscal year 1974. Recreational use of the lake and its facilities has brought new businesses and has taken in large amounts of money from tourism.

University of Oklahoma Biological Station

For the past 30 years the University of Oklahoma has maintained a biological station on a peninsula east of Willis, Oklahoma, some 15 mi south of Madill. The station is complete with mess hall, dormitories, faculty housing, and boat-dock facilities. Research is conducted in ecology, natural history, taxonomy, morphology, and physiology of aquatic organisms. The constantly changing environmental conditions created by fluctuation of water from power drawndown and periods of excessive runoff offer the student a variety of interesting ecological problems.

Tishomingo National Wildlife Refuge

The Tishomingo National Wildlife Refuge was acquired in 1946 from the U.S. Army Corps of Engineers. Since that date it has been managed by the Bureau of Sports Fisheries and Wildlife Service of the U.S. Department of the Interior. The game refuge consists of some 16,600 acres serving as a way station for ~120,000 migratory waterfowl (ducks and geese) each year, and as a permanent home for beaver, quail, white-tailed deer, and many species of fish. The refuge also includes the Tishomingo National Fish Hatchery, where 53 ponds covering some 46 acres are used for hatching and rearing fish and for experimental work. Fish reared at the station are used to stock Oklahoma ponds and streams, and some are shipped to Hawaii. The station has sponsored research on spawning of channel catfish, control of vegetation by herbicides, and shipping of live fish for distribution to other areas.

The refuge is open to the public at specified periods of the year; and camping, boating, picnicking, and hunting are encouraged. A section of the Lake Texoma portion is closed from October to April to minimize disturbance of the waterfowl.

Climate

Marshall County has a warm, temperate climate with warm summers and mild winters. The average annual rainfall during 1951–74 was 38.59 in., and average annual snowfall was 3.1 in. Rainfall is distributed throughout the year, April, May, and September being the wettest months (Table 5). Temperatures >100°F have been recorded in the summer, and temperatures <0°F have been known. These temperatures are the extremes and seldom last for more than a few

TABLE 5.—AVERAGE TEMPERATURES AND PRECIPITATION IN MARSHALL COUNTY

Month	Average daily maximum temperature (°F)	Average daily minimum temperature (°F)	Average temperaturre (°F)	Average rainfall (in.)	Average snowfall (in.)
January	53.5	28.9	41.2	1.48	1.5
February	59.0	32.8	45.9	2.03	1.1
March	66.1	40.3	53.2	2.94	0.2
April	75.6	51.0	63.3	4.78	0.0
May	82.4	59.3	70.9	4.65	0.0
June	90.0	67.6	78.8	3.76	0.0
July	95.2	71.0	83.1	2.62	0.0
August	95.2	69.3	82.3	2.49	0.0
September	87.6	62.7	75.2	5.08	0.0
October	77.8	51.3	64.6	3.91	0.0
November	65.0	39.8	52.5	2.65	0.0
December	55.9	31.6	43.8	2.20	0.3
YEAR	75.3	50.5	62.9	38.59	3.1

Source: Burgess (1980, table 1).

days. The mean maximum temperature is 75.3°F, the mean minimum temperature is 50.5°F, and the average temperature is 62.9°F. The average January temperature is 41.2°F, and the average July temperature is 83.1°F.

The growing season lasts for ~233 days. The last killing frost in the spring occurs around March 25, and the first killing frost in the fall occurs around November 10 (Morris, 1954).

Historic Sites

Marshall County played a minor part in the historical development of Oklahoma. The Oklahoma Historical Society has placed roadside markers at or near the site or sites of famous landmarks. Descriptions of these sites have been published in two booklets (Wright and Shirk, 1958; Oklahoma Historical Society, 1958). These booklets list the more important sites for each county in Oklahoma. Only two major sites are recorded for Marshall County.

Camp Leavenworth

Gen. Henry Leavenworth, Dragoon Expedition, was wounded near the site of Camp Leavenworth about two miles south of Kingston, Oklahoma, and died near there July 21, 1834. A marker has been placed on U.S. Highway 70 at the west side of Kingston in his honor.

Burney Institute

Burney Institute was erected by an act of the Chickasaw Legislature in 1857 and opened for Chickasaw pupils in 1859. The Rev. Robert S. Bell and his wife served as teachers. The institute's name was changed to Chickasaw Orphan Home and Manual Labor School in 1887. The site was 2.5 mi east of Lebanon; the present marker is on State Highway 99C, 1.5 mi east of Lebanon.

Other Historic Sites

Other interesting sites include (1) the W. N. Taliaferro Home in Madill City Park, now being restored by the Oklahoma Historical Society, and (2) Fort Washita, an important military fort established by Gen. Zachary Taylor in 1842 to protect the Chickasaw Indians from the warlike plains Indians. The fort is ~1 mi east of the Washita River in western Bryan County.

STRATIGRAPHY

Stratigraphic Summary

Rocks exposed at the surface in Marshall County range in age from Middle Ordovician (Trentonian) limestone of the Viola Group to the Late Cretaceous (Gulfian) Woodbine Formation. These units are overlain at places by extensive deposits of gravel and alluvium of Pleistocene and Holocene age. The stratigraphic sequence in Marshall County is shown in Figure 4.

Paleozoic strata are effectively concealed throughout Marshall County, except for limited exposures along Turkey Creek (now inundated by Lake Oteka), in secs. 34 and 35, T4S, R4E, ~7 mi northwest of Madill (Pl. 1). There, exposures include beds of the Viola, Sylvan, Hunton, Wood-

SYSTEM	SERIES	GROUP, FORMATION, MEMBER			LITHOLOGY	THICKNESS (feet)	DESCRIPTION
QUATERNARY	Holocene	Alluvium				15–25	Clay, sand, and silt of modern flood plains.
QUATERNARY	Pleistocene	Terrace deposits				0–120	Sand, silt, clay, and gravel deposited at various levels by Red River and Washita River. Levels are designated Qt_2, Qt_3, Qt_4, and Qt.
CRETACEOUS	Gulfian	Woodbine Formation		Dexter Member		0–35	Reddish-brown, ferruginous pebble conglomerate, overlain by light-brown, fine-grained sandstone with medium-scale cross-bedding; exposed thickness, 17 feet.
CRETACEOUS	Comanchean	Washita Group	Grayson Marlstone			0–20	Thin-bedded, greenish-gray marlstone with interbeds of white nodular limestone; upper beds are olive-green calcareous shale.
CRETACEOUS	Comanchean	Washita Group	Bennington Limestone			1.5-2.5	Blue-gray to brown, heavy-bedded, fine- to medium-crystalline, fossiliferous limestone with *Ilymatogyra arietina* (Roemer).
CRETACEOUS	Comanchean	Washita Group	Bokchito Formation	Pawpaw Sandstone Member		55	Yellow to reddish-brown ferruginous sandstone interbedded with lenses of grayish-brown sandy shale and clay; abundant molds of *Protocardia*.
CRETACEOUS	Comanchean	Washita Group	Bokchito Formation	McNutt Limestone Member		1–20	Reddish-brown, sandy, fossiliferous limestone with abundant *Lopha quadriplicata* (Shumard). "Quarry limestone" of older reports.
CRETACEOUS	Comanchean	Washita Group	Bokchito Formation	Weno Clay Member		60–90	Gray to brown, iron-stained, ferruginous sandy shale with molds of *Protocardia* and *Turritella*; grades upward into yellow-orange, fine-grained, massive sandstone.
CRETACEOUS	Comanchean	Washita Group	Bokchito Formation	Soper Limestone Member		1–2	Brown, fossiliferous limestone containing *Arctostrea carinata* (Lamarck), *Texigryphaea washitaensis* (Hill).
CRETACEOUS	Comanchean	Washita Group	Bokchito Formation	Denton Clay Member		45–55	Blue clay shale in lower part; bed of brown, ripple-marked sandstone near middle; upper part is brownish-yellow and silty and grades into shaly, fossiliferous marlstone at the top.
CRETACEOUS	Comanchean	Washita Group	Caddo Formation	Fort Worth Member		40	Light-gray shale interbedded with gray to white to buff limestones which weather cream-colored; fossiliferous.
CRETACEOUS	Comanchean	Washita Group	Caddo Formation	Duck Creek Member		110–130	Lower part includes gray shale and interbedded blue-gray silty limestone containing large cephalopods; upper part mainly blue-gray unfossiliferous shale.

Figure 4. Stratigraphic sequence of rocks exposed in Marshall County.

SYSTEM	SERIES	GROUP, FORMATION, MEMBER			LITHOLOGY	THICKNESS (feet)		DESCRIPTION
CRETACEOUS	Comanchean	Fredericksburg Group	Kiamichi Formation			35–40		Black, fissile clay shale with scattered siltstone lenses; 1-foot bed of siltstone near middle; thin interbeds of yellow-gray, fossiliferous limestone near the top, forming the "shell beds," composed of abundant *Texigryphaea navia* (Hall).
CRETACEOUS	Comanchean	Fredericksburg Group	Goodland Limestone			15–25		White, massive, biomicritic limestone; weathers gray to yellow; upper beds weather into thin curved plates; lower beds argillaceous and locally nodular; Walnut Clay facies with *Ceratostreon texanum* (Roemer) at base of some exposures.
CRETACEOUS	Comanchean	Trinity Group	Antlers Formation	Antlers sandstone facies		200–600		White to dull-orange, fine- to medium-grained quartz sand; locally cross-bedded; ferruginous, with lenses of clay.
CRETACEOUS	Comanchean	Trinity Group	Antlers Formation	Baum Limestone Member		0–13		Upper part: light-gray, fine-grained, micritic limestone. Lower part: pale-yellow to white, coarsely crystalline conglomeratic limestone.
MISSISSIPPIAN	Osagean–Meramecian	Sycamore Limestone				100±	Incompletely exposed in Turkey Creek inlier (Amsden, 1985)	Massive to thick-bedded, very finely crystalline, blocky limestone, slightly shaly and sandy at base.
DEVONIAN	Senecan–Kinderhookian	Woodford Formation	upper cherty member			40–100		Banded black and white chert interbedded with dark-gray, fissile shale; some iron staining.
DEVONIAN	Senecan–Kinderhookian	Woodford Formation	lower carbonate-siltstone member			50		Light-colored dolomitic chert and siltstone; brown- to tan-weathering dolomitic siltstone; light-gray to greenish-gray, fossiliferous calcarenite.
DEVONIAN	Ulsterian	Turkey Creek limestone				5		
ORDOVICIAN	Cincinnatian	Sylvan Shale				0–26		Greenish-gray to yellow-gray calcareous claystone.
ORDOVICIAN	Cincinnatian / Trentonian	Viola Group				250±		Bluish-gray, cherty, thick-bedded, fossiliferous limestone; coarsely crystalline "Fernvale" facies at top.

ford, and Sycamore, which have been brought to the surface along the southwest flank of the complexly faulted and eroded, NW-trending Mannsville anticline. The Paleozoic strata are overlain unconformably by beds of Early Cretaceous age (Pl. 1).

Lower Cretaceous rocks are divided into the Trinity, Fredericksburg, and Washita Groups. The Trinity Group in this area contains the Antlers Formation, which includes the Baum Limestone Member and the overlying Antlers sandstone facies; the Fredericksburg Group includes the Goodland Limestone and the Kiamichi Formation; the Washita Group is represented by the Caddo Formation (Duck Creek and Fort Worth Members), the Bokchito Formation (Denton Clay, Soper Limestone, Weno Clay, McNutt Limestone, and Pawpaw Sandstone Members), the Bennington Limestone, and the Grayson Marlstone.

The Antlers Formation contains a sandstone which is a time-transgressive, nearshore marine deposit. Locally the Baum Limestone Member of the Antlers is the basal Cretaceous deposit; it is believed to be a restricted-lagoon deposit representing fresh to brackish water. Succeeding strata represent shallow-water marine and deltaic deposits. Basal Cretaceous beds lie on eroded Paleozoic rocks in Marshall County and onlap the Precambrian Tishomingo Granite northward in Johnston County.

The Woodbine Formation (basal Upper Cretaceous) lies disconformably on Lower Cretaceous strata; it is limited in distribution to two outliers southeast of Kingston in the trough of the Kingston syncline, where only the lower 35 ft of the formation is present. These beds represent the Dexter Member, the basal unit of the Woodbine.

Several distinct terrace levels have been recognized along the Red River Arm and the Washita River Arm of Lake Texoma. These levels have been correlated with corresponding levels in other parts of Oklahoma and Texas and have been assigned to terraces Qt_2 (Ambrose level), Qt_3 (intermediate level), and Qt_4 (Hardeman level), of Wisconsinan, Illinoian, and Kansan age, respectively.

Cretaceous strata were deposited upon and locally draped across preexisting Paleozoic structures that have undergone Cretaceous and possibly post-Cretaceous movement. Subsequent erosion of Cretaceous strata has developed an outcrop pattern that delineates such structural features as the Cumberland syncline, Oakland anticline, Madill anticline, Kingston syncline, and Preston anticline. In the subsurface of southeastern Marshall County, Cretaceous strata lie on the Ouachita-facies rocks of the Bryan basin.

Paleozoic Rocks

Cretaceous sediments conceal the underlying Paleozoic rocks (Pl. 1) in all parts of Marshall County except for isolated exposures along Turkey Creek (now inundated by Lake Oteka) in the north-central section of the county (secs. 34 and 35, T4S, R4E), ~7 mi northwest of Madill (Holtzman, 1978, p. 19). Paleozoic exposures were described by Tomlinson (1926) as "buried hills." On a detailed map, Tomlinson (p. 140, fig. 2) indicated the location of one outcrop of the Sycamore Limestone, four of the Woodford chert, four of the "Hunton Formation," and three of the "Viola Limestone" (Viola Group of this report). All of these outcrops are limited to the beds and lower walls of ravines occupied by Turkey Creek and its tributaries where erosion has partially removed the overlying Cretaceous rocks. Strike-and-dip readings indicate a NW-trending anticline, the exposed beds dipping 40–65° SW. The northernmost Viola exposure makes a distinct semicircular swing around the end of the Mannsville anticline, changing strike from NW to NE.

Tomlinson (1926) described the Sycamore as including ~100 ft of drab, massive, blocky, finely crystalline limestone (partially concealed), a 2-ft bed of green shale, and a 1-ft bed of basal sandstone. The Woodford in the southern exposure includes 100 ft of black and white chert, whereas the northernmost exposure consists of 40 ft of black chert and white, siliceous clay or clayey chert in thin bands. The "Hunton" was described as including 6 ft of white, massive, coarsely crystalline, glauconitic limestone and 18 ft of white to drab, blocky to platy, noncrystalline limestone. Viola exposures include 250 ft of bluish-gray, finely crystalline limestone in well-defined beds with several layers of cream-colored chert.

Bullard (1926, p. 13–16) discussed the Turkey Creek exposures, depending primarily on the map and description furnished by Tomlinson.

Tomlinson and others (1952, plate 2) presented a slightly revised version of the 1926 Tomlinson map; they also gave the following description:

> Outcrops of all the formations from the Sycamore limestone (Mississippian) to the Viola limestone (Ordovician) in the core of the Mannsville anticline, in a gorge cut through the nearly horizontal strata of the Trinity group (Comanchean). Facies items of interest include chert seams in the Sycamore, green shales in the Sylvan, and silicified fossils in the Fernvale. Beautiful exposures of angular unconformity including subsoil penetration by the younger formation, the Baum limestone at the base of the Trinity. The Baum here is unusually massive with local jointing more conspicuous than bedding.

Considerable controversy has arisen concerning the age and relationship of the so-called "Hunton" strata along Turkey Creek. Walters (1958, p. 14–21, pls. 1,3) demonstrated that Hunton strata were removed by pre-Woodford erosion along the Mannsville–Madill–Aylesworth anticline and that a detrital section of the "Misener(?)" interval, at the base of the Woodford, is present along the flanks of the uplift. He described the "Misener(?)" as off-white to tan, glauconitic, arenaceous, cherty, locally calcareous dolomite containing fragments of eroded Hunton limestone embedded in a dolomitic matrix.

Maxwell (1959) described a major regional unconformity at the base of the Woodford, the absence of Hunton strata along the Mannsville–Madill–Aylesworth anticline, and a brown carbonate facies that he called the "basal Woodford carbonate," noting that Woodford "spores" are present 10 ft above the contact with the underlying Sylvan Shale. He described angular, fragmental limestone, chert, and glauconite derived from a nearby source, the Mannsville–Madill–Aylesworth anticline.

Amsden (1960, p. 151–159, fig. 47) restudied the rocks in the Turkey Creek inlier as part of his regional studies on Hunton stratigraphy and paleontology in the Arbuckle region; he modified the map prepared by Tomlinson and others (1952). According to Amsden, the stratigraphic sequence (formerly) exposed along Turkey Creek includes "the Viola Limestone," (now designated the Viola Springs Formation), the "Fernvale" limestone, (now designated the Welling Formation), the Sylvan Shale, a carbonate–siltstone sequence assigned to the Hunton by Tomlinson and others (1952), the Woodford Formation, and the Sycamore Limestone. Amsden divided the carbonate–siltstone sequence into a lower 5-ft unit of fossiliferous and glauconitic calcarenite, a middle 29-ft unit of brown-weathering dolomitic siltstone, and an upper 20-ft unit of light-colored dolomitic chert and siltstone. He concluded that the lower glauconitic unit resembles certain Hunton strata, especially bioclastic limestone of the Clarita and Cochrane Members of the Chimneyhill Formation, but that the fauna has a post-Deerparkian (post-Frisco) aspect and is therefore younger than the typical Haragan–Bois d'Arc sequence of Early Devonian age. Amsden compared the overlying carbonate–siltstone beds with the "Misener(?)" facies of Walters (1958), the Woodford(?) brown carbonate of the Oil Creek area in Johnston County (sec. 18, T3S, R4E), and the basal Woodford carbonate of Maxwell (1959). He noted that these units occupy the same stratigraphic position and appear to be post-Hunton, but lack evidence for interrelations. Amsden's most recent (1985) interpretation of the Turkey Creek geology is shown in Figure 5.

Shannon (1962, p. 18–19) applied the name "Mannsville Dolomite" to strata previously referred to as "Woodford? brown carbonate" by Amsden (1960, p. 141–151, appendix), "carbonate–siltstone sequence on Turkey Creek" (Amsden, 1960, p. 151–159), "basal Woodford carbonate" (Maxwell, 1959, p. 121), and "Misener(?) facies" (Walters, 1958, p. 14). Shannon used as the type section for the "Mannsville Dolomite" a 23-ft sequence measured and described by Amsden (1960, p. 227–228) as the "Woodford? brown carbonate" on the Goddard Ranch, NW¼NE¼ sec. 20, T3S, R4E, in Johnston County. Shannon assigned the "Mannsville Dolomite" to the basal part of the "Kaskaskia Sequence" of Late Devonian–Early Mississippian age. He extended the "Mannsville Dolomite" into the subsurface of Marshall County to include beds previously assigned to the "Misener(?)" by Walters.

Amsden and others (1968) presented new evidence concerning the age of the carbonate–siltstone sequence in the Turkey Creek inlier and its relationship to the "Mannsville Dolomite" of Shannon. On the basis of faunal evidence, they divided the Turkey Creek rocks into two stratigraphic units, a 5-ft limestone of early Emsian (Devonian) age, which they called the "Turkey Creek limestone," and a 50-ft unit which they regarded as an atypical facies of the Woodford.

Amsden (1985) described the brachiopods from the "Turkey Creek limestone." In a correlation chart (Amsden, 1985, fig. 1) showed the "Turkey Creek limestone" as middle Early Devonian (Deerparkian) in age and correlative with the Frisco Formation of the Arbuckle Mountains and eastern Oklahoma.

Conodonts collected by Gilbert Klapper (cited in Amsden, 1985), of the University of Iowa, from the base and top of Shannon's "Mannsville Dolomite" on Oil Creek in Johnston County (sec. 20, T3S, R4E) demonstrate an Early Silurian age and an equivalence to the Cochrane Formation of the Chimneyhill Subgroup. Amsden and others (1968) believed that there is no relationship between Shannon's "Mannsville Dolomite" and the carbonate–siltstone beds on Turkey Creek. Thus, Shannon's type "Mannsville Dolomite" becomes a facies of the Cochrane Formation of the Chimneyhill Subgroup and is limited to the outcrops on Oil Creek. The carbonate–siltstone sequence on Turkey Creek is considered a basal clastic facies of the Woodford ("Misener" equivalent).

Recent studies by Holtzman (1978, p. 19–23) were made difficult by the construction of a dam across Turkey Creek to create Lake Oteka. As a result of the damming, most of the Paleozoic exposures are under water and no longer accessible. Today, only a few small exposures of Viola Group limestone, Woodford chert, and Sycamore Limestone can be observed above lake level. These rocks are overlain unconformably by the Lower Cretaceous Baum Limestone Member of the Antlers Formation (Pl. 1).

Cretaceous System, Comanchean Series

Trinity Group

The Trinity Group was originally described by Hill (1887c, p. 296–298) as the "Dinosaur Sand." Hill (1891, p. 510) assigned exposures of white pack-sand near the town and creek of Paluxy,

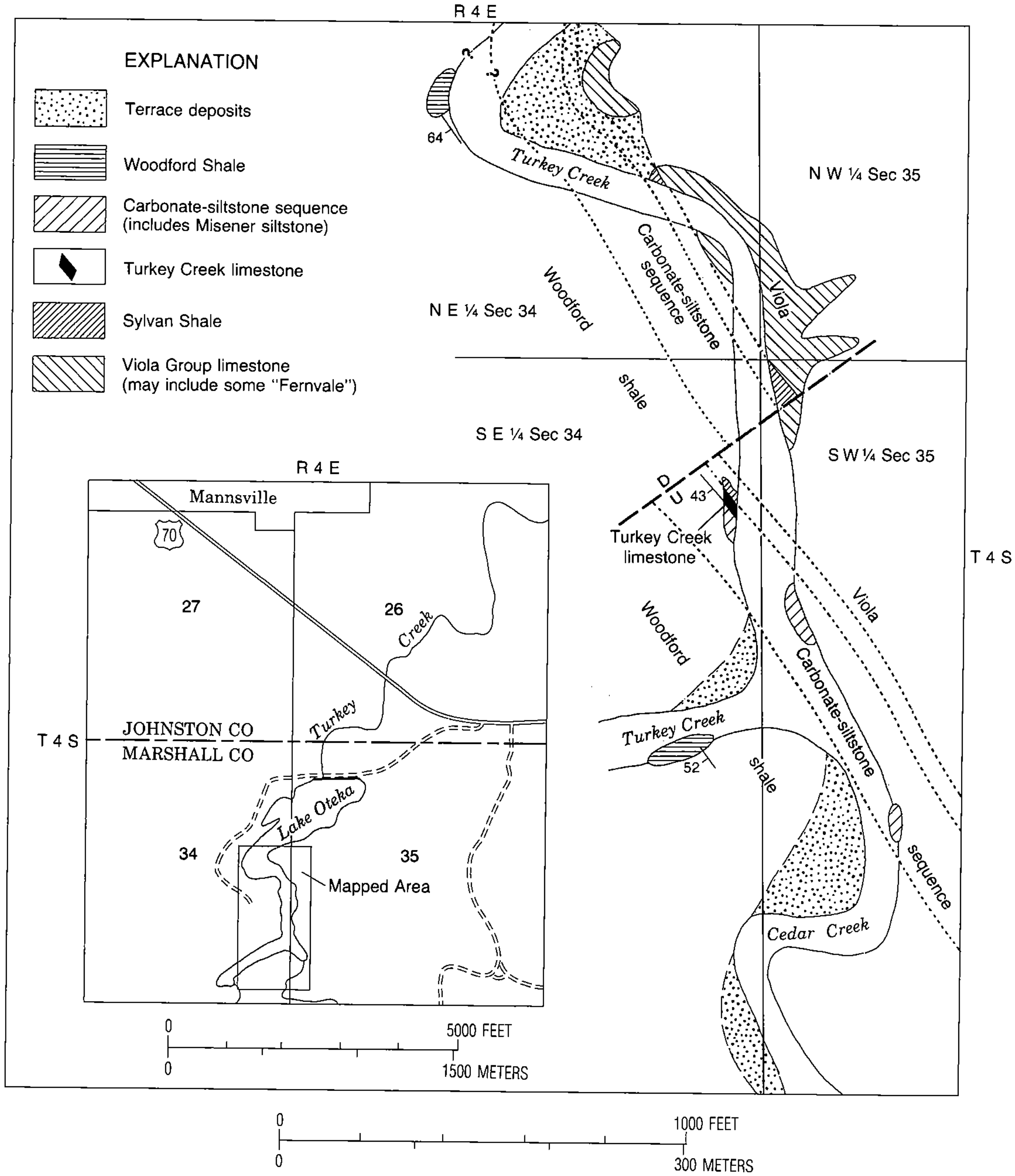

Figure 5. Geologic map of Turkey Creek inlier south of Mannsville, Oklahoma. (After Amsden, 1985, fig. 2.)

Somerville County, Texas, to the Paluxy Sandstone, a unit of the Fredericksburg Group. Taff (1892) placed the Paluxy in the "Bosque Division" (Trinity Group). Hill (1894, p. 317) reassigned the Paluxy to the Trinity Group, and in 1901 (p. 131) he assigned Trinity equivalents in Oklahoma to the Antlers.

The Trinity Group in Texas is typically represented by three units, a basal sandstone (Travis Peak equivalent), a medial limestone (Glen Rose Formation), and an upper sandstone (Paluxy). In the arcuate band from southwestern Arkansas to the Trinity River of north-central Texas, the basal Cretaceous is dominated by fluviatile, brackish-

TABLE 6.—GEOGRAPHIC VARIATION IN THE TRINITY GROUP

Central Wise County, Texas	Love, Marshall, Bryan, and Choctaw Counties, Oklahoma	Eastern McCurtain County, Oklahoma
Paluxy Sandstone	Antlers Formation (Baum Limestone Member at base locally)	Paluxy Sandstone
Glen Rose Formation		DeQueen Limestone
Basal sandstone (Travis Peak equivalent)	(missing or represented by undifferentiated sandstone)	Holly Creek Sandstone
		Dierks Limestone
		Pike Gravel

water, and sandy marine deposits. From Wise County, Texas, southward, and from central McCurtain County, Oklahoma, eastward, the section is divided by a medial limestone wedge into several named formations. In Love, Marshall, Bryan, and Choctaw Counties, Oklahoma, the Antlers sandstone facies predominates (Table 6).

Antlers Formation.—In parts of Marshall County and adjacent counties (Johnston and Carter) the Antlers Formation includes two facies, the Baum Limestone Member and the Antlers sandstone.

Baum Limestone Member.—The Baum limestone is a nonmarine, algal-rich carbonate that occurs as a local facies in the basal part of the Antlers Formation. The Baum is best known in south-central Oklahoma in the area of outcrop south of the Arbuckle Mountains, from the town of Ravia westward to Baum and southward to the vicinity of Mannsville (Wayland and Ham, 1955, p. 9). The limestone had been noted by Taff (1903) but had not been mapped separately. Tomlinson (1926) referred to the basal limestone of the Trinity Formation resting on eroded Paleozoic rocks on the Mannsville anticline in northwestern Marshall County; in 1952 (p. 3–4; pls. 2–4) the term "Baum limestone" was used informally (Tomlinson and others, 1952).

The Baum limestone was studied carefully by Wayland (1954). During the same year (1954) Wayland formally recognized the Baum Limestone Member, named for beds exposed near the village of Baum, in Carter County (SW¼NE¼ sec. 35, T3S, R3E).

Wayland (1954, p. 2404–2406) described the Baum Limestone Member as comprising four intertonguing facies: (1) a basal red clay that disappears eastward; (2) a limestone conglomerate that is best developed at the northern margin of outcrop near the Arbuckle Mountains; (3) a massive, fine-grained limestone that is the thickest and most widely distributed of all the Baum units; and (4) arkosic limestone and calcareous arkose present only in the eastern outcrop near Ravia, in Johnston County. This description was repeated by Wayland and Ham (1955, p. 14).

The Baum Limestone Member is well exposed in parts of Johnston and Carter Counties. The principal localities are (1) near Ravia, where the Baum lies on Precambrian granite and folded Paleozoic rocks; (2) between Mill Creek and Oil Creek (secs. 6 and 7, T4S, R5E; secs. 1, 2, 3, 11, 12, and 13, T4S, R4E); (3) along Wolf Creek, ~3 mi west of Mannsville (secs. 8, 18, and 19, T4S, R4E; secs. 13, 14, and 24, T4S, R3E); and (4) east of Baum (sec. 36, T3S, R3E; and secs. 31 and 32, T3S, R4E). Two small exposures extend southward along Camp Creek and Turkey Creek into northwestern Marshall County.

The thickness of the Baum Limestone Member ranges from 13 ft on Turkey Creek (SW¼NW¼ sec. 35, T4S, R4E) to a maximum of 73 ft along the Washita River (NE¼NW¼ sec. 14, T4S, R4E). Wayland and Ham (1955, p. 13) listed the following thicknesses: Wolf Creek, 13–23 ft; type locality, 41.5 ft; between Mill Creek and Courtney Creek, 28–40 ft; and near Ravia, 2–24 ft. Noting that the base is usually exposed but that the top is eroded, these authors suggested a maximum thickness of 80–90 ft for the unit. The Baum disappears both eastward and westward by gradation into sand, and at places thin lentils of limestone or limestone conglomerate occur in the lower part of the Antlers sandstone facies.

According to Wayland and Ham (1955, p. 16), the only common fossils in the Baum are charophyte oogonia identified as *Atopochara trivolvis* Peck and *Clavator harrisi* Peck. Ostracodes include the fresh-water genus *Metacypris*.

Based on the abundance of algae, and the presence of fresh-water fossils, it is inferred that the Baum limestone was deposited in a lagoon or bay separated from the Antlers sea by sand bars or local uplifts of bedrock (Wayland and Ham, 1955, p. 17). Fresh water flowing into the bay evidently mixed with sea water to form a brackish water charged with calcium bicarbonate; limestone was precipitated chemically and organically (by algae) at the same time as the basal red shales were forming.

Exposures of the Baum Limestone Member in northwestern Marshall County were studied by Holtzman (1978), who recognized two facies (p. 31): (1) a limestone conglomerate containing pebbles and fragments derived from the underlying Paleozoic rocks, and (2) a massive, fine-grained, micritic limestone containing fossils (algae and ostracodes) and traces of quartz sand. The limestone is off-white, weathers yellow, and forms conspicuous, rounded boulders. Thickness ranges from 0 to 13 ft in Marshall County.

In Marshall County and elsewhere, the Baum rests unconformably on folded and faulted Paleozoic rocks. To the north in Johnston County it lies on Precambrian granite. It grades laterally and vertically into the Antlers sandstone facies. These relations are shown diagrammatically in Figure 6. The Baum limestone-conglomerate facies is shown in Figure 7.

Antlers sandstone facies.—The provisional term "Antlers" was proposed by Hill (1894, p. 303) for the arenaceous section forming the base of the Cretaceous System in Indian Territory (Oklahoma), the name being taken from exposures near the town of Antlers, in Pushmataha County, Oklahoma. Subsequently, because of uncertain stratigraphic relations, use of the term "Antlers" in Oklahoma sequentially has been (1) abandoned as a synonym of the Trinity sand or formation (Hill, 1888); (2) replaced by the term "Paluxy," by extension of observed overlap relations to the east, as on the geologic map of Oklahoma (Miser, 1954), and by projection of subsurface work; and (3) revived by workers in Oklahoma and northern Texas as valid and appropriate (F. E. Lozo, personal communication, 1977). (For details, see Barnes and others, 1966,1967; Frederickson and others, 1965; and Huffman and others, 1975, 1978.)

Following current usage in Oklahoma, the Antlers Formation as recognized herein embraces a lithostratigraphic unit composed mainly of sands, lying between the post-Paleozoic unconformity and rocks assigned to the Fredericksburg Group.

The Antlers sandstone (or sand) is exposed in a narrow belt in extreme northeastern Marshall County in T4–5S, R6E, and in a broad belt in western and southern Marshall County, where it forms the outcrop over ~100 mi^2. Its extensive belt of exposure clearly outlines the position and trend of the major tectonic features, including the Preston anticline, Kingston syncline, Mannsville–Madill–Aylesworth anticline, Cumberland syncline, and the west flank of the Cumberland anticline.

The Antlers sandstone and associated beds are

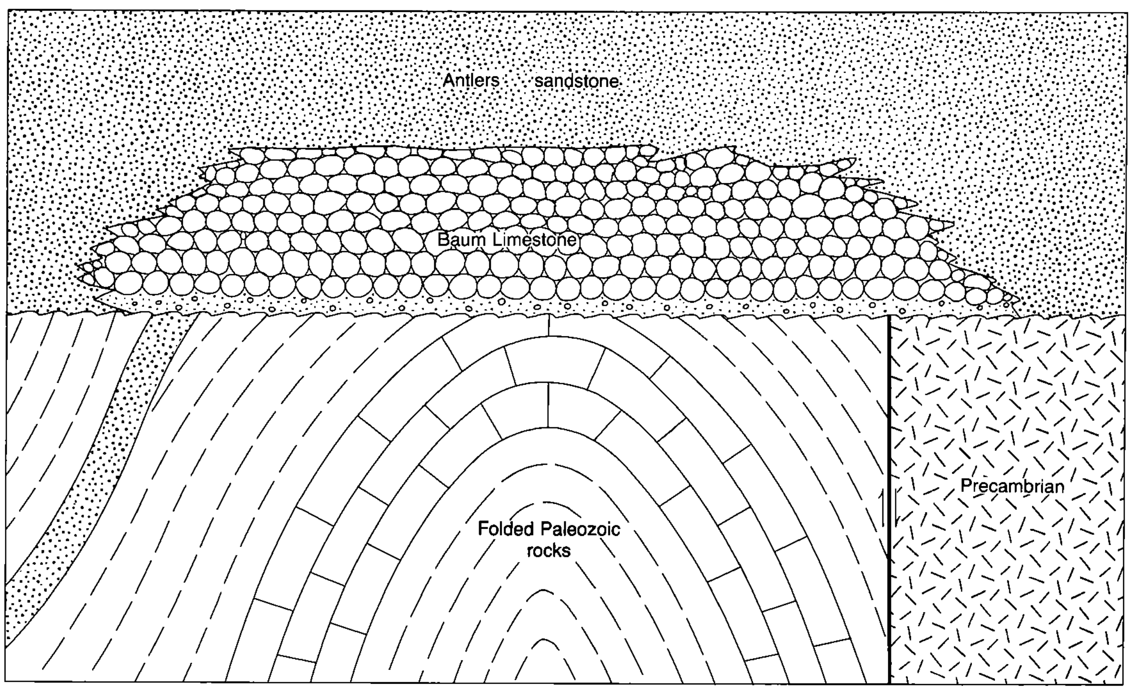

Figure 6. Relationship of the Baum Limestone Member of the Antlers Formation to underlying rocks and to the Antlers sandstone facies. Schematic only. (Redrawn from Wayland and Ham, 1955, fig. 1.)

shown in Figures 8, 9, and 10.

The Antlers Formation, exclusive of the Baum Limestone Member, consists of loosely consolidated, weakly cemented, white to yellow, cross-bedded, unfossiliferous pack-sand with subordinate amounts of clay. The sand is fine- to medium-grained, soft, and friable, some layers being better indurated than others. The clays are gray to black to dark grayish purple, slightly silty, and locally stained a reddish orange or yellow from iron oxide and other minerals that form in the weathering zone. The clays and sands offer little resistance to erosion and are exposed in deep ravines and on steep slopes developed beneath the Goodland escarpment.

The thickness of the Antlers Formation cannot be determined from surface investigations, inasmuch as a complete, measurable section is nowhere exposed. Subsurface information (Prewit, 1961, pl. 2) indicates that the formation, where capped by the Goodland Limestone, ranges from 200 ft in thickness in the northern part of the county to >600 ft at the southeast corner. According to Bullard (1926, p. 21), the thickness of the Antlers along the Red River is 400–600 ft.

A detailed study by Manley (1965) on the mineralogy of the Antlers Formation includes observations on several localities in Marshall County. Manley reported (p. 28) that the Antlers sands are composed of quartz, with accessory zircon, rutile, tourmaline, pyrite, leucoxene, and magnetite. He reported four major clay-mineral zones in the Antlers, including (1) a lower mixed illite–montmorillonite zone, probably derived from the Ouachita Mountains and developed primarily in eastern Choctaw and McCurtain Counties; (2) a transitional middle montmorillonite–illite–kaolinite zone, probably derived from the Ouachita and Arbuckle Mountains and the Arkoma basin and typically developed in Choctaw and southern Atoka and Pushmataha Counties; (3) an upper montmorillonite zone with trace amounts of illite and kaolinite, probably derived from the Anadarko basin and typically developed in Johnston, Marshall, Carter, and Love Counties; and (4) an uppermost kaolinite zone, probably derived from both the Appalachian and Wichita Mountains, developed in central McCurtain County and in scattered exposures in Marshall and Love Counties.

Sieve analyses of sands in the upper 80 ft of the Antlers in southern Marshall County by Bridges (1979, p. 17,100–103, appendix) show that the Antlers is a very fine-grained, moderately well-sorted, clayey sandstone. The mean grain size is 2.78–3.85 phi (very fine to fine sand), and the standard deviation is 0.56–0.88 phi. Silt-sized or finer grains make up 3–35% of the sand section

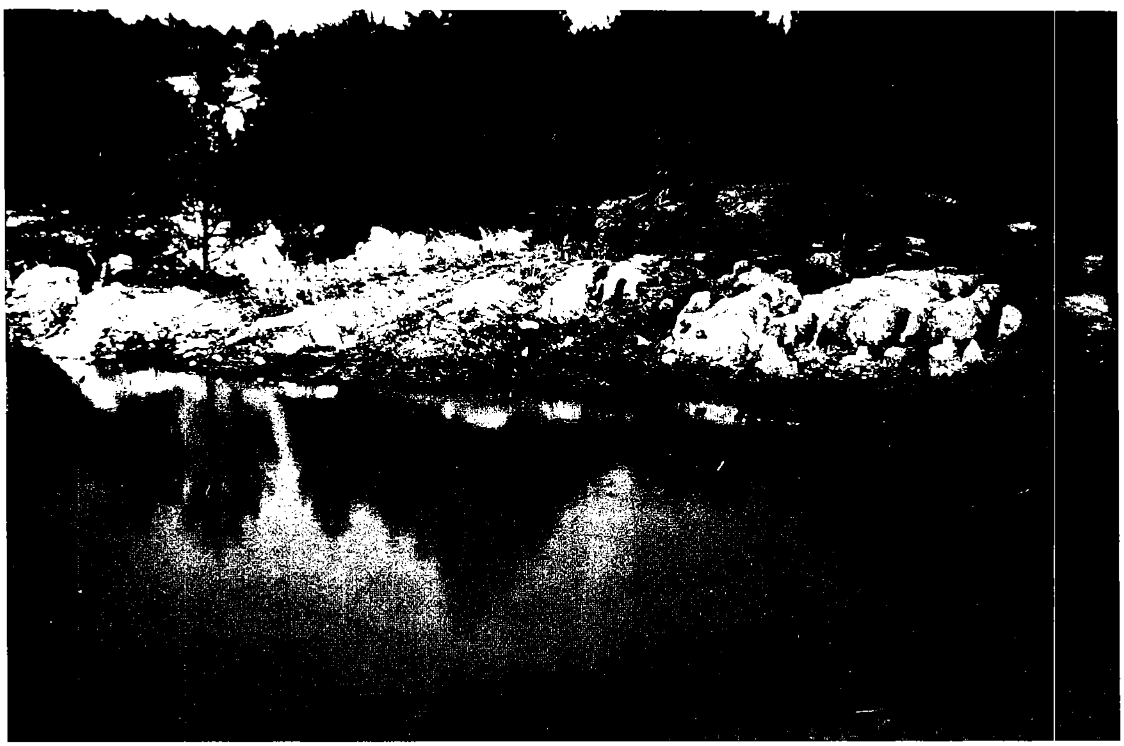

Figure 7. Baum limestone conglomerate on west bank of Lake Oteka, NW¼SE¼NE¼ sec. 34, T4S, R4E. (Photo by A.M. Holtzman.)

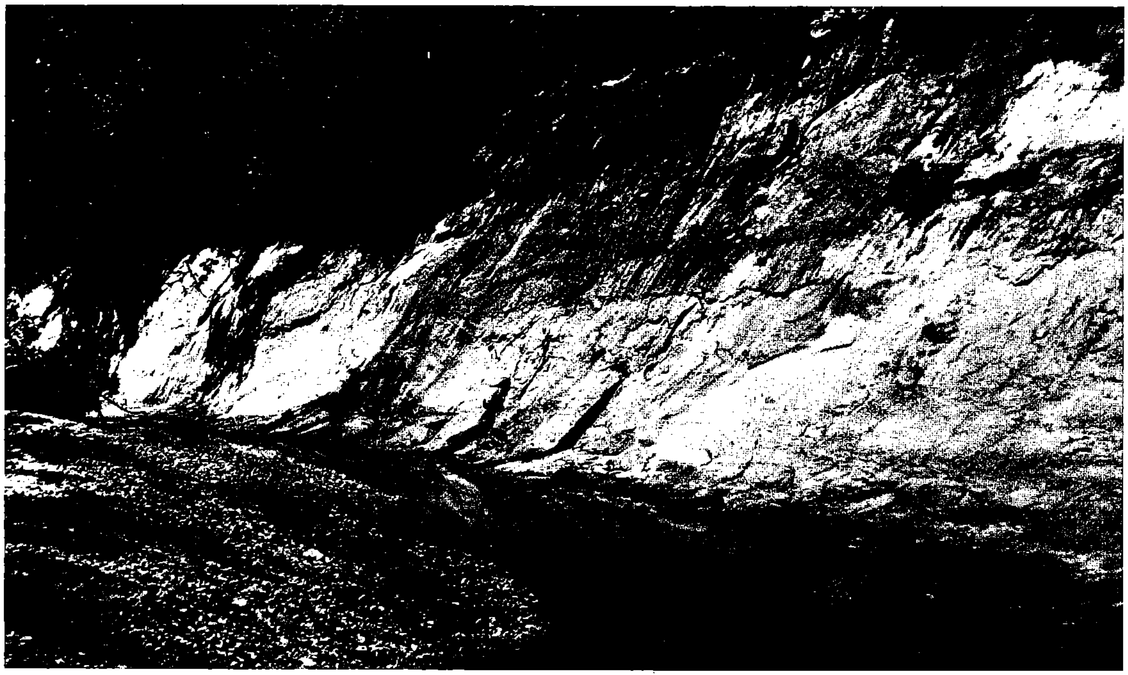

Figure 8. Antlers sandstone on Hauani Creek, NW¼NE¼NE¼ sec. 3, T6S, R4E. (Photo by A.M. Holtzman.)

Figure 9. Antlers sandstone overlain by terrace gravels along a cutbank of a tributary of Buncombe Creek, NE¼SE¼NW¼ sec. 9, T7S, R5E. (Photo by K.F. Bridges.)

and are composed mainly of angular to rounded clasts of quartz. The Antlers sands are loosely consolidated, and upon weathering they produce a clay-rich, sandy mantle. Much of the Antlers is a massive sandstone; however, small- to medium-scale cross-bedding is seen in some sections.

The Antlers Formation lies unconformably on eroded Paleozoic rocks. To the north in Johnston County, the Antlers overlaps the Paleozoic rocks and rests on the Precambrian Tishomingo Granite. The Antlers is essentially unfossiliferous, except for a few fragments of fossil wood (probably palm) collected by the senior author along the shore of Lake Texoma ~8 mi southeast of Kingston.

The basal part of the Antlers is characterized by lenses of conglomerate resting on eroded Paleozoic rock, suggesting alluvium deposited by Early Cretaceous streams. Succeeding beds of sandstone and thin, lenticular conglomerates grading upward into very fine-grained sandstones suggest transition from an alluvial to a nearshore environment. The uppermost section of sand and thin, lenticular clays probably represents beach and shoreface environments (Bridges, 1979, p. 20).

The Antlers is believed to be a transgressive, nearshore deposit formed as the Early Cretaceous sea advanced northward from Texas into southern Oklahoma, where the Antlers now overlaps the folded, faulted, and eroded Paleozoic rocks and the Precambrian. The Antlers is probably the lateral equivalent of the "Paluxy Sandstone" of previous

Figure 10. Antlers sandstone and Goodland Limestone (capping escarpment). The Walnut Clay is seen at the base of the Goodland. NE¼NE¼NE¼ sec. 9, T7S, R5E. (Photo by K.F.Bridges.)

reports and is post-Glen Rose (or De Queen) in Marshall County. The Baum Limestone Member is a local facies deposited in a brackish-water lagoon or sheltered bay. The Antlers sandstone is succeeded conformably by the Goodland Limestone (or by the Walnut Clay facies, which is present at places in the basal Goodland).

Fredericksburg Group

The term "Fredericksburg" was proposed by Hill (1887c, p. 296–299) for the middle subdivision of the Comanchean Series in honor of Ferdinand Roemer's pioneer study of the rocks and fossils in the namesake locality of Fredericksburg in central Texas. Inasmuch as the Fredericksburg is transitional between the underlying "Trinity division" and the overlying "Washita division," the limiting formations have had varied descriptions and boundaries as personal opinion, area of investigation, and practicality of usage have dictated (F. E. Lozo, personal communication, 1977). In Oklahoma and Texas the commonly accepted formations of the Fredericksburg Group, in ascending order, are the Walnut Clay, Goodland Limestone, and Kiamichi Formation. The bases for differing classifications have been discussed by Adkins (1933), Young (1957), and Lozo (1959).

Walnut Clay.—The Walnut Clay was named by Hill (1891, p. 504,512) for yellow, laminated clay marls containing abundant "*Exogyra texana*" [= *Ceratostreon texanum* (Roemer)], overlying the Paluxy sand and underlying the Comanche Peak Limestone. The type section is near Walnut Springs, Bosque County, Texas.

The Walnut Clay is poorly developed north of the Red River in Oklahoma. Bullard (1926, p. 26), Frederickson and others (1965, p. 18–21), Ganser (1968, p. 13), and Hart (1970, p. 26–30) recognized a thin Walnut Clay in Marshall, Love, Johnston, and Bryan Counties and concluded that it grades upward into the Goodland Limestone. Holtzman (1978), working in northwestern Marshall County, noted that the lower part of the Goodland contains beds of yellow, marly limestone that may be a facies of the Walnut Clay but is too poorly developed to map separately. Bridges (1979, p. 22) recognized 2.5–11 ft of Walnut Clay in southern Marshall County containing *Ceratostreon texanum* and *Texigryphaea mucronata*. Hart (1970, p. 26–31) described three localities in northwestern Bryan County where the Walnut Clay was tentatively identified. From these localities he collected a fauna including *Ceratostreon texanum* (Roemer), *Exogyra plexa* Cragin, *Isocardia medialis* (Conrad), *Pecten (Neithea) irregularis* (Böse), *Pecten (Neithea) subalpinus* (Böse), *Tapes* *aldamensis* (Böse), *Homomya* sp. or *Tapes* sp., *Texigryphaea mucronata* (Gabb), *Barbatia subquadrata* Perkins, *Protocardia* sp., *Cyprimeria texana* (Roemer), *Turritella seriatum-granulata* (Roemer), *Aporrhais tarrantensis* Stanton, *Enallaster mexicanus* Cotteau, and *Hemiaster whitei* (Clark).

Bridges (1979, p. 25), working in southern Marshall County, collected and identified a fauna consisting of *Ceratostreon texanum* (Roemer), *Homomya* sp., *Protocardia texana* (Conrad), *Rastellum (Arctostrea) crenulimargo* (Roemer), *Texigryphaea mucronata* (Gabb), *T. navia* (Hall), *Turritella* sp., and *Tylostoma elevatum* (Shumard).

The best exposures of the Walnut Clay in southern Marshall County include west-facing scarps in the SE¼NW¼ sec. 26, T7S, R4E, and in the NW¼NE¼ sec. 31, T6S, R5E. Other exposures were observed in the NE¼NE¼ sec. 9, T7S, R5E (Fig. 9), and along the shores of Lake Texoma in the SW¼SW¼ sec. 20, T7S, R6E (Bridges, 1979, p. 21–22).

The Walnut Clay is probably time-transgressive and is the lateral equivalent of the lower part of the Comanche Peak Limestone. In southern Oklahoma the yellow, fossiliferous marlstones seem to be more closely related to the Goodland Limestone than to the underlying Antlers Formation; however, beds of sandstone similar to the sands in the Antlers have been observed in the Walnut Clay at places. The Walnut Clay is believed to be transitional from the Antlers into the Goodland Limestone. It appears to represent a gradation from nearshore terrigenous deposition to shallow-water marine deposition behind an advancing shoreline (Bridges, 1979, p. 24).

Goodland Limestone.—The Goodland Limestone was named by Hill (1891, p. 514) for exposures near the former site of Goodland (now Good Station), Choctaw County, Oklahoma. Good Station is near the center of sec. 9, T6S, R17E, ~2.5 mi north of Hugo. Excellent exposures are found in several limestone quarries ~1.5 mi northeast of Good Station. (It is reported that Goodland Presbyterian Mission, now at the northeast corner of sec. 6, T7S, R17E, was moved from the original site.)

Hill (1894, p. 303–304) described the Goodland as a "hard, pure white, crystalline limestone" capping the Walnut Clay. He concluded that the Goodland is a northward continuation of the Edwards and Comanche Peak Limestones of Texas. Taff (1902,1903) included the Walnut Clay in the Goodland, and in 1905 (p. 309) he described the Goodland as equivalent to the Edwards and Comanche Peak Limestones. Recent workers, including Lozo (1959), Young (1959), and Blau (1961), concurred with this assignment. Blau (p. 3–11) gave a detailed account of the history of nomenclature of the Goodland.

The Goodland Limestone is 15–25 ft thick in Marshall County. It is resistant to erosion and typically caps the escarpments formed on the underlying Antlers Formation. It crops out in a narrow, continuous band through much of the county, following a sinuous pattern around the hillsides and on the flanks of the major structures, including the Cumberland syncline, Madill and Oakland anticlines, Kingston syncline, and Preston anticline. It forms a resistant cap rock above the Antlers, resulting in high bluffs that overlook valleys cut in the less-resistant Antlers sandstone. Large outliers of Goodland cap the uplands in the northwestern part of the county, and numerous small outliers are present in the southern part.

The Goodland is a white to gray, relatively pure, massively bedded, dense to finely crystalline, biomicritic limestone. It is generally fossiliferous, but microcrystalline calcite makes up most of the allochems, thus making the Goodland a typical wackestone. The lower part of the formation tends to be nodular and weathers gray to buff. The upper part is massive and white and tends to exfoliate into thin, curved plates that litter the surfaces of exposures. The uppermost beds tend to weather with a distinct honeycombed appearance, owing to dissolution of sparry calcite precipitated in voids formerly occupied by fossils. Typical exposures are shown in Figures 11, 12, and 13.

Chemical analyses indicate that the Goodland Limestone in southern Oklahoma is a nearly pure limestone, with an average calcium carbonate content of 97.00%. Calcium carbonate ranges from 91.24 to 98.45%; magnesium carbonate from 0.68 to 1.21%; and silica, the major contaminant, from 0.25 to 6.16%.

Stratigraphic relations of the Goodland with the underlying Antlers are conjectural. Jeffries (1965), Dalton (1966), Duarte-Vivas (1968), and Alfonsi (1968) postulated disconformable relations in Choctaw County, based on the absence of the Walnut Clay and a slightly undulating lower Goodland contact. Bullard (1926, p. 27) noted one small exposure where a slight disconformity appears to be present. Blau (1961), Frederickson and others (1965), Huffman and others (1975,1978), Holtzman (1978), and Bridges (1979) maintained that the Antlers–Goodland boundary is transitional where the Walnut Clay is present and that no unconformity is present where the Goodland rests directly on the Antlers. The contact with the overlying Kiamichi Formation is abrupt and slightly undulating locally, but there seems to be no indication of emergence and unconformity.

The Goodland Limestone is abundantly fossiliferous, especially in basal beds where marly clay layers are present. Fossils collected and identified by Holtzman (1978, p. 36) include *Ceratostreon texanum* (Roemer), *Cyprimeria texana* Roemer, *Pecten (Neithea) irregularis* (Böse), *Pecten*

Figure 11. Goodland Limestone on east bank of Hauani Creek ~25 yd south of State Highway 199, NE¼NW¼NW¼ sec. 27, T5S, R4E, overlying Antlers sandstone. (Photo by A.M. Holtzman.)

Figure 12. Goodland Limestone and overlying Kiamichi Formation in abandoned quarry (Smith Quarry), south of State Highway 32, NE¼NW¼ sec. 33, T6S, R5E. (Photo by K.F. Bridges.)

Figure 13. Weathered upper Goodland Limestone in contact with overlying shales of the Kiamichi Formation in abandoned quarry south of State Highway 32, NE¼NE¼ sec. 33, T6S, R5E. (Photo by K.F. Bridges.)

(Neithea) occidentalis Conrad, *Pecten (Neithea) texanus* Roemer, *Protocardia texana* (Conrad), *Texigryphaea mucronata* (Gabb), *Turritella* sp., *Tylostoma regina* Cragin, *Oxytropidoceras acutocarinatum* (Shumard), *Oxytropidoceras* sp. aff. *O. chihauhuense* (Böse), and *Enallaster texanus* (Roemer).

Fossils reported by Bridges (1979, p. 29) from southern Marshall County include *Exogyra plexa* Cragin, *Pecten (Neithea) irregularis* (Böse), *Pecten (Neithea) subalpinus* (Böse), *Protocardia* sp., *Texigryphaea mucronata* (Gabb), *Pleurotomaria* sp., *Turritella seriatum-granulata* (Roemer), *Tylostoma elevatum* (Shumard), and *Oxytropidoceras acutocarinatum* (Shumard).

The abundance of *Oxytropidoceras* led Bridges (1979, p. 28) to postulate that the Goodland was deposited in the epineritic zone (water depth <120 ft), following Scott (1940).

Kiamichi Formation.—The name "Kiamitia" (= Kiamichi) was applied by Hill (1891, p. 504,515) to exposures on the plains of the Kiamichi River near Fort Towson, Choctaw County, Oklahoma. Hill originally assigned the Kiamichi to the Washita Group, regarding the Kiamichi as the initial deposit of the Washita depositional cycle. Taff and Leverett (1893, p. 258–262) presented paleontological evidence that supported assignment of the Kiamichi to the Fredericksburg Group. There is still no general agreement as to its proper assignment, although the U.S. Geological Survey (Imlay, 1944, chart 3) placed it in the Fredericksburg Group, as did Wilmarth (1938, p. 1091).

The Kiamichi Formation crops out along a narrow, sinuous, continuous band (Pl. 1). It is well exposed in a NE-trending belt north of Willis in T7N, R4–5E, along the west flank of the Preston anticline. The Kiamichi crops out on the slopes immediately above the Goodland escarpment (Figs. 13,14).

The Kiamichi Formation maintains a relatively uniform thickness along the belt of outcrop in Marshall County. Ganser (1968, p. 16) reported a maximum thickness of 40 ft in northeastern Marshall County. Bullard (1926, p. 31) measured a 36-ft section along Brier Creek, west of Kingston. Holtzman (1978, p. 37) reported thicknesses of 32 and 37 ft in parts of northwestern Marshall County and measured 37 ft along a tributary to Glasses Creek in sec. 6, T6S, R6E. Bridges (1979, p. 30) reported a thickness of 38 ft in a quarry in the NE¼NW¼ sec. 33, T6S, R5E.

The Kiamichi Formation is represented primarily by a clay-shale sequence with one or two beds of limestone near the top. The clayey shale ranges from dark gray or black to brown where fresh, and from brownish gray to gray where weathered. A thin basal bed of yellow limestone is present in some sections. Succeeding beds are composed of platy or laminated clay shale with thin beds of siltstone in the lower part. A thin, buff-colored, silty limestone was observed at one locality ~7 ft above the base. In another area a bed of thin, ripple-marked, brown, fine-grained, calcareous sandstone is near the top. The upper part of the Kiamichi is characterized by two or more thin beds of fossiliferous limestone separated by several inches of shale. The limestones are gray to brown, weather yellow, and are mostly a coquina of *Texigryphaea navia* (Hall). These beds range from 0.5–1.5 ft in thickness. Erosion and undercutting of the shell beds cause the rock to break into large slabs that are tilted at various angles, giving rise to so-called "edge rock." These slabs make it relatively easy for the geologist to locate the top of the Kiamichi Formation.

The Kiamichi weathers to form a heavy black soil that supports vegetation. The steeper slopes support a growth of trees, whereas the upland surfaces are grass-covered or planted in cotton or other crops. Where exposed on a hillside, the formation is typically grass-covered. The upper

Figure 14. Kiamichi Formation on tributary of Glasses Creek, NW¼NE¼NW¼ sec. 6, T5S, R6E. Note bed of laminated sandstone near center of picture. (Photo by A.M. Holtzman.)

shell bed is usually marked by a tree line, and prickly pear cactus grows on its residual soil.

The contact of the Kiamichi and the Goodland is marked by a sharp change in lithology. The change to a dark shale suggests a slight regression of the sea accompanied by stagnation, as in a tidal marsh. The shell beds at the top suggest deposition in a shallow-water marine carbonate environment.

The contact between the Goodland and the Kiamichi appears to be conformable in Marshall County. The Duck Creek Member of the Caddo Formation conformably overlies the Kiamichi. Fossils are not abundant in the shale of the Kiamichi. The shell beds are composed primarily of *Texigryphaea navia* (Hall). *Lopha subovata* (Shumard), previously assigned to *Ostrea subovata* Shumard, is also common.

Washita Group

The Washita Group, uppermost subdivision of the Comanchean Series, was named and described by Hill (1887b, p. 298) from exposures near old Fort Washita, T5S, R7E, Bryan County, Oklahoma. In Bryan and Marshall Counties the Washita Group comprises the Caddo Formation, Bokchito Formation, Bennington Limestone, and Grayson Marlstone. A comparison of the Marshall County divisions with those of north-central Texas is shown in Table 7.

Caddo Formation.—The Caddo Formation was named by Taff (1902, p. 6) for exposures of marl, shale, and limestone in the vicinity of Caddo, Bryan County, Oklahoma. Hill (1901, p. 504,516) had previously named the Duck Creek and Fort Worth for beds of comparable age in northern Texas. The Duck Creek includes ~100 ft of limestone and shale exposed along Duck Creek near Denison, Grayson County, Texas, and the Fort Worth includes ~32 ft of limestone and shale exposed near Fort Worth, Texas.

Taff assigned a thickness of 150 ft to the Caddo Formation in Bryan County. Hart (1970, p. 53), by careful calculations, estimated a thickness of 166 ft for the Caddo along a line from sec. 10, T5S, R9E, to sec. 9, T6S, R9E. Near the town of Caddo he assigned a thickness of 131 ft for the Duck Creek Member and 29 ft for the Fort Worth Member. These measurements are in accord with those of Slocki (1967, p. 189,194) for north Texas, and with those of Bullard (1925, p. 34; 1926, p. 33–34) for Love and Marshall Counties, Oklahoma.

In Choctaw and Bryan Counties the Caddo was mapped as a single unit, inasmuch as no recognizable boundary could be traced across the area (Huffman and others, 1975,1978). In Marshall County, separation of the Caddo into two map-

TABLE 7.—GEOGRAPHIC VARIATION IN THE WASHITA GROUP

North-central Texas	Marshall County, Oklahoma
Buda Limestone	(absent)
Grayson Shale*	Grayson Marlstone*
Main Street Limestone	Bennington Limestone
	Bokchito Formation**
Pawpaw Formation	Pawpaw Sandstone Member
"Quarry" limestone	McNutt Limestone Member
Weno Clay	Weno Clay Member**
"*Ostrea carinata*" bed	Soper Limestone Member
Denton Clay	Denton Clay Member**
	Caddo Formation
Fort Worth Limestone	Fort Worth Member
Duck Creek Limestone	Duck Creek Member

*The Grayson Marlstone has been assigned to the Cenomanian and is considered Upper Cretaceous by some stratigraphers (R. O. Fay, Oklahoma Geological Survey, personal communication, June 1983).
**Emended.

pable units, the Duck Creek and the Fort Worth, has been attempted with limited success.

Duck Creek Member.—The Duck Creek was named by Hill (1891, p. 516) for beds composed of white chalky limestone and alternating chalky marls, ~100 ft thick, exposed along Duck Creek, near Denison, Texas. In Oklahoma the Duck Creek is considered a member of the Caddo Formation.

The Duck Creek Member forms a broad outcrop belt ranging from 1 to several miles in width. The Duck Creek crops out over ~18 mi^2 in the Cumberland syncline and in >45 mi^2 in the Kingston syncline. The outcrop pattern follows the structure of the major tectonic elements, occupying the flanks of the Cumberland and Kingston synclines and crossing the nose of the SE-plunging Oakland and Madill anticlines.

The Duck Creek Member consists of thin, silty, argillaceous limestone alternating with beds of blue-gray shale and clay (Figs. 15,16). It can be divided into two parts by the relative abundance of limestone interbeds. In the lower part, alternating beds of shale and limestone are 8–14 in. thick through a 30-ft section. Near the top of this section is a limestone bed containing large ammonites identified as *Eopachydiscus brazoensis* (Shumard) and *Idiohamites fremonti* (Marcou). Immediately below this zone are abundant fossils. Above the fossiliferous beds, the upper part of the Duck Creek consists of 50–60 ft of clay shale with a few thin interbeds of limestone containing relatively few fossils, except for a thin bed with ammonites near the top. The Duck Creek is ~110 ft thick, which is in agreement with the 100-ft thickness recognized by Stephenson (1918, p. 139) near Denison, Texas, and the 117-ft thickness reported by Hart (1970, p. 53) in Cumberland Cut, western Bryan County.

Insoluble residues from limestone beds in the lower part of the Duck Creek indicate (Bridges, 1979, p. 35) that the beds are 90–96% calcium carbonate, with a residue of clay minerals and silt-sized quartz grains. Limestones in the upper part of the Duck Creek average 81% calcium carbonate, with a residue of silt-sized detritus.

The lower part of the Duck Creek Member is abundantly fossiliferous, whereas the upper part is almost devoid of fossils. Forms reported by Ganser (1968, p. 21–22), Holtzman (1978, p. 45), and Bridges (1979, p. 39) include the following:

Brachiopoda
  Articulata
    Kingena wacoensis (Roemer)
    Terebratulina guadalupae Roemer
Mollusca
  Pelecypoda
    Ceratostreon texanum (Roemer)
    C. plexa (Hill)
    Inoceramus comancheanus Cragin
    Lopha subovata (Shumard)
    Pecten (Neithea) subalpinus (Böse)
    P. (Neithea) texanus (Roemer)

Plicatula incongrua Böse
Protocardia texana (Conrad)
P. multistriata (Shumard)
Texigryphaea navia (Hall)
T. pitcheri (Morton)
T. washitaensis (Hill)
Gastropoda
Turritella sp.
Cephalopoda
Eopachydiscus brazoensis (Shumard)
Drakeoceras kummeli Young
Idiohamites comancheanus (Adkins and Winton)
I. fremonti (Marcou)
I. nokonis (Adkins and Winton)
Mortoniceras leonensis (Conrad)
M. smedalae Young
M. trinodosum (Böse)
Echinodermata
Echinoidea
Hemiaster (Epiaster) whitei (Clark)
H. (Macraster) elegans (Shumard)
H. (Macraster) texanus (Roemer)

Fort Worth Member.—The Fort Worth Member crops out in the Cumberland syncline, where it occupies an area of ~25 mi^2. It forms a belt 1–2 mi wide on both flanks of the Kingston syncline and forms the cap rock on a prominent ridge in secs. 7, 8, 9, 15, and 16, T6S, R6E.

The Fort Worth consists of alternating beds of limestone and clayey shale. The limestone is gray

Figure 15. Lower part of the Duck Creek Member of the Caddo Formation overlying the shell beds of the Kiamichi Formation, Buncombe Creek, NW¼NW¼NE¼ sec. 28, T6S, R5E. (Photo by A.M. Holtzman.)

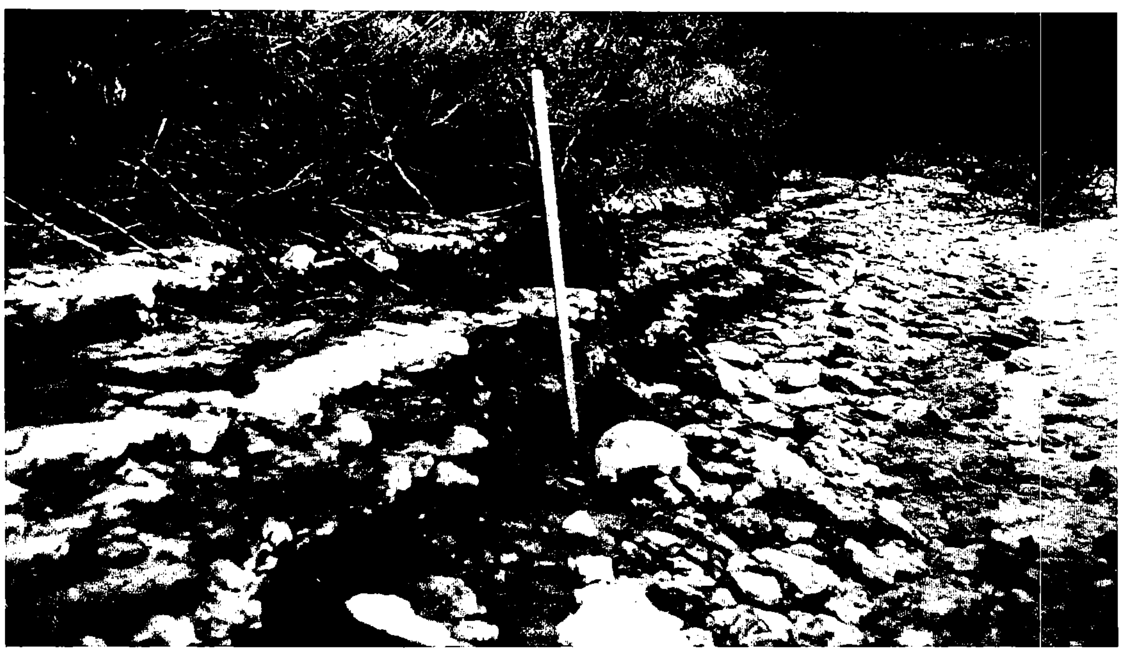

Figure 16. Gray clays and nodular marlstones in the lower Duck Creek Member of the Caddo Formation along shore of Lake Texoma, NW¼NW¼ sec. 27, T7S, R6E. (Photo by K.F. Bridges.)

to white when fresh and weathers cream. The shales are gray to bluish gray.

Bullard (1926, p. 34) subdivided the Fort Worth into three units: a lower unit (10–15 ft) consisting of alternating beds of yellowish-white limestone and grayish to blue shaly clay, a middle unit (10–15 ft) consisting of shale, and an upper unit of limestones separated by thin beds of shale. These three units are recognizable and useful in field work.

The lower unit consists of light-gray, slightly fossiliferous beds of limestone 1–2 ft in thickness. The clayey beds average 10–15 in. in thickness and are various shades of gray. The middle unit is composed predominantly of calcareous shale devoid of fossils. The upper unit consists of 10- to 12-in. beds of white to cream-colored limestone separated by thin layers of shale; fossils are abundant in the beds of limestone (Figs. 17, 18).

Bullard (1926, p. 34) reported an average thickness of 40 ft for the Fort Worth in Marshall County; Ganser (1968, p. 20) reported 40–50 ft in northeastern Marshall County; Holtzman (1978, p. 46) noted a thickness of 40–50 ft in northwestern Marshall County; and Bridges (1979, p. 40) reported 38 ft in a well in sec. 13, T7S, R6E.

Insoluble residues from the upper part of the Fort Worth indicate that the limestones average >90% calcium carbonate, with a residue of silt-

Figure 17. Limestone beds in the lower Fort Worth Member, NW¼SW¼SW¼ sec. 18, T6S, R6E. (Photo by A.M. Holtzman.)

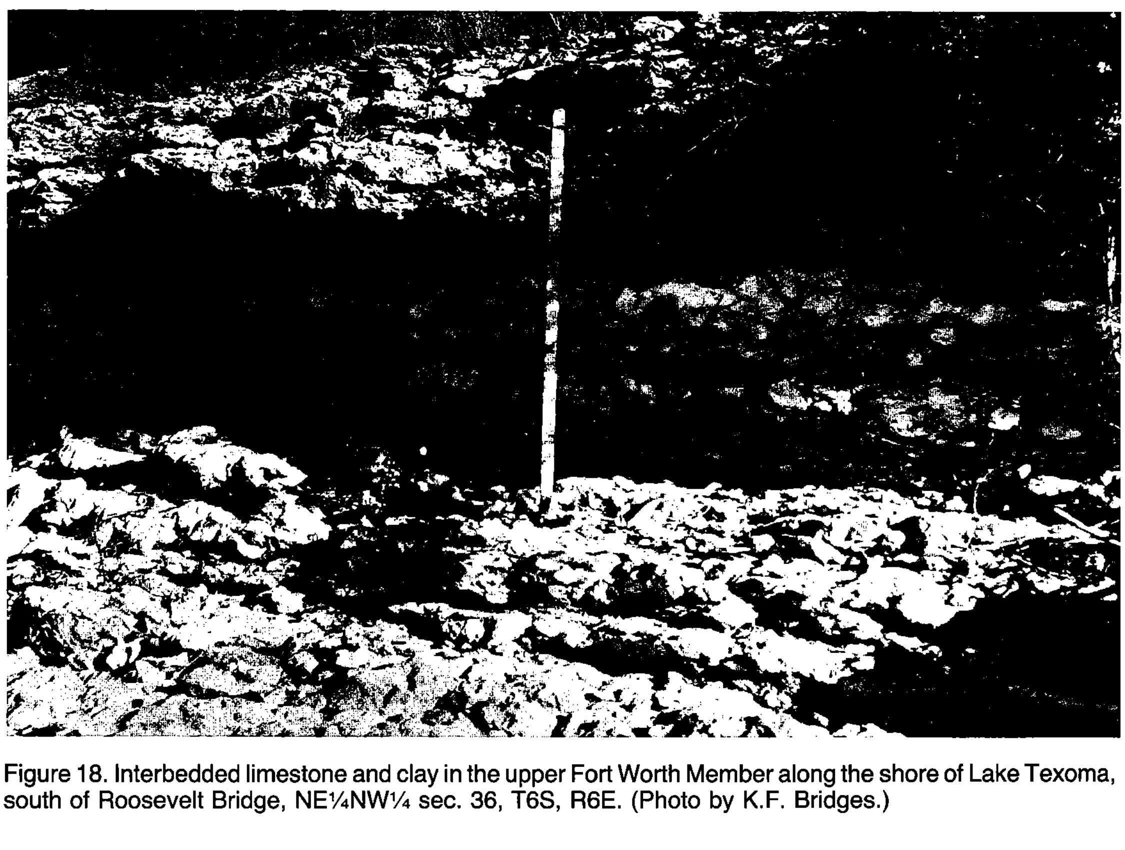

Figure 18. Interbedded limestone and clay in the upper Fort Worth Member along the shore of Lake Texoma, south of Roosevelt Bridge, NE¼NW¼ sec. 36, T6S, R6E. (Photo by K.F. Bridges.)

sized detritus and clay minerals (Bridges, 1979, p. 42–43).

The lower beds of the Fort Worth are characterized by branching structures ("fucoids") that have been interpreted by Currier (1968, p. 15) as possible marine algae or seaweeds and by Perkins (1960, p. 26) as fillings of burrows made by marine invertebrates. Abundant cephalopods, especially *Mortoniceras*, suggest that the Fort Worth was deposited in shallow marine water <120 ft deep (Bridges, 1979, p. 43).

The Fort Worth Member supports relatively steep slopes and broad expanses of flat land, owing to the resistant layers in the upper part. Vegetation growing on its surficial soils includes grasses, shrubs, and bois d'arc trees. The Fort Worth Member conformably overlies the Duck Creek Member of the Caddo Formation and is overlain conformably by the Denton Clay Member of the Bokchito Formation.

The Fort Worth Member is abundantly fossiliferous. Ganser (1968, p. 21–22), Holtzman (1978, p. 49–50), and Bridges (1979, p. 44) reported these forms:

- Mollusca
  - Pelecypoda
    - *Aetostreon walkeri* (White)
    - *Arctostrea carinata* (Lamarck)
    - *Cyprimeria* sp. aff. *C. texana* (Roemer)
    - *Lima wacoensis* Roemer
    - *L. wacoensis* var. *quadrangularis* Stanton
    - *Lopha subovata* (Shumard)
    - *Pecten (Neithea) bellatus* (Cragin)
    - *P. (Neithea) subalpinus* (Böse)
    - *P. (Neithea) texanus* Roemer
    - *P. (Neithea) wrighti* (Shumard)
    - *Plicatula dentonensis* Cragin
    - *P. incongrua* Conrad
    - *Protocardia texana* (Conrad)
    - *Texigryphaea washitaensis* (Hill)
    - *T. pitcheri* (Morton)
  - Gastropoda
    - *Turritella* sp.
  - Cephalopoda
    - *Drakeoceras maximum* (Lasswitz)
    - *Mortoniceras leonensis* (Conrad)
- Echinodermata
  - Echinoidea
    - *Hemiaster (Macraster) comanchei* Clark
    - *H. (Epiaster) whitei* (Clark)
    - *H. (Macraster) elegans* (Shumard)
    - *Holaster simplex* Shumard
- Brachiopoda
  - Articulata
    - *Terebratulina* sp.

Bokchito Formation.—The Bokchito was named by Taff (1902, p. 6) for a sequence of ~160 ft of clay, sandy clay, clay-ironstone concretions, arenaceous limestone, and fossiliferous limestone exposed along Bokchito Creek, near the town of Bokchito, Bryan County, Oklahoma. Bullard (1925,1926) recognized three members, in ascending order the Denton, Weno, and Pawpaw. Above the Denton is a persistent limestone bed commonly referred to as the "*Ostrea carinata*" bed; this reliable marker was named the Soper Limestone Member by Huffman and others (1975) for exposures near the town of Soper, Choctaw County, Oklahoma. A persistent, useful marker at the top of the Weno, an arenaceous limestone formerly referred to as the "quarry lime" by workers in Texas and Oklahoma, was named the McNutt Limestone Member by Huffman and others (1975); it was named from exposures on the McNutt Ranch, southeast of Soper. The stratigraphy and nomenclature of the Bokchito Formation and its members have been discussed by Huffman (1977), and Huffman and others (1978). The Bokchito Formation is a good example of a "genetic sequence of strata" as defined by Busch (1971), it is bounded above and below by major limestone units and consists of three terrigenous members separated by thin, persistent limestone markers. The Denton, Weno, and Pawpaw are "genetic increments of strata" deposited in the marginal marine zone in littoral and deltaic environments.

Denton Clay Member.—The Denton Clay was named by Taff and Leverett (1893, p. 272) from exposures along Denton Creek near the city of Denton, Texas. At the type locality, the Denton consists of 40 ft of bluish clay shale and marl capped by a thin, resistant limestone previously referred to as the "*Ostrea carinata*" bed (= Soper Limestone).

The Denton Clay Member forms a nearly continuous belt approximately half a mile wide around the flanks of the Cumberland syncline in northeastern Marshall County (T5–6S, R6–7E). A second belt of outcrop is in the Kingston syncline in southeastern Marshall County, where a belt nearly half a mile wide can be traced along the northeastern and southwestern flanks of the syncline. The Denton also is well developed in the Catfish Bay area south of Lake Texoma Lodge. Excellent exposures are in road cuts 2 mi north of Kingston on U.S. Highway 70 and at the west end of Roosevelt Bridge north of Lake Texoma Lodge in sec. 36, T6S, R6E.

The Denton Clay Member consists of blue-gray to brownish-yellow clay shale with thin beds of siltstone and sandstone. It is overlain conformably by the fossiliferous Soper Limestone Member. The thickness of the Denton in Marshall County is 45–55 ft (Bullard, 1926, p. 36). A 50-ft thickness was measured by Bridges (1979, p. 45) in southeastern Marshall County.

The lower part of the Denton consists of blue-gray, calcareous clay shale with thin beds of siltstone. Overlying beds become increasingly sandy, and a prominent bed of hard, thinly laminated, brown, ripple-marked sandstone or siltstone occurs 30–35 ft above the base. This resistant bed serves as a marker and can be traced around the northwestern end of the Kingston syncline. The upper part of the Denton consists of blue-gray to yellow, silty and sandy clay shale. In places, two or three thin beds of calcareous siltstone are interbedded with the shale. The siltstones are reddish brown to maroon, well sorted, and slightly micaceous. Thin beds of fossiliferous marlstone are present near the top of the Denton; these seem to grade upward into the Soper Limestone Member.

The Denton Clay Member is sparingly fossiliferous, and most of the fossils associated with the Denton are in the marlstones near the top of the member, directly below the Soper Limestone. Forms include *Pecten (Neithea) subalpinus* (Böse), *Pecten (Neithea) texanus* Roemer, *Plicatula* sp., *Protocardia* sp., *Arctostrea carinata* (Lamarck), *Lopha quadriplicata* (Shumard), *Texigryphaea washitaensis* (Hill), and *Trigonia clavigera* Cragin.

The Denton Clay Member is conformable with the underlying Fort Worth Member. The contact is sharp and clearly defined. The Denton grades upward into the Soper Limestone Member with no evidence of unconformity. The Denton is believed to have been deposited in a nearshore marine environment, possibly in the neritic zone. The change in type of sedimentation from the carbonate environment of the Fort Worth limestone to the shale environment of the Denton reflects a sudden influx of fine-grained clastics. Interbedded siltstones and shell beds indicate fluctuation of land–sea relations, and the thin, fossiliferous marlstones near the top suggest a rise of sea level during latest Denton deposition.

Soper Limestone Member.—The Soper Limestone was named by Huffman and others (1975, p. 16–17) from an exposure in a railroad cut 1.5 mi east of Soper, Choctaw County, Oklahoma; there it consists of a single bed of well-indurated limestone ("*Ostrea carinata*" bed) that conformably overlies 2–3 ft of yellow, fossiliferous marlstone. These marlstone beds were excluded from the original definition of the Soper Limestone because they are not everywhere present in exposures, and where present they typically are poorly exposed. The hard, compact, resistant Soper Limestone is a persistent marker across several counties in southern Oklahoma and is believed to approximate a time plane. Owing to its resistance, it forms a ledge across streams and along road cuts and hillsides (Fig. 19).

The Soper Limestone can be traced almost continuously from a point in sec. 7, T6S, R7E,

Figure 19. Denton Clay Member of the Bokchito Formation underlying the Soper Limestone Member (hammer rests on Soper) on hillside above Catfish Bay, NE¼SW¼ sec. 36, T6S, R6E. Note marly beds immediately below Soper. (Photo by K.F. Bridges.)

northwestward into sec. 23, T5S, R6E, where it passes beneath alluvial cover in the Cumberland syncline. It also can be traced from a point in sec. 36, T6S, R6E, northwestward to the vicinity of Kingston, thence southeastward along the southwest limb of the Kingston syncline to the edge of Lake Texoma, in sec. 23, T7S, R6E. The thickness in Marshall County is 6–18 in., averaging 1 ft.

The Soper Limestone is fossiliferous and has yielded a fauna comprising *Pecten (Neithea) texanus* Roemer, *Arctostrea carinata* (Lamarck), *Lopha quadriplicata* (Shumard), *Texigryphaea washitaensis* (Hill), and *Trigonia clavigera* Cragin.

The contact of the Soper with the overlying Weno Clay Member is conformable but abrupt.

Weno Clay Member.—The Weno Clay was named by Hill (1901, p. 121) from exposures near the village of Weno (now abandoned), northeast of Denison, Grayson County, Texas. The type Weno was described as consisting of 92 ft of ferruginous, brown clayey marl and marly clay. The "quarry" limestone, a massive, arenaceous limestone that oxidizes yellow, was included in the Weno by Hill but was later placed in the lower part of the Pawpaw Sandstone Member by Stephenson (1918, p. 142). Huffman and others (1975, p. 18) renamed the "quarry" limestone the McNutt Limestone Member on the basis of its excellent development and lateral persistence throughout Choctaw County, Oklahoma, taking the name from the McNutt Ranch south of Soper. The Weno is emended (restricted) to include the shale and sand between the Soper Limestone and the McNutt Limestone in southern Oklahoma.

The Weno Clay is limited in distribution in Marshall County to two small areas. It crops out over ~7 mi^2 along the axis of the Cumberland syncline in T5–6S, R6–7E, passing beneath alluvial cover on the northeast. It forms the surface rock in an area of ~15 mi^2 in the Kingston syncline, especially in T6–7S, R6E.

The Weno is 60–90 ft thick. Holtzman (1978, p. 55) reported a thickness of 60 ft near Kingston, and Ganser (1968, p. 28) reported a thickness of 90 ft in an exposure 3 mi east of Kingston. The Weno thickens eastward to ~100 ft in western Bryan County, but thins to <50 ft in Choctaw County.

The lower part of the Weno consists of 45–50 ft of greenish-gray clay with thin interbeds of brown, ferruginous sandstone and siltstone (Fig. 20). The beds of sandstone are friable and weather yellow-orange. Clay-ironstone concretions are common, and weathered slopes are littered with slabby, broken fragments of ferruginous concretions and

Figure 20. Lower Weno Clay Member of the Bokchito Formation exposed along Rooster Creek, SW¼SW¼ sec. 8, T7S, R6E. Base of exposure (not pictured) is Soper Limestone Member. (Photo by K.F. Bridges.)

pseudomorphs of limonite or goethite after pyrite.

The upper part of the Weno consists of ~20 ft of medium- to thick-bedded, ripple-marked, ferruginous, micaceous sandstone and interbedded clay shale overlain by 20 ft of clay shales and massively bedded, yellow to orange, fine-grained, friable, fossiliferous, micaceous sandstone. Complex changes of facies in this part of the section are common, and uninterrupted units of sandstone or clay as thick as 17 ft occur in the sequence below the McNutt Limestone.

Overlying, interfingering with, or locally channeling into the clay and sand of the upper Weno are beds of arenaceous limestone ranging in thickness from a few feet to ~20 ft. These beds are discussed under the McNutt Limestone Member.

The Weno conformably overlies the Denton–Soper sequence and is succeeded conformably by the McNutt Limestone Member, with which it intergrades at places. Fossils are rare in the Weno, although some beds carry molds and casts of *Protocardia* sp., *Turritella* sp., *Nucula* sp., and *Corbula* sp.

Bridges (1979, p. 54), after a careful study of the Weno Member, concluded that the Weno sediments are part of a deltaic sequence. A prodelta environment is suggested by the lower silty, calcareous clay interbedded with thin, very fine-grained calcareous sandstone; by the absence of fossils; and by other characteristics. The overlying sandstone, which is ferruginous, cross-bedded, ripple-marked, and unfossiliferous except for a few molds and casts of pelecypods, is thought to represent the proximal facies of a prograding delta front and delta fringe.

McNutt Limestone Member.—The McNutt Limestone Member was named by Huffman and others (1975, p. 18), who applied the name to beds previously referred to as the "quarry limestone." The name derives from exposures on the McNutt Ranch, 4 mi southeast of Soper, Choctaw County, Oklahoma. The McNutt Limestone maintains a uniform thickness of ~2 ft across Choctaw and eastern Bryan Counties, but thickens to ~20 ft in western Bryan County and eastern Marshall County by the addition of lower limestone beds interbedded with shale.

The McNutt varies from an arenaceous limestone to a highly calcareous sandstone. The limestone is a thick-bedded, well-indurated, fine- to medium-grained calcarenite. Studies of insoluble residues by Currier (1968, p. 24) indicate 76–82% calcium carbonate and 18–24% insoluble silt, clay, and quartzose sand, with traces of feldspar, glauconite, and unidentified ferromagnesian minerals. The limestone is fossiliferous and reddish brown to gray-brown.

Outcrops of the McNutt Limestone in Marshall County are limited to the Cumberland and Kingston synclines, where it forms a 2-ft bed separating the Weno Clay and Pawpaw Sandstone Members. In western Bryan County and eastern Marshall County, the McNutt Limestone thickens at the expense of the Weno, and beds of McNutt Limestone are interbedded with shales like those in the Weno. The McNutt Limestone reaches maximum thickness only where the Weno is thickest (90–100 ft) and is seldom >2 ft thick where the Weno is thin (30–60 ft), as in Choctaw County. This suggests a depoaxis in western Bryan County and eastern Marshall County, where thickening of part of the Bokchito Formation occurs.

Abnormally thick (15–20 ft) sections of the McNutt Limestone have been observed in western Bryan County by Hart (1970) and Currier (1968). Bridges (1979) reported ~20 ft of McNutt Limestone in an exposure along the shores of Lake Texoma in the SE¼NE¼ sec. 6, T7S, R7E, where the McNutt appears to channel into the underlying Weno. The lower part of the McNutt at this locality consists of fossiliferous, massive, cross-bedded, calcareous sandstone. The underlying Weno sandstone is calcareous and exhibits a concretionary structure owing to uneven distribution of the calcareous cement, which penetrated the sandstone from above. The basal part of the McNutt grades upward into brown, unevenly bedded, fossiliferous limestone containing very coarse sand, pebbles of quartz and clay, and flattened concretions. The top of the section is a 1-ft bed of gray-brown, very fine-grained, fossiliferous limestone separated from the lower units by 3 ft of cover (Fig. 21).

The McNutt Limestone serves as a reliable marker separating the upper Weno from similar beds in the Pawpaw Sandstone Member. Although variable in thickness, the McNutt Limestone is almost everywhere present and mappable. The uppermost bed appears to be synchronous and to represent a reliable time marker. Thickening of basal units at the expense of the Weno is probably due to submarine channeling or to tidal channeling in the upper part of the Weno delta.

Fossils are abundant in the limestone beds of the McNutt Limestone Member. The most abundant fossil is the pelecypod *Lopha quadriplicata* (Shumard), whose outlines are preserved on weathered surfaces. Other forms common to the McNutt include *Texigryphaea washitaensis* (Hill), *Lopha subovata* (Shumard), *Pecten (Neithea) subalpinus* (Böse), *Lima wacoensis* var. *quadrangularis* Stanton, and *Protocardia* sp.

Pawpaw Sandstone Member.—The name "Pawpaw" was applied by Hill (1894, p. 330) to exposures along Pawpaw Creek, near Denison, Grayson County, Texas; there the unit was described as fossiliferous, light-drab, thinly laminated clay lying between the Weno Clay and the Main Street Limestone. It was reported as becoming increasingly sandy northward in northern Texas.

In Marshall County, the Pawpaw Sandstone is

Figure 21. Weno sandstone (basal 10 ft of exposure) overlain by unusually thick McNutt Limestone Member of the Bokchito Formation. East-facing escarpment in a cove on Lake Texoma, NW¼SW¼ sec. 5, T7S, R7E. (Photo by K.F. Bridges.)

limited to two small areas. It crops out in T5–6S, R7E, along the axis of the Cumberland syncline; it forms a conspicuous band around two Woodbine outliers in the Kingston syncline, T7S, R6–7E, east and southeast of Woodville; and it caps a small hill near Kingston.

The Pawpaw as described by Bullard (1926, p. 43) consists of a lower clay shale 22 ft thick and an upper sandstone 38 ft thick. The best exposures are along the railroad cuts of the St. Louis and San Francisco Railroad east of Woodville in secs. 3 and 5, T7S, R6E, and along Lake Texoma, secs. 17 and 20, T7S, R7E. The lower clay shale is gray to blue, weathers yellow, and is interbedded with thin sandstones and siltstones and clay-ironstone concretions. The upper sandstone is gray to brown, fine-grained, and well sorted; it weathers yellow to reddish orange and locally contains ripple marks and cross-bedding. Mica flakes, glauconite, clay-ironstone concretions, and macerated pelecypod shells have been observed. Molds and casts of the pelecypods *Protocardia, Nucula*, and *Cyprimeria* have been reported.

The Pawpaw forms a rolling, hilly topography covered by a dense growth of timber. A red, sandy soil littered with clay-ironstone fragments is developed on the Pawpaw.

The Pawpaw is conformable with the underlying McNutt Limestone Member and with the overlying Bennington Limestone. It is interpreted by Bridges (1979, p. 62) as the marginal facies of a deltaic depositional system.

Bennington Limestone.—The Bennington Limestone was named by Taff (1902, p. 6) from exposures of massive, dull-blue limestone near Bennington, Bryan County, Oklahoma, where a thickness of 10 ft was reported. The Bennington of Oklahoma is correlative with the Main Street Limestone (restricted) of Texas.

In Marshall County, the Bennington crops out as a narrow band around two outliers in the Kingston syncline in T7S, R6–7E, east and southeast of Woodville. A small hill in the SW¼ sec. 27, T6S, R6E, along U.S. Highway 70, 2.5 mi east of Kingston, is capped by Bennington Limestone. In the Cumberland syncline, exposures are limited to the cap rock on two small hills in sec. 6, T6S, R7E.

The Bennington Limestone consists of gray to yellow-brown, fine-grained (biomicritic) to medium-crystalline (bioclastic calcarenite), fossiliferous, arenaceous limestone that weathers pitted and honeycombed. The Bennington in Marshall County is 1.5–2.5 ft thick; it thickens eastward to 10 ft in western Bryan County. Insoluble residues from Marshall County exposures indicate that the bed is 86–95% calcium carbonate, with a residue of fine- to very fine-grained quartzose sand and traces of clay. In western Bryan County, beds of well-indurated limestone alternate with beds of soft, marly limestone. The well-indurated beds are 93–96% calcium carbonate, and the marly layers are 88% calcium carbonate (Ganser, 1968, p. 32).

Fossils are abundant in the Bennington. Characteristic forms include *Kingena wacoensis* (Roemer), *Ilymatogyra arietina* (Roemer), *Lopha quadriplicata* (Shumard), and *Pecten (Neithea) texanus* Roemer.

The Bennington lies with sharp contact on the underlying Pawpaw Sandstone Member of the Bokchito Formation and grades upward into the overlying Grayson Marlstone (Fig. 22).

Grayson Marlstone.—The term "Grayson Marl" was applied by Cragin (1894) to a sequence of yellow, calcareous, fossiliferous marls in the upper part of the Main Street Limestone Member of the Denison Formation in Grayson County, Texas. Hill (1901, p. 114–115, 280–288) restricted the Main Street to the lower limestone and adopted Cragin's term for the overlying marly strata.

The Grayson is poorly exposed in the grass-covered slopes above the Bennington Limestone and below the Woodbine Formation. The outcrop is narrow and sinuous and parallels that of the Bennington. In Marshall County the exposures of Grayson are limited to those around the Woodbine outliers in the Kingston syncline east and southeast of Woodville, T7S, R6–7E.

The Grayson Marlstone consists of blue-gray, fossiliferous clay and thin beds of nodular limestone. Currier (1968, p. 32) divided the Grayson of southwestern Bryan County, Oklahoma, into the following four units, comparable to those established by Perkins (1960, p. 37) in Tarrant County, Texas: (1) a lower, 8-ft-thick, light-gray, regularly interbedded nodular limestone and marlstone, containing an abundance of fossils, *Ilymatogyra arietina* (Roemer) being the most abundant, accompanied by a few *Texigryphaea roemeri* (Marcou); (2) a 4-ft-thick, very sparsely fossiliferous, olive-gray marl; (3) an 11-ft-thick, olive-gray shale containing abundant *Texigryphaea roemeri* (Marcou). Currier (1968) reported a thickness of 27 ft for the Grayson in southwestern Bryan County.

Bridges (1979, p. 66–67) divided the Grayson in eastern Marshall County into two units, a lower 8-ft section of thin, irregularly bedded, argillaceous limestones separated by thin beds of clay, and a 6-ft upper unit of olive-gray, calcareous

Figure 22. Bennington Limestone overlying the Pawpaw Sandstone Member of the Bokchito Formation (not exposed) and overlain by Grayson Marlstone. Railroad cut, SW¼SW¼ sec. 5, T7S, R7E. (Photo by K.F. Bridges.)

clay containing *Texigryphaea roemeri* (Marcou)—a total thickness of 14–15 ft. The two upper units of the Bryan County section are missing in Marshall County, owing to erosion and a consequent unconformity at the base of the overlying Woodbine Formation.

Grayson sediments represent a continuation of nearshore carbonate deposition, which began with deposition of the underlying Bennington Limestone. Late Comanchean seas withdrew from the area, and subsequent erosion removed part of the Grayson.

The Grayson Marlstone is abundantly fossiliferous. The most characteristic forms are *Texigryphaea roemeri* (Marcou), *Ilymatogyra arietina* (Roemer), *Plesioturrilites brazoensis* (Roemer), *Pecten (Neithea) texanus* Roemer, *Cyprimeria* sp., *Protocardia texana* (Conrad), *Heteraster adkinsi* Lambert, and *Kingena wacoensis* (Roemer).

Cretaceous System, Gulfian Series

Woodbine Formation.—The Woodbine Formation was named by Hill (1901, p. 293) from strata cropping out beneath the Eagle Ford Formation near the town of Woodbine, Cooke County, Texas. Taff (1902, p. 6) applied the name "Silo" to partially equivalent beds near the village of Silo, Byran County, Oklahoma. The term "Silo" did not receive general acceptance, and the Woodbine is recognized in Oklahoma. Hill (1901, p. 297) subdivided the Woodbine into three members (ascending order): Dexter, Lewisville, and an unnamed unit of sands and clays (later assigned to the Eagle Ford in part). Bergquist (1949) subdivided the Woodbine of Cooke, Fannin, and Grayson Counties, Texas, into four named units of member rank (ascending order): (1) Dexter Member, comprising 100–140 ft of nonmarine, lenticular, white to ferruginous sandstone and silty clay, with carbonaceous clays at the base, scattered leaf and wood prints, and a persistent bed of varicolored clay (Rainbow Clay) at the top; (2) Red Branch Member, comprising lenticular beds of cross-bedded, tuffaceous sandstone or ferruginous sandstone with leaf prints, with interbeds of carbonaceous shale and lignite, having a total thickness of 60–70 ft; (3) Lewisville Member, comprising 100–125 ft of fossiliferous, glauconitic, brown sandstone, lenses of shale, some local tuffaceous material, and a number of oyster beds with *Crassostrea soleniscus* (Meek); and (4) Templeton Member, comprising gray shale with lenses of gray and tan glauconitic sand, containing large, rounded concretions filled with mollusk shells.

Bullard (1926) mapped and described a small area in eastern Marshall County where the Woodbine (probably the Dexter Member) caps an outlier in the middle of the Kingston syncline. This exposure is isolated by erosion from the main body of the Woodbine Formation in Bryan County.

Bridges (1979, p. 69–74) studied the Woodbine of eastern Marshall County. By means of newer, detailed topographic maps, he was able to refine previous mapping and to divide the Woodbine outcrop into two outliers separated by erosion along Alberta Creek. The northernmost outlier lies 1 mi east of Woodville, in secs. 1 and 12, T7S, R6E, and secs. 5, 6, 7, and 8, T7S, R7E. The southern outlier is southeast of Woodville and occupies parts of several sections, including secs. 12 and 13, T7S, R6E, and secs. 7, 8, 17, 18, 19, 20, and 21, T7S, R7E (Pl. 1).

Bullard estimated the thickness of the Woodbine to be ~50 ft in eastern Marshall County, whereas Bridges observed a total of 17 ft in exposures east of Woodville. The true preserved thickness in that area is ~35 ft, as estimated from the topographic map. The entire thickness there is assigned to the Dexter Member.

Dexter Member.—A complete section of the Dexter Member is nowhere exposed in eastern Marshall County, and only the basal 17 ft has been observed. Excellent exposures are present in cuts along the St. Louis and San Francisco Railroad east of Woodville, in sec. 1, T7S, R6E, and in sec. 6, T7S, R7E; there the Dexter can be divided into two units. The lower unit is a highly ferruginous pebble conglomerate, whereas the upper unit comprises very fine- to coarse-grained, cross-bedded sandstone interbedded with large ironstone concretions.

The basal conglomerate was described by Bridges (1979, p. 71). It consists of rounded, medium- to pebble-sized clasts, mostly chert and quartz. The pebbles are bound together with clay and very fine-grained ferruginous sand, giving the conglomerate a brown color. Hard, dark-brown ironstone layers are present as partings within the unit. The ironstone layers dip at angles of 0–30°, giving a cross-bedded appearance. Hill (1901, p. 294–295) thought that the dark-brown, ferruginous ironstone layers were the result of interstratal solution which concentrated the iron minerals into distinct bands. The basal unit attains a thickness of 10 ft in Marshall County.

Above the basal conglomerate is a section of sandstone interbedded with large ironstone concretions (Fig. 23). The sandstone is light brown to reddish brown, ferruginous, and cross-bedded. The average grain size, according to sieve analysis, is 3.0 phi, indicating a fine-grained rock; the standard deviation of 0.62 phi indicates moderate sorting (Bridges, 1979, p. 110). Individual grains are angular to rounded and are composed of quartz and feldspar; there are some igneous-rock clasts.

The Dexter Member of the Woodbine Formation rests on the eroded surface of the Grayson Marlstone. The basal conglomerate in southern Marshall County and parts of northwestern Bryan County indicates renewed sedimentation in southern Oklahoma following an episode of re-

Figure 23. Cross-bedded chert conglomerate and ferruginous sandstone of the Dexter Member of the Woodbine Formation. Railroad cut, sec. 6, T7S, R7E. (Photo by K.F. Bridges.)

gional erosion. According to Bridges (1979, p. 74), the high concentration of ferruginous material, along with the poor sorting and local distribution of the basal unit, suggests an alluvial-channel environment for part of the basal Dexter. The overlying, fine-grained, cross-bedded sandstones indicate a subsequent rise of sea level and near-shore deposition. Diagnostic fossils are not present in the Dexter Member.

Quaternary System

Terrace Deposits

Several terrace levels and extensive areas covered by alluvial deposits can be recognized along the Red River in southern Marshall County and along the Washita Arm of Lake Texoma in eastern Marshall County. These areas occur at approximately the same elevations as those in Bryan County, with which they can be correlated, using a classification scheme based on vertical distance above the channel of the Red River.

Stephenson (1918, p. 132) was one of the first geologists to recognize multiple terrace levels along the Red River. He observed the present flood plain of the river, a well-defined terrace 45–75 ft above the low-water level of the river, a terrace plain 140–160 ft above water level, and remnants of surficial deposits at higher elevations.

Stream terraces along the Red River, especially on the Texas side, were differentiated by Frye and Leonard (1963) into five levels, ranging in age from Nebraskan to late Wisconsinan. Their classification was based on assemblages of fossil mollusks, and on physiographic expression and elevations. The terrace levels in northern Texas according to Frye and Leonard are shown in Table 8.

Five terrace levels were recognized in the Texarkana Quadrangle and the Sherman Quadrangle (Barnes, 1966,1967); these levels extend into southern Oklahoma (Table 9).

Three terrace levels have been identified in Marshall County and are tentatively assigned to the Ambrose level (Qt_2), the intermediate level (Qt_3), and the Hardeman level (Qt_4). Correlation of these terraces with the Texas levels has been made difficult by the presence of Lake Texoma, whose waters conceal part or all of the lower terrace levels west of Denison Dam for several miles.

Cooke Terrace (*late Wisconsinan*, Qt_1).—In Bryan County, immediately east of Denison Dam, the late Wisconsinan Cooke terrace is a well-defined surface ~15 ft above the level of the flood plain and 25–30 ft above the channel of the Red River. The base of the terrace deposits is at an

TABLE 8.—TERRACES IN NORTHERN TEXAS (FRYE AND LEONARD, 1963)

Level	Elevation above Red River (ft)
Nebraskan terrace (Qt_5)	150–160
Hardeman terrace (Kansan) (Qt_4)	90–110
Intermediate terrace (Illinoian) (Qt_3)	65–70
Ambrose terrace (early Wisconsinan) (Qt_2)	30–45
Cooke terrace (late Wisconsinan) (Qt_1)	18–20

TABLE 9.—TERRACE LEVELS IN NORTHERN TEXAS AND SOUTHERN OKLAHOMA (BARNES, 1966,1967)

Level	Elevation above flood plain (ft)
Qt_5 (Nebraskan)*	160±10
Qt_4 (Kansan)	110±10
Qt_3 (Illinoian)	65±10
Qt_2 (Wisconsinan)	30±5
Qt_1 (Wisconsinan)	17±3

*Surface of residual gravels.

elevation of 500 ft, and the top is just below the 530-ft contour. The Cooke terrace lies below the waters of Lake Texoma, both in the Red River Arm and the Washita Arm. It is exposed immediately northeast of Deckerds Bend on the Oklahoma side of the Red River. It has not been recognized in Marshall County.

Ambrose Terrace (early Wisconsinan, Qt_2).—The Ambrose terrace is well developed immediately east of Denison Dam in Bryan County, where it lies 10–15 ft above the Cooke terrace, 30 ft above the flood plain, and 40–45 ft above the Red River channel. Its deposits consist of gravel, sand, silt, and clay. The base of the terrace deposits lies near the 540-ft contour, and the top is just above the 570-ft contour; thickness of the deposits is thus ~30 ft. The crest of the dam is at an elevation of 670 ft, and the power-pool level of Lake Texoma is 617 ft; thus the Ambrose level is ~47 ft below the power-pool level of the lake.

The estimated gradient of the former Red River channel beneath the lake is 2 ft/mi. From a point southwest of Thackerville (Love County) where the 650-ft contour crosses the Red River to a point just below Denison Dam where the 500-ft contour crosses the Red River—a distance of 80 mi as measured along the former course of the river beneath the lake—the river bed slopes at the rate of 1.875 ft/mi. Assuming that the gradient on the river during Wisconsinan time was approximately the same as the present gradient, the elevation of the flat area near the Willis Bridge in southern Marshall County would be ~630 ft. Examination of that area indicates that the elevation there is 622–640 ft, which indicates that the lowest terrace level in Marshall County is the Ambrose.

The Ambrose terrace appears to be restricted to the north shore of Lake Texoma in Marshall County. It is present in parts of secs. 16, 22, and 23, T7S, R4E; in the peninsula south of Willis in secs. 2, 3, 10, and 11, T8S, R6E, along the north shore; in the islands in Lake Texoma south of the Enos peninsula; and possibly in a thin band along the lake shore from near McBride westward to sec. 27, T7S, R6E.

The base of the Qt_2 terrace deposit is below the water level of Lake Texoma (617 ft) and the top is at 640 ft where the entire thickness has been preserved. Deposits associated with the terrace are composed of clay and fine sand. Soils formed on its surface belong to the Dougherty–Konawa and the Konawa–Teller associations (Burgess, 1980). Specific soil types include the Eufaula loamy fine sand, the Konawa fine sandy loam, the Teller fine sandy loam, and the Bastrop fine sandy loam. Vegetation includes some woodlands, pasture grasses, and a few fields of peanuts.

Intermediate Terrace (Illinoian, Qt_3).—The intermediate or Illinoian terrace (Qt_3) is well developed along both the Washita Arm and Red River Arm of Lake Texoma in Marshall County.

A large area assigned to the intermediate (Qt_3) level extends along the west side of the Washita River in northeastern Marshall County. The contact of the base of the terrace and the alluvium is between 580 and 600 ft. Recorded elevations on the terrace surface are 632, 635, 639, and 641 ft, and the break in slope occurs at the 650-ft contour. Thus, this level is ~70 ft above the flood plain in the position of the intermediate terrace of Frye and Leonard (1963). This terrace covers parts or all of secs. 20, 21, 28, 29, and 33, T5S, R7E. Deposits consist of sand, clay, silt, and gravel, and several pits indicate where gravels have been taken. Much of Cumberland oil field lies beneath this terrace. The soils formed on the terrace surface belong mainly to the Bastrop–Konawa association and include such types as the Bastrop fine sandy loam, the Konawa sandy loam, the Konsil fine sandy loam, the Madill sandy loam, and a small amount of Wilson loam. The vegetation includes pasture grasses and woodland.

The intermediate terrace level (Qt_3) can be traced southwestward from sec. 3, T6S, R7E, along the west side of the Washita Arm of the lake to the vicinity of Aylesworth, in sec. 19, T6S, R7E. The base of the terrace is below lake level, and the top extends to a break in slope at the 650-ft contour. The exposed thickness is >33 ft. There, the soils are of the Bastrop–Konawa association, especially the Bastrop fine sandy loam. Also included are areas of Konsil fine sandy loam. The area is relatively flat and poorly drained in places. Vegetation includes grasses and woodlands.

The intermediate terrace has been recognized in the area south and southeast of the town of Lebanon, where it extends from lake level to 680 ft, with a thickness of ~50 ft. The terrace is well dissected and slopes southward at 15 ft/mi. Parts or all of secs. 4–10, 14–16, 22, and 23, T7S, R4E, are covered by this terrace. The soils have been assigned to the Bastrop–Konawa association and include the Bastrop fine sandy loam and the Konawa fine sandy loam. These soils have a high potential for row crops such as peanuts and cotton, as well as for tame pastures and native grasses.

The boundary between the intermediate terrace (Qt_3) and the overlying Hardeman terrace (Qt_4) is concealed by slope wash and possible windblown sediments in the two large areas of terrace cover on the peninsula in the Willis area and on the peninsula south of Enos. There, the authors were confronted with the problem of lumping the thick terrace deposits as undifferentiated terrace deposits or separating them on the basis of elevation. Elsewhere, as near Lebanon, the contact of Qt_3 and Qt_4 was placed at the 680-ft contour. By projecting this level, it is possible to make a subdivision based on elevation rather than topographic expression.

Accordingly, the steep slope lying between the 640- and 680-ft contours has been mapped as Qt_3 in a band extending eastward from sec. 35, T7S, R4E, to sec. 5, T8S, R5E. It has been extended also around the Enos peninsula from sec. 4, T8S, R5E, to sec. 6, T8S, R6E, a distance of nearly 8 mi.

Hardeman Terrace (Kansan, Qt_4*).*—Most of the high-level terrace deposits are herein assigned to the Qt_4 or Hardeman level of possible Kansan age. This includes scattered terrace deposits in northeastern Marshall County, extensive areas in southern Marshall County, and the terraces north of Lebanon.

High-level terrace deposits have been mapped in several isolated areas in northeastern Marshall County. The northernmost of these occupies parts of secs. 1, 11, and 12, T5S, R6E. A second deposit covers parts of secs. 7 and 18, T5S, R7E. Smaller patches are in secs. 19, 30, and 33, T5S, R7E. The base of these deposits has been drawn at ~680 ft, and the tops extend to 720 ft, giving a thickness of ~40 ft of preserved terrace. The deposits are composed of sand, silt, clay, and gravel, and gravel has been taken from pits in these deposits.

The largest area assigned to the Hardeman (Qt_4) level lies along the north shore of Lake Texoma in the vicinity of Enos, where it occupies ~12 mi^2 in secs. 33–36, T7S, R5E; secs. 1–4, 9–14, and 23, T8S, R5E; and secs. 6 and 7, T8S, R6E. There, the terrace lies along its northern edge on the Antlers sandstone and along its western edge on outcrops of Goodland Limestone and Kiamichi shale. The southern edge or contact with the underlying Qt_3 is drawn approximately along the 680-ft contour. The principal soil association is the Dougherty–Konawa, and both the Dougherty loamy fine sand and the Konawa fine sandy loam are well developed.

The second-largest expanse of the Qt_4 or Hardeman terrace extends from near Willis northward for a distance of 3 mi, occupying parts or all of secs. 25, 26, 35, and 36, T7S, R4E, and secs. 1 and 2, T8S, R4E, for a total of ~5 mi^2. The terrace lies mainly on the Antlers sandstone along the eastern side and on the Goodland–Kiamichi–Duck Creek sequence to the north and west. The base of the terrace has been drawn at the 680-ft contour along the south side, where a break in slope marks the approximate contact. Above the 700-ft level, the upper surface is gently sloping and suitable for agriculture. Above the 780-ft level, the surface is nearly flat. Slope wash and wind activity are believed to have played a role in forming this abnormally thick deposit. Again, the soils belong to the Dougherty–Konawa association, the Dougherty loamy fine sand predominating. Minor amounts of Bastrop fine sandy loam and Konawa fine sandy loam are present. The soils have the potential for crops, grasses, and pasture, and the level upland surface is used for row crops of peanuts and cotton.

The third major area of high-level terrace (Qt_4) extends westward to the county boundary from a line drawn from southeast of Powell northwestward to the southern edge of Lebanon. There, the Hardeman terrace (Qt_4) lies on the Antlers sandstone and on the intermediate terrace (Qt_3). The contact of the two terraces can be seen at places on the surface and can be traced on aerial photographs. Sediments making up this terrace consist of sand, silt, clay, and gravel; several gravel pits have been observed (Figs. 24,25). The soils are very sandy and probably include material derived from the weathered Antlers sandstone. The soils belong to the Bastrop–Konawa association, the Bastrop fine sandy loam and the Konawa fine sandy loam predominating. The base is drawn at ~680 ft.

Undifferentiated Terrace Deposits (Qt).—Isolated deposits of sand and gravel associated with terraces occur at places in Marshall County, mainly along streams. These serve as local sources of gravel. No attempt has been made to assign these to specific levels.

Alluvium

Extensive deposits of Holocene alluvium border all of the major tributaries of the Washita and Red

Figure 24. Terrace deposits of cross-bedded sand, silt, and gravel exposed in a pit on the west side of Brier Creek, south of blacktop road, NW¼ sec. 13, T7S, R4E. (Photo by K.F. Bridges.)

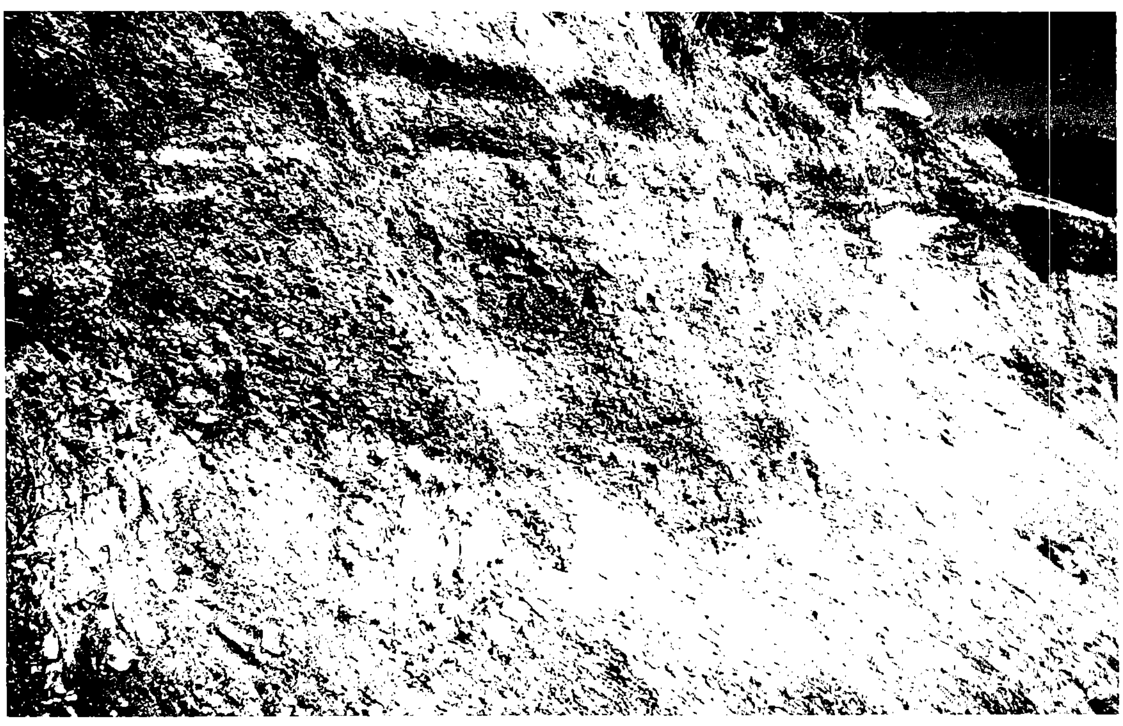

Figure 25. Terrace deposits exposed in a gravel pit, NW¼SW¼SW¼ sec. 20, T6S, R4E. (Photo by A.M. Holtzman.)

Rivers. The broad flood plains of these rivers are covered by Lake Texoma, except in the northeastern part of the county, where the Cumberland Levee and the Cumberland Cut have diverted the Washita River into an artificial channel, leaving the old channel and the flood plain exposed in the Cumberland oil field. This belt of alluvium is ~3 mi long and ~1 mi wide. The surface of the flood plain lies 10–15 ft above the water level in the old channel.

Flood-plain alluvium has been mapped along Wilson Creek, Hauani Creek, Little Hauani Creek, Brier Creek, Buncombe Creek, Caney Creek, Soldier Creek, Rooster Creek, Little Glasses Creek, Glasses Creek, Turkey Creek, and other streams. The belts of alluvium are long and narrow and seldom exceed one-half mile in width. The soils have been assigned to the Frioton–Gracemont association and are described as deep, nearly level, and well-drained to poorly drained, with a loamy surface layer on a loamy subsoil. These soils have a high potential for crops, but are subject to flooding. They have high potential for tame pastures and native grasses and a medium potential for woodlands (Burgess, 1980).

STRUCTURAL GEOLOGY

Regional Tectonic Setting

Marshall County is part of the coastal plain province, where in general Cretaceous strata dip gently southward at ~50 ft/mi. This gentle homocline is interrupted at places in Marshall County and western Bryan County by SE-plunging anticlines and synclines that are superimposed on major fault blocks and associated flexures in the underlying Paleozoic rocks. These structural features are in turn related to nearby tectonic elements of regional magnitude. A knowledge of the general regional tectonic features of southeastern Oklahoma (Fig. 26) is essential to an understanding of the relationship of Paleozoic structures to the structure and areal distribution of Cretaceous strata.

Pre-Cretaceous rocks and structures in south-central Oklahoma are shown in Figure 27, and major surface structures of Marshall County are shown in Figure 28.

Arbuckle Mountains

The Arbuckle Mountains complex lies north of Marshall County in Johnston, Carter, Murray, and Pontotoc Counties. There, the Paleozoic rocks have been folded into NW-trending structures (Arbuckle anticline, Tishomingo anticline, Mill Creek syncline, Belton anticline, and Hunton anticline). These linear features are separated by major NW-trending faults (Washita Valley fault, Reagan fault, Mill Creek fault, and Sulphur fault; Ham, 1969, fig. 13) that postdate the folding. Mississippian and Morrowan uplifts occurred at the southeastern end of the Arbuckle complex, and Early Pennsylvanian (post-Morrowan) movement uplifted the Hunton anticline and deformed Arbuckle Mountain rocks. Close folding of the Arbuckle anticline, with overturning and thrusting, occurred during two or more major pulses in Virgilian time, producing the Collings Ranch Conglomerate and conglomerates of the Vanoss Group. The Arbuckle Mountains faults extend southeastward beneath Cretaceous strata, where they are associated with subsurface anticlines and horst blocks that control hydrocarbon production in Marshall and Bryan Counties.

Ardmore Basin

The Ardmore basin lies south of the Arbuckle Mountains, between the Arbuckle anticline and the Criner Hills–Wichita Mountains trend of folds and faults. During pre-Pennsylvanian time, the Ardmore basin was part of the southern Oklahoma geosyncline, a large depositional basin lying between the Tishomingo horst and the Waurika–Muenster block. The southern Oklahoma geosyncline received >17,000 ft of pre-Pennsylvanian sediments (Ham, 1969, p. 19) and ~13,000 ft of pre-Virgilian Pennsylvanian strata. These rocks are overlain by two orogenic conglomerates, the Collings Ranch Conglomerate, preserved in a graben between segments of the Washita Valley fault system, and the Vanoss Group.

The Ardmore basin continues northwestward into the Anadarko basin and southeastward into the Kingston and Cumberland synclines of Marshall County.

Caddo Anticline

The Caddo anticline is a NW-trending uplift north of Ardmore in the center of the Ardmore basin. It is a doubly plunging fold 9 mi long and 3 mi wide. It has trapped hydrocarbons in Mississippian through Ordovician units. The Caddo anticline is aligned with the Madill–Aylesworth anticline and associated faults but is separated from them by the Berwyn basin. The Caddo anticline was formed during the Late Pennsylvanian Arbuckle orogeny (post-Hoxbar, early Virgilian).

Criner Hills

The Criner Hills uplift is a complexly faulted and folded structure comprising the eroded Criner Hills anticline, Brock anticline, Pleasant Hill syncline, Hickory Creek syncline, and Overbrook anticline. The Overbrook fault is on the north, and the Criner–Meers fault is on the south, dipping SW at a high angle. The Criner axis extends northwestward into the Wichita–Amarillo arch complex, and southeastward through the southern tip of Marshall County into Grayson and

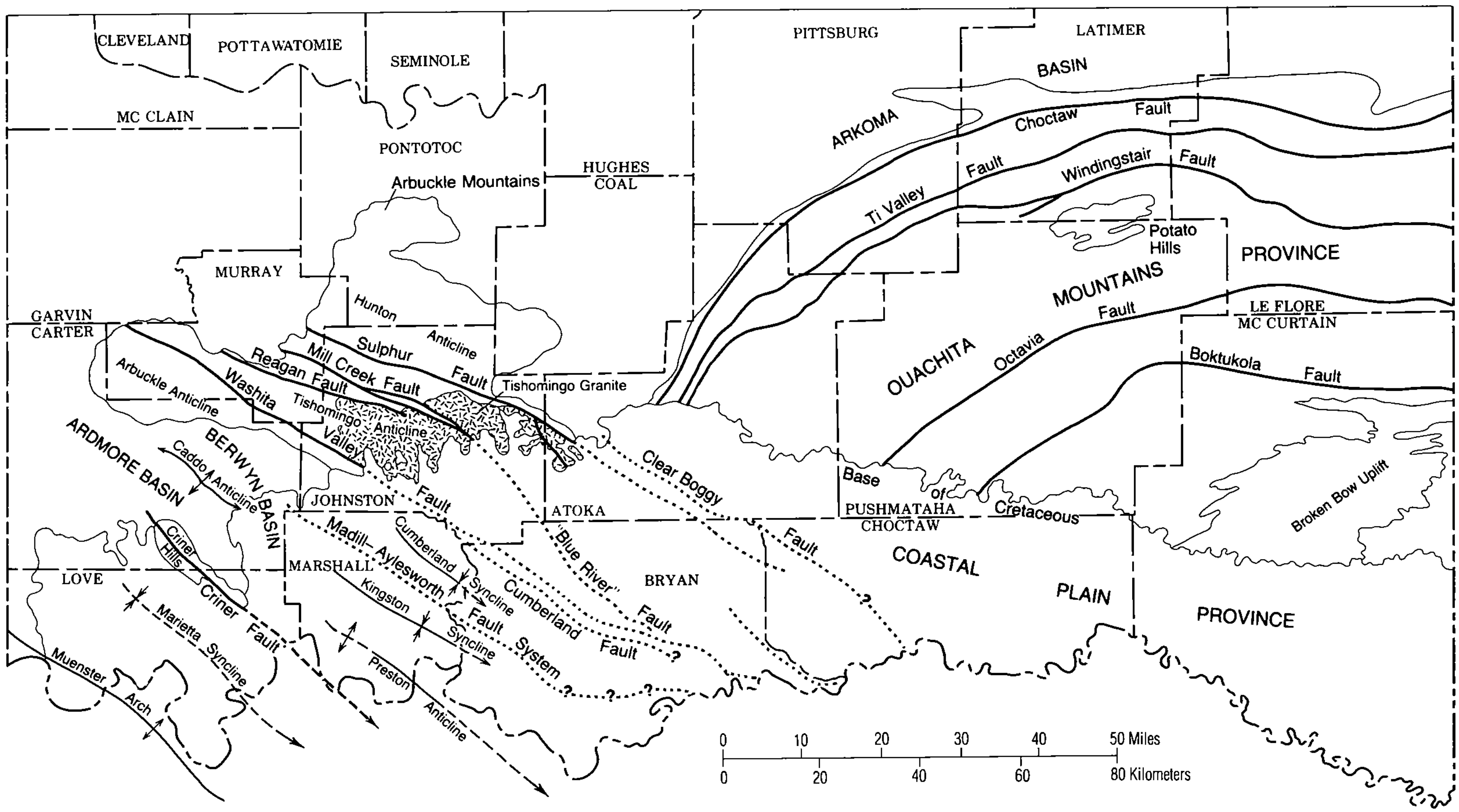

Figure 26. Principal tectonic features of southeastern Oklahoma. (After Huffman and others, 1978, fig. 32.)

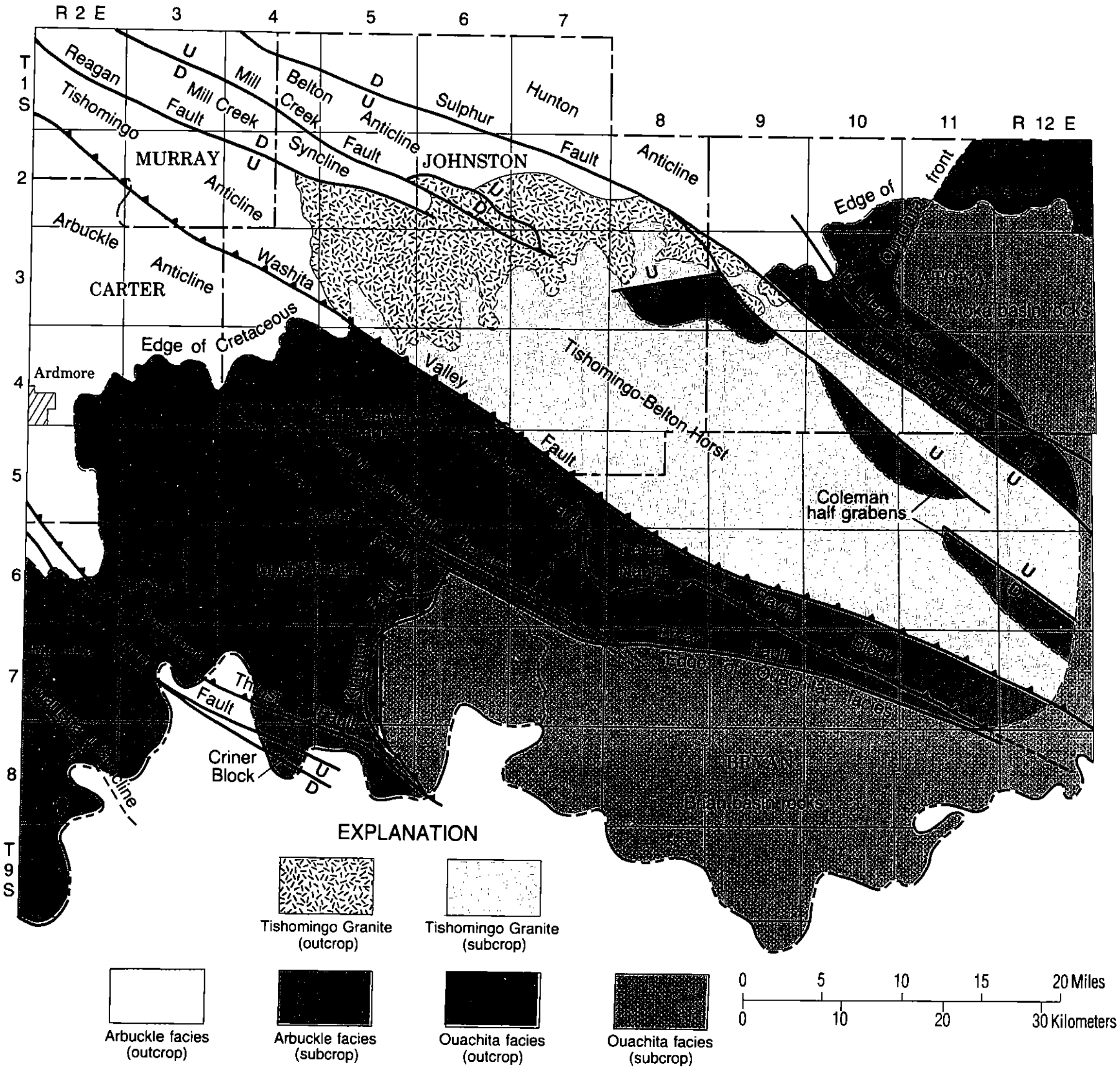

Figure 27. Pre-Cretaceous rocks and structures in south-central Oklahoma. (After Huffman and others, 1978, fig. 33.)

Cooke Counties, Texas. Deformation took place during Morrowan time (Wichita orogeny) and during post-Hoxbar time (Arbuckle orogeny).

Marietta Basin

The Marietta basin is a SE-plunging synclinal flexure between the Criner fault and the Muenster–Waurika fault and associated flexures. It was initiated during the Wichita orogeny (Morrowan) and received a thick section of Deese (Desmoinesian) and Hoxbar (Missourian) sediments. The SE-plunging syncline extends southeastward into Cooke and Grayson Counties, Texas, where it becomes the Gordonville basin and Sherman basin.

Ouachita Mountains Province

The Ouachita Mountains province comprises a complex system of folds and faults that occupy an area of 4,250 mi^2 in southeastern Oklahoma and more than 700 mi^2 in the subsurface of Marshall and Bryan Counties, Oklahoma. The well-known Ouachita facies includes the Womble, Bigfork, Polk Creek, Missouri Mountain, Arkansas Novaculite, Stanley, and Jackfork stratigraphic units, which are composed of graptolitic slates,

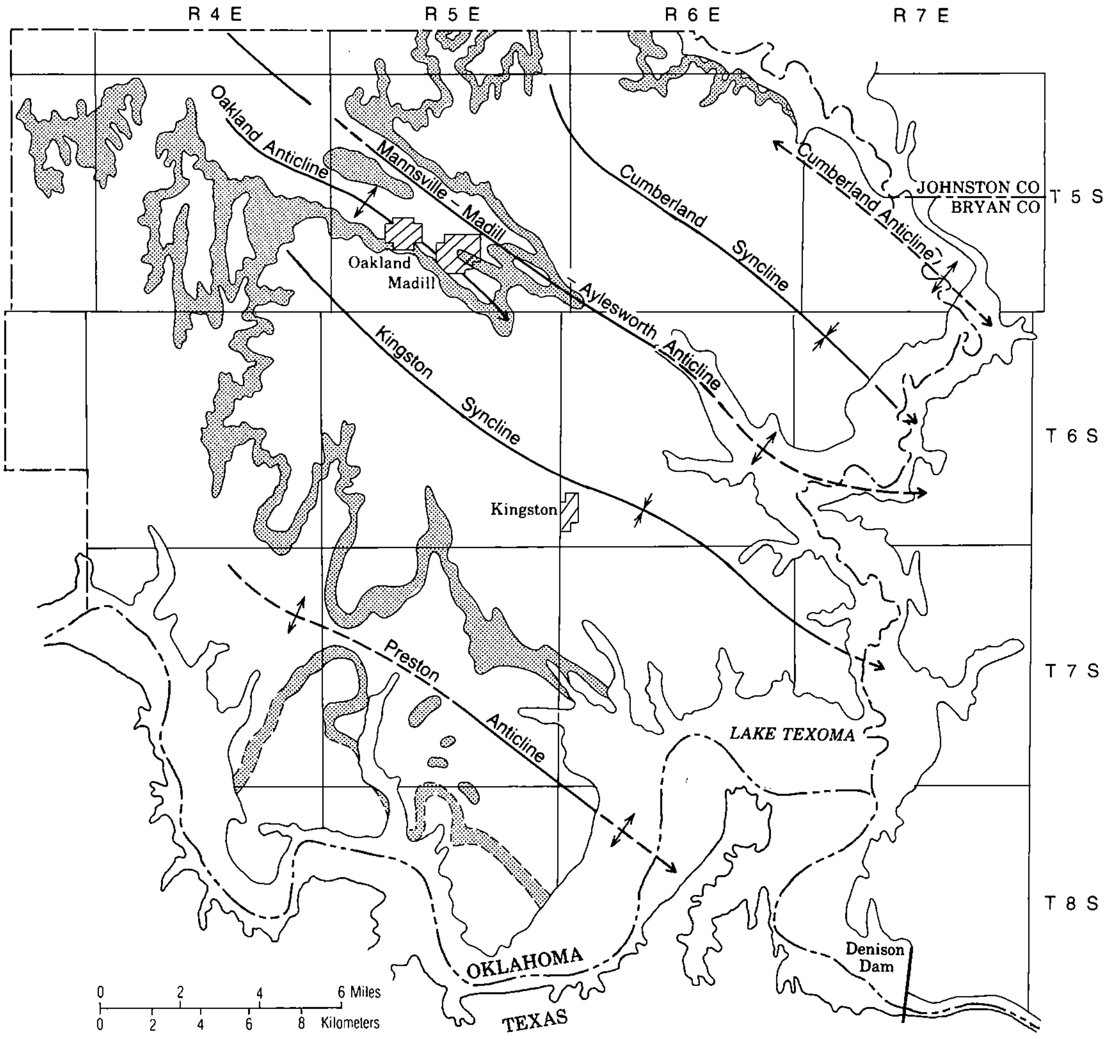

Figure 28. Major surface structures in Marshall County. Stippled area is outcrop belt of Goodland Limestone.

cherts, and graywacke and which range in age from Ordovician to Pennsylvanian. Orogenic and epeirogenic movements during Deese (Desmoinesian) and Hoxbar (Missourian) time supplied coarse clastic sediments for the Devils Kitchen and younger conglomerates in the Lake Murray area.

Ouachita structures are concealed beneath Cretaceous cover in southeastern Marshall and southern Bryan Counties. Where drilled, the Ouachita rocks are cherty, siliceous, and dark gray to black—contrasting sharply with normal marine carbonates, sandstones, and fissile shales of the Arbuckle facies, except near the boundaries of facies, where it is difficult to distinguish them. That area of Ouachita rocks south of the Tishomingo–Belton horst was named the Bryan basin (Huffman and others, 1978, p. 47) at the suggestion of Dr. R. O. Fay, of the Oklahoma Geological Survey. Rocks of the Bryan basin were thrust northwestward during late Virgilian time.

The area of Ouachita rocks northeast of the Arbuckle complex (Tishomingo–Belton horst) has been named the Atoka basin (Huffman and others, 1978, p. 47). From Cambrian through Morrowan time, the Atoka basin received Ouachita sediments, which accumulated to great thickness and were later uplifted to form part of the present

Ouachita structures. This basin, too, was deformed in Late Pennsylvanian (Virgilian) time.

Arkoma Basin

The Arkoma basin is adjacent to the frontal Ouachitas, separating that area from the Ozark Mountains Province to the northeast and the Arbuckle Mountains to the southwest. During Atokan and Desmoinesian time, the Arkoma basin was a foredeep into which thousands of feet of clastic sediments derived from the Ouachita uplift or areas to the east were deposited. Major structural deformation appears to have been post-Boggy (middle Desmoinesian) at which time numerous gas-trapping anticlines were formed.

Local Surface Structures

Several prominent synclines and anticlines have been mapped in Cretaceous strata. Late Paleozoic faults and folds in the subsurface underlie the principal Cretaceous structures. Many of these Paleozoic structures are known to extend northwestward into the Arbuckle Mountain and Ardmore basin structures, and southeastward beneath a plate of Ouachita rocks that were thrust northwestward during the late Virgilian. Overlying Cretaceous rocks have responded to structural adjustments along these older, preexisting Paleozoic structures.

Preston Anticline

The Preston anticline, as outlined by Stephenson (1918, pl. 17) and Hopkins and others (1922, pl. 1) is a large, plunging structure that extends southeastward from a point near the northwest corner of T7S, R5E, in Marshall County, passing south of Bonham, Texas, to the vicinity of Gober, Texas, a distance of nearly 60 mi. The dip of Cretaceous strata ranges from a few feet per mile to more than 300 ft/mi and is steeper on the southwest flank. The Preston anticline represents an uplift of 700–800 ft. It is bordered on the northeast by the shallow Kingston syncline and on the southwest by the broad Sherman syncline. The Antlers sandstone is exposed along the crest, and the Goodland Limestone crops out on both flanks. Shallow oil and gas production has been established in Trinity (Antlers) sandstone in the Enos and Isom Springs fields, and oil was discovered recently in Devonian–Mississippian cherts of the Ouachita facies at depths of 3,500–6,000 ft. The Preston anticline is believed to be a late Paleozoic fold extending downward into basement rocks. Ouachita rocks were thrust northwestward across the structure, partially eroded, then subsequently buried beneath Cretaceous strata. Post-Cretaceous structural adjustment and subsequent erosion produced the feature that we see today.

Kingston Syncline

The Kingston syncline is a broad, shallow structure separating the Preston anticline and the Madill–Aylesworth anticline. The axis of the syncline is delineated at the surface in eastern Marshall County by a row of hills capped by the Dexter Member of the Woodbine Formation. The Kingston syncline plunges SE and loses its identity northwestward as it passes into the larger Ardmore basin.

Madill–Aylesworth Anticline

The Madill–Aylesworth anticline separates the Kingston syncline from the Cumberland syncline. It trends NW and plunges SE at 20–40 ft/mi (Bullard, 1926, p. 52). The Madill–Aylesworth anticline is nearly symmetrical, with dips of 60–90 ft/mi on the Goodland Limestone. According to Bullard (1926, p. 52), the anticline extends southeastward from sec. 36, T5S, R5E, to a point southwest of Aylesworth where Glasses Creek joins the Washita River (now inundated by waters of Lake Texoma). The present study indicates that the anticline extends northwestward from sec. 36 into sec. 17, T5S, R5E, along Glasses Creek, through Carter Lake, and beyond (Holtzman, 1978, p. 66).

Mannsville Anticline

The Mannsville anticline, first mapped by Tomlinson (1926, p. 139), is a northwestern extension of the Madill–Aylesworth flexure. Along the crest of the Mannsville anticline, erosion has cut through the Cretaceous strata, exposing a Paleozoic sequence comprising the Viola Group, Sylvan Shale, Hunton Group, Woodford Formation, and Sycamore Limestone in scattered exposures along Turkey Creek, in secs. 34 and 35, T4S, R4E. Only the southwestern limb of the anticline is visible from surface exposures, where dips are 41–64° SW. The northeastern limb is faulted and concealed by Cretaceous cover. To the northwest, in Johnston and Carter Counties, Pennsylvanian rocks are exposed along the axis of this fold in secs. 18 and 19, T4S, R4E, and sec. 13, T4S, R3E.

Oakland Anticline

The Oakland anticline was named and described by Hopkins and others (1922, p. 9). It is a long, plunging anticline that extends from the southeast corner of sec. 13, T5S, R4E, southeastward through Oakland and the southwestern part of Madill to the northeast corner of sec. 3, T6S, R5E, where it plunges to the southeast and disappears. The Oakland anticline is parallel to the Madill–Aylesworth anticline. The crest is in the Glasses Creek valley in sec. 18 and 19, T5S, R5E.

The Goodland Limestone is present on both flanks of the anticline, and a small syncline separates it from the Madill–Aylesworth flexure. A large outlier of Goodland Limestone marks the axis of this syncline in secs. 17 and 18, T5S, R5E.

The dip on the southwestern flank of the anticline is 110–130 ft/mi; on the northeastern flank the dip is 25–80 ft/mi (Hopkins and others, 1922, p. 9).

Cumberland Syncline

The Cumberland syncline is a broad, shallow, asymmetrical downwarp lying between and essentially parallel to the Madill–Aylesworth anticline on the southwest and the Cumberland anticline on the northeast. The axis plunges gently SE through eastern Marshall County and northwestern Bryan County, passing beneath the Ouachita thrust sheet. To the northwest, the structure becomes part of the Ardmore basin. The Goodland Limestone and the Kiamichi shale are present on both limbs, and younger Cretaceous strata crop out along the axis, where members of the Bokchito Formation are present.

Cumberland Anticline

The Cumberland anticline is a low-amplitude, asymmetrical fold lying immediately northeast of the Cumberland syncline and immediately southwest of the Washita Valley fault and the Cumberland fault, a branch of the Washita Valley fault. The Cumberland fault zone is reflected at the surface in the outcrop pattern of the Goodland Limestone in northeastern Marshall and southern Johnston Counties. The axis of the fold lies beneath the alluvium of the Washita River in secs. 18, 20, 28, and 34, T5S, R7E, in Marshall and Bryan Counties.

Relationship of Cretaceous Structures and Paleozoic Features

The relationship of Cretaceous structures and Paleozoic features has been discussed by numerous writers, including Miser and Honess (1927), Prewit (1961), Frederickson and others (1965), and Huffman and others (1978). Examination of surface outcrops indicates a NW–SE alignment of Cretaceous structures. This alignment is parallel to and is superimposed on Paleozoic folds and faults, which control hydrocarbon accumulation and production. Prewit (1961, p. 47) suggested that the folds in Cretaceous rocks were formed by draping of Cretaceous sediments over structurally controlled topographic highs and lows in the underlying Paleozoic strata, with thickening in synclines and thinning over anticlines. Frederickson and others (1965, p. 47) disagreed with Prewit, stating that deposition of the thick Antlers sandstone would have filled the low areas, resulting in an essentially horizontal attitude of succeeding strata, including the Goodland Limestone. They postulated that present structures in Cretaceous strata are the result of continued structural adjustment during Cretaceous time along Paleozoic structural elements. Huffman and others (1978, p. 50) suggested that differential compaction across preexisting structures and renewed adjustment along the lines of Paleozoic folding and faulting would explain the relationship of Cretaceous structures to underlying Paleozoic tectonic elements.

GEOLOGIC HISTORY

The geologic and tectonic history of southern Oklahoma and the Midcontinent region has been summarized by various authors, including Tomlinson and McBee (1959), Huffman (1959), and Ham and Wilson (1967). For a more complete understanding of the regional history, the reader is referred to these publications. The following is a brief summary of the history of southern Oklahoma as it pertains to Marshall and Bryan Counties, Oklahoma (taken from Huffman and others, 1978).

During the Paleozoic Era, two distinct geosynclines characterized the southern Midcontinent region. One of these, the Ouachita–Marathon System, extended NE—SW across southern Arkansas, southeastern Oklahoma, and central Texas, passing between the Tishomingo–Belton horst block and the Texarkana platform, southward beyond the Llano uplift, and thence southwestward to the Marathon region of Trans-Pecos Texas. From Cambrian through Morrowan time, two prominent arms or embayments of this geosyncline extended into southeastern Oklahoma. The area southeast of the Arbuckle Mountains (Tishomingo–Belton horst), the Atoka basin, received thick Ouachita sediments. A second embayment, the Bryan basin, southwest of the Tishomingo–Belton horst block, also received Ouachita sediments. Thus, the Bryan basin and the Atoka basin were the sites of deposition of thick sequences of clastic sediments and colloidal silica which formed the dark-gray shales, cherts, and sandstones of the Ouachita facies. In Mississippian and early Pennsylvanian time, growth faulting began around the edges of the basins, and the Atoka basin became the site of maximum deposition of the Stanley, Jackfork, and Johns Valley sediments. Tectonic activity during post-Morrowan time shifted the axis of maximum deposition northward into the Arkoma basin, where thick Atoka and younger beds were deposited. Renewed uplift occurred in the Desmoinesian (post-Boggy) and later produced highlands in the Ouachita Mountains province; these became the source area for the chert-pebble conglomerate in the Thurman and younger rocks. The Bryan uplift during Boggy (Desmoinesian) and post-Boggy time was the source of the conglomerates in the Devils Kitchen, Rocky Point, and later Deese and Hoxbar units in the Ardmore basin. A culminating pulse in late Virgilian time produced the thrust faults that characterize the present Ouachita province and caused the apparent overriding of the Ouachita facies upon the Arbuckle facies. This movement may have coincided with or may have been slightly earlier than the Marathon orogeny of western Texas. Final movement in latest Pennsylvanian time produced a set of joints whose orientation was used by Melton (Ham and Wilson, 1967, p. 387) to postulate a late episode in the Ouachita Mountains province. Pre-orogenic sediments (pre-Mississippian) are 10,000 ft thick in the Arkansas part of the Ouachita Mountains, whereas upper Paleozoic beds (Stanley, Jackfork, Johns Valley, and "Atoka") have a maximum thickness of 42,000 ft (Ham and Wilson, 1967, p. 383).

The second geosyncline in the Midcontinent region was the NW-trending southern Oklahoma geosyncline (variously referred to as the "southern Oklahoma aulacogen," "Wichita trough," "Arbuckle geosyncline," "Harrisburg trough," and "ancestral Anadarko–Ardmore basin"). This intracratonic rift valley was bordered on the southwest by the Texas craton and on the northeast by the Tishomingo–Belton horst and the stable cratonic shelf.

The NW-trending southern Oklahoma geosyncline may have connected the Rocky Mountain geosyncline (Cordilleran) to the northwest and the Bryan basin part of the Ouachita geosyncline to the southeast. The geosyncline is characterized throughout much of its trend by great thicknesses of Paleozoic strata: 37,500 ft (Upper Cambrian through Permian) in the western Anadarko basin and 30,000 ft (Upper Cambrian through Pennsylvanian) in the Ardmore and Bryan basins. According to Ham and Wilson (1967, p. 393), sedimentation in the southern Oklahoma geosyncline resulted in two depositional phases, an Upper Cambrian–Lower Devonian carbonate sequence (11,000 ft) and an Upper Devonian–Permian clastic sequence (27,000 ft maximum). The carbonate sequence is often referred to as the Arbuckle facies of the Ardmore and Anadarko basins. The areas of maximum thicknesses for each formation do not coincide but reach their maximum along the depoaxis of the basin that lies northeast of the Wichita front (Huffman, 1959).

Major tectonic movements in the southern Oklahoma geosyncline began in post-Hunton, pre-Woodford time, as evidenced by uplift and erosion of Hunton strata on the Aylesworth–Madill anticlinal flexure and the unconformity at the base of the Woodford. Additional movement during Carboniferous time gave rise to reworked and "exotic" boulders of Arbuckle rocks seen in the Johns Valley Formation.

Three major episodes of folding and faulting characterize Pennsylvanian history. The first episode, the Wichita orogeny, produced the Wichita–Criner Hills line of folds, elevated the Hunton anticline and the Pauls Valley uplift, and initiated many of the hydrocarbon-bearing structures of southern Oklahoma.

The second episode of deformation was during early to middle Desmoinesian time (Ham and Wilson, 1967, p. 398). Conglomerate-bearing beds of the Arbuckle facies of the Deese and Hoxbar Groups unconformably overlie older rocks in the Arbuckle Mountains and Criner Hills. In the Ardmore basin, the Devils Kitchen and Rocky Point Conglomerates of the Desmoinesian Series record important movements in the Bryan basin (Bryan Uplift). The culminating deformation of the second episode involved strong compression. Most of the folds in the Arbuckle anticline, Criner Hills, Ardmore basin, Marietta basin, Bryan basin, and Anadarko basin originated at this time (Ham and Wilson, 1967, p. 398). Orogenic conglomerates, the Collings Ranch and Vanoss (Pontotoc), indicate two phases of the Arbuckle orogeny, one in middle Virgilian and one in late Virgilian time. The major NW-trending faults of the Arbuckle complex are post-Collings Ranch and pre-Vanoss, inasmuch as these faults die out in the Vanoss (Ham, 1969, p. 18).

In the third and final episode of deformation, rocks of the Marathon–Ouachita tectonic belt were uplifted and thrust northwestward onto rocks and structures of the Arbuckle facies. In the Atoka basin, the Ouachita facies appear to have been thrust northward north of the Potato Hills area and southward in the Broken Bow uplift area, the Lynn Mountain graben lying between (R.O. Fay, personal communication, 1978). Growth faults parallel to the Tishomingo–Belton horst may have had some lateral movement. In the southeastern part of the Ardmore basin, rocks of the Bryan basin (Ouachita facies) appear to have been moved northwestward into the downdropped block between the Bryan fault, which passes southwest of and parallel to the Madill–Aylesworth flexure, and the Criner Hills complex. Locally the "Ouachita front" may coincide with a line of abrupt facies change between Arbuckle and Ouachita facies.

The Marathon–Ouachita system, the Arbuckle Mountains, and surrounding areas remained high during the Permian and supplied sediments to the still-subsiding Anadarko basin and the Oklahoma platform, where Permian sediments reach a maximum thickness of 6,800 ft. Erosion and peneplanation characterized Triassic and Jurassic times in southern Oklahoma, where beds of these ages are absent.

During the Early Cretaceous, a shallow sea advanced into southern Oklahoma from the south, depositing the Antlers sandstone (and older units in McCurtain County) upon the sub-Cretaceous erosional surface. In parts of Johnston, Carter, and northern Marshall Counties, the Baum Limestone Member of the Antlers Formation was deposited in a lagoon, where brackish-water conditions locally prevailed. With subsequent stillstand of the sea, deposition of the carbonates and shales of the Goodland, Kiamichi, and Caddo Formations occurred. Renewed uplift produced the clastic sediments of the Bokchito Formation, which were deposited in nearshore, littoral, and possibly deltaic environments. Marine inundation and stillstand resulted in deposition of the Bennington Limestone and the Grayson Marlstone. Post-Grayson regression was followed by transgression of the Late Cretaceous (Woodbine and Eagle Ford) sea to complete the apparent depositional history of southern Oklahoma. Nearby volcanic centers, probably in Arkansas or Louisiana, supplied abundant tuffaceous material to the Woodbine Formation. Thickening and thinning of Cretaceous strata across Paleozoic synclines and anticlines and the reflection of Paleozoic structures in Cretaceous beds are probably the result of differential compaction across preexisting structures and renewed adjustment along the lines of Paleozoic folding and faulting.

Post-Cretaceous erosion removed all of the Upper Cretaceous beds from Marshall County except for ~35 ft of basal Woodbine preserved in the Kingston syncline. Tertiary sediments are absent. Extensive development of terraces and alluvial deposits with renewed downcutting during Pleistocene and Holocene time complete the geologic history of the area.

ECONOMIC GEOLOGY

Marshall County is well endowed with economic resources. Nonmetallic mineral products yielded $8,865,000 in 1975 (Table 6), the latest year for which figures are available. The economic products are (1) petroleum, (2) natural-gas liquids, (3) natural gas, (4) sand and gravel, and (5) stone. In addition, there is an abundant supply of fresh water from lakes and streams as well as from underground aquifers.

Oil and Gas

Approximately 15 oil and gas fields have been drilled and developed in Marshall County since the discovery well was drilled in 1909. Several of the fields have been combined, and others have been abandoned. In 1986, the following seven fields are producing: (1) Aylesworth, (2) Southeast Aylesworth, (3) Cumberland, (4) Isom Springs, (5) Southwest Isom Springs, (6) Madill, and (7) South Powell. As of January 1, 1985, the Cumberland field had produced 72,042,054 bbl; Madill had produced 15,298,335 bbl; and Aylesworth had produced 10,800,678 bbl. Aylesworth SE had produced 2,202,726 bbl; Isom Springs had produced 3,725,130 bbl; Powell South had produced 840,360 bbl; and Isom Springs SW had produced 416,845 bbl (Table 3). To January 1, 1977, Madill had produced 33,120,187 Mcf of gas; Aylesworth 3,378,909 Mcf; and Cumberland 1,463,303 Mcf. Several of the older fields, including Duffy, Kingston, and Southeast Mannsville, have been abandoned. Renewed activity in the area includes the recent discoveries in the Ouachita cherts in the Isom Springs area. Most of the production is from Paleozoic rocks, including the Oil Creek, McLish, and Bromide sandstones in the Simpson Group; the Misener–Hunton, Woodford, Sycamore; and several sandstones in the Pennsylvanian. Shallow production is from the basal Cretaceous Trinity (Antlers) sandstone. (See also Part II of this report.)

Figure 29 shows the locations of oil and gas fields in Marshall County. Several small, one- or two-well fields—including Tyler, SE Simpson, SE Enville (abandoned), Willis, North Willis, East Willis, SE Kingston, and NE Kingston—are shown, as well as those fields with greater production.

Stone

Limestone for agricultural lime, road material, concrete aggregate, and building stone is abundant in Marshall County. The most valuable stone is probably the Goodland Limestone, which has been quarried for many years, although no important operations are in progress at this time. The Baum Limestone in northern Marshall County and southern Johnston County has been used for production of agricultural lime. According to Wayland and Ham (1955, p. 19), the area in Johnston and Carter Counties having the highest-purity Baum Limestone has not been quarried; the potential for economic quarrying of high-calcium limestone in Marshall County is not great.

Sand and Gravel

Sand and gravel are abundant in Pleistocene terrace deposits, and some sand and gravel has been taken from pits in the southwestern part of the county for road-surfacing materials.

Clay and Shale

Clays and shales are present in several formations, including the Kiamichi, Caddo, Bokchito, and Grayson. Currier (1968, p. 51) noted that, of these formations, the clays in the Bokchito seem most promising. The clay minerals in the Bokchito are illite, kaolinite, and an expandable clay, probably montmorillonite. Huffman and others (1975) collected samples from an exposure of the Denton Clay Member of the Bokchito near Soper, Choctaw County, Oklahoma, for analysis by the Oklahoma Geological Survey. Tests indicated that the pres-

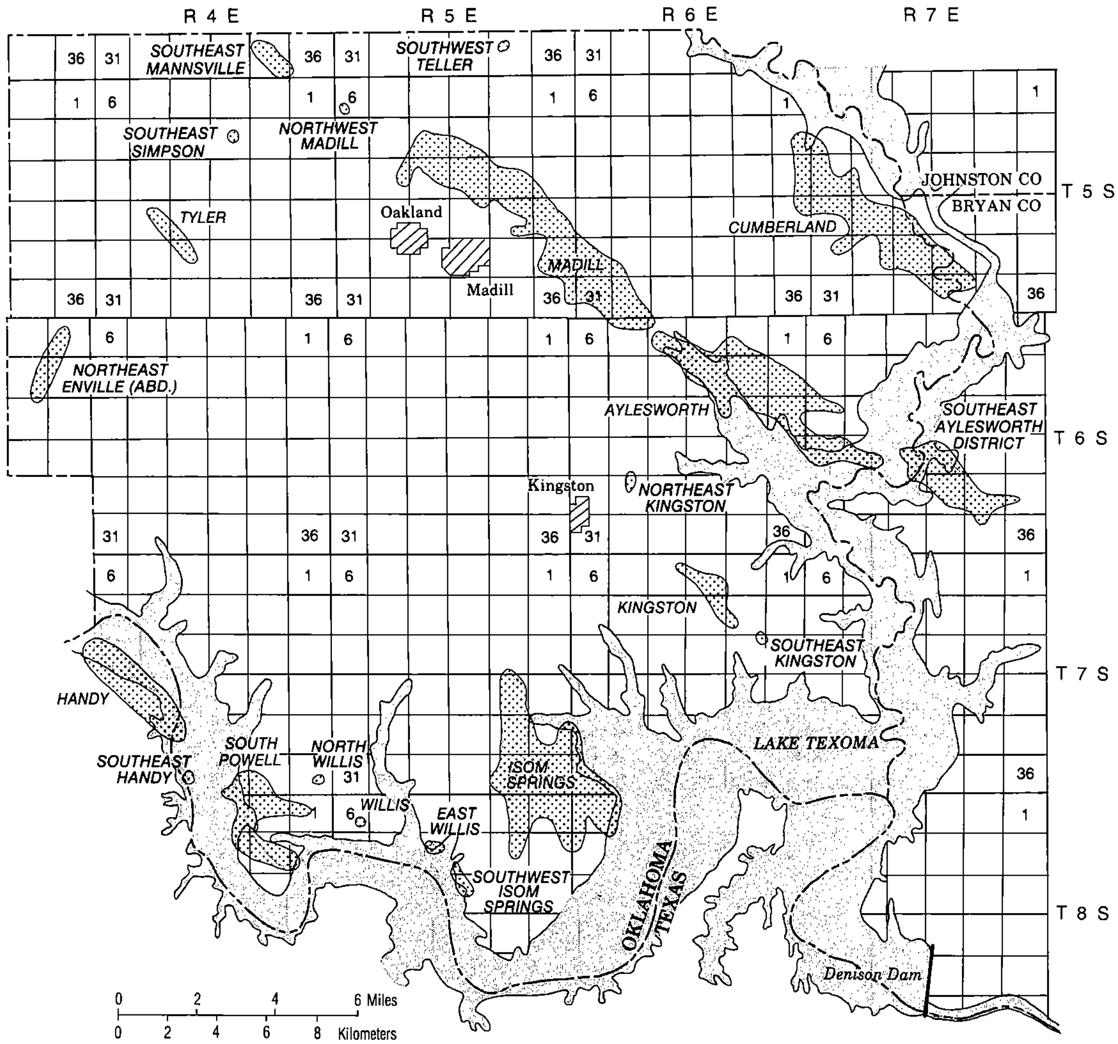

Figure 29. Oil and gas fields in Marshall County.

ence of montmorillonite and the relatively high shrinkage factor of the fired material rendered this clay unfit for making high-quality brick.

Water Supplies

One of the greatest natural resources in Marshall County is the abundant supply of water. Lake Texoma and the Washita River provide the most abundant and readily available supplies. In northwestern Marshall County, lakes have been constructed for community and farm supplies. City Lake and Carter Lake supply water to Madill and nearby Oakland. Lake Oteka has been built for a rural water supply. The most promising aquifer is the Antlers sandstone, which carries large amounts of ground water (Hart and Davis, 1981).

Water is also available for recreational purposes, and for the generation of hydroelectric power at Denison Dam on Lake Texoma.

Part II

Petroleum Geology

George G. Huffman
Michael L. Merritt

PART II. PETROLEUM GEOLOGY

George G. Huffman and Michael L. Merritt

INTRODUCTION

Marshall County lies in the coastal plain province of southern Oklahoma and Texas. Surface rocks are of Cretaceous age and dip gently into the Cumberland–Kingston syncline, a combined structure that is the southeastward extension of the Ardmore basin (Pl. 2). The Cretaceous strata are superposed on preexisting Paleozoic folds and faults, which largely control hydrocarbon accumulations. The folds and faults trend SE from the Arbuckle Mountains, Ardmore basin, and Criner Hills. Draping of Cretaceous strata over these older structures and subsequent adjustment along these structures has only slightly deformed the Cretaceous strata.

Precambrian basement rocks (Tishomingo Granite) underlie the Cretaceous rocks directly northeast of Marshall County in the upthrown block of the Washita Valley fault in northern Bryan and southern Johnston Counties. Beneath most of Marshall County, Paleozoic rocks of the Arbuckle facies, ranging in age from Ordovician (Viola Group) to Pennsylvanian (Hoxbar), subcrop under the Cretaceous cover. In southeastern Marshall County, the Ouachita facies, composed of Paleozoic cherts, slates, and graywackes, lies directly beneath the Cretaceous Antlers sand.

There are several major oil fields in Marshall County. The Cumberland field, in the northeastern corner of the county, produces from Simpson sandstones on the Cumberland anticline. The Cumberland anticline is a nearly symmetrical fold lying directly southwest of the Cumberland and Washita Valley faults. The Mannsville, Madill, and Aylesworth fields are on anticlinal uplifts associated with the Mannsville–Madill–Aylesworth fault system. Several smaller fields in southern Marshall County (e.g., Powell, Southwest Isom Springs) produce from complexly faulted structures related to an extension of the Criner Hills fault system. Shallow fields, including the Kingston (abandoned), Enos, and Isom Springs, have produced from basal Cretaceous sands. Recent discoveries in the Ouachita facies in the Enos–Isom Springs area are believed to be related to thrusting across the Preston uplift.

Numerous papers have been written concerning hydrocarbon production in Marshall County and adjacent counties, but none has included a complete subsurface interpretation for the entire county. Papers closely related to the subsurface geology of Marshall County include those by Cram (1948), Godfrey (1956), Gahring (1959), Womack (1956), Prewit (1961), Bradfield (1959), Reed (1959), Beckman and Sloss (1966), Harlton (1966,1976), Frederickson and others (1965), Huffman (1976), and Huffman and others (1978).

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SUBSURFACE STRATIGRAPHY

Precambrian Basement Rocks

Precambrian basement rocks have not been found at the surface or in the subsurface in Marshall County. Directly northeast of the northeastern corner of Marshall County, Precambrian rocks occupy a large block, the Tishomingo–Belton horst, between the Sulphur fault on the northeast and the Washita Valley (Ravia) fault on the southwest. The Precambrian Tishomingo Granite crops out over ~180 mi^2 in Johnston County and underlies the Cretaceous over ~360 mi^2 in Bryan County (Fig. 27).

The Tishomingo Granite is a medium- to coarse-grained pink, porphyritic rock with an average composition of 70% feldspar, 22% quartz, and 2–5% biotite. Accessory minerals are magnetite, apatite, zircon, and sphene. Radiometric dating, based on zircons containing isotopes of uranium, thorium, and lead, indicates an age of 1.35 b.y. for the granite (Ham, 1969, p. 45). Also present are dikes and sills of diabase and biotite–hornblende diorite. An Rb^{87}/Sr^{87} determination on biotite from the diorite in the Phillips 1 Matoy well (sec. 24, T5S, R11E, Bryan County, gave an age of ~1.2 b.y., which places the rock in the Precambrian (Ham and others, 1964, p. 127).

Precambrian rocks have not been penetrated by wells in Marshall County. Presumably such rocks lie beneath the thick lava flows of the Cambrian(?), which underlie the southern Oklahoma geosyncline.

Cambrian(?) Basement Rocks

Southwest of the Washita Valley fault and the Tishomingo–Belton horst, the basement rock is much younger and includes rhyolite and basalt flows cut by irregular plutons of gabbro and granite. The most widespread rock is the Carlton Rhyolite (Colbert Porphyry of the Arbuckle Mountains), which attains a thickness of >4,500 ft and underlies >7,000 mi^2 in southern Oklahoma. A radiometric age determination of 525 m.y. (Ham, 1969, p. 7) indicates that the main body of the rhyolite is Middle Cambrian.

These rhyolites of the Wichita Mountains province extend from the Muenster–Waurika fault on the southwest to the Washita Valley fault on the northeast. According to Ham and others (1964, p. 127), the Carlton Rhyolite flows were bounded on the northeast by an upthrown block of Precambrian granite, which formed a scarp against which the flows were terminated.

The Carlton Rhyolite has not been penetrated by drilling in Marshall County. Projections by Ham and others (1964, pl. 2) indicate a subsea depth to the Carlton Rhyolite of −8,000 ft on the Mannsville anticline, −13,500 ft on the North Madill structure, −12,500 ft on the Madill–Aylesworth anticline east of Madill, −10,500 ft on the Aylesworth structure in westernmost Bryan County, and −24,000 ft in southern Marshall County (T8S, R5E). A maximum depth of −30,000 ft was indicated for the area near Kingston.

Cambrian–Ordovician Rocks

Reagan Sandstone.—The Reagan Sandstone is the basal unit of the sedimentary section in Oklahoma. Named for exposures near the town of Reagan in Johnston County, the Reagan is 75–450 ft thick and is absent above local basement highs that stood as granite islands in the Late Cambrian sea. The Reagan is a feldspathic, glauconitic sandstone assigned to the Dresbachian Stage of the Upper Cambrian Croixan Series. It has not been penetrated by wells in Marshall County, but has been reported in wells near Durant in nearby Bryan County (Huffman and others, 1978, p. 54). Its thickness is 90–160 ft.

Honey Creek Limestone.—The Honey Creek Limestone includes ~100 ft of gray pelmatozoan limestone that grades into fossiliferous, sandy dolomite (Ham, 1969, p. 8). The Honey Creek has not been penetrated in Marshall County, but has been reported in wells near Durant in Bryan County (Huffman and others, 1978, p. 54), where its thickness is 135–188 ft.

Arbuckle Group

In the Arbuckle Mountains, the Arbuckle Group of Cambrian–Ordovician age includes a maximum of 6,700 ft of gray, fossiliferous, shallow-water carbonates. In the Healdton field, in Carter and Jefferson Counties to the west, the group reaches a thickness of 8,700 ft (R. O. Fay, personal communication, 1983). Included in the Arbuckle Group are interbedded thin calcilutites, calcarenites, stromatolitic limestones, and laminated dolomites or dolomitic limestones (Ham, 1969, p. 8). These beds are assigned to the Upper Cambrian Franconian and Trempealeauan Stages and to the Lower Ordovician Canadian Series.

Cram (1948, p. 348) described the upper 686 ft of Arbuckle in the Cumberland field as buff to light and dark brown, granular to dense dolomite with beds of dense, buff to brown limestone. Womack (1956, p. 381) described the upper part of the Arbuckle in the Aylesworth field as 600 ft of white to brown, very finely crystalline, cherty, dolomitic limestone, with some white, medium-grained, tightly cemented sandstone. More than 457 ft of Arbuckle limestone was drilled in the Texaco 1 Chapman well (sec. 35, T4S, R4E) in the Southeast Mannsville field. Approximately 2,500 ft was drilled in the American Quasar Petroleum 1-11 Federal well (sec. 11, T8S, R4E) in the South Powell field.

More than 4,500 ft of Arbuckle limestone was drilled in Bryan County in the Ravia nappe (T6S, R8E; Huffman and others, 1978, p. 54). Only the upper Arbuckle (West Spring Creek Formation) has been completely penetrated in Love County to the west; these rocks are light-tan, semi-dense, slightly dolomitic limestones, sucrosic dolomites; thin beds of poorly cemented, medium-grained sandstone; dolomitic limestones; and fine-grained to sucrosic dolomites (Westheimer, 1965, p. 51).

Simpson Group

Joins Formation.—The Joins Formation, the basal division of the Simpson Group, comprises 160–211 ft of white to brown, finely crystalline limestone that in places is slightly dolomitic and sandy. At Cumberland, the Joins has been described as including 201 ft of dolomite, limestone, and sandstone with a basal sandstone 14 ft thick (Cram, 1948, p. 348). Godfrey (1956) described the Joins as comprising some 200 ft of tan to brown, finely crystalline, slightly dolomitic limestone. Womack (1956) reported 160 ft of white to brown, finely crystalline, slightly dolomitic, sandy limestone at Aylesworth. According to Merritt (1978, p. 19), the Texaco 1 Chapman well (sec. 35, T4S, R4E; Southeast Mannsville field) drilled 180 ft of Joins.

Westheimer (1965, p. 51) described the Joins Formation of Love County as consisting of two units, a lower dolomitic member (100–150 ft thick) and an upper limestone member (100–150 ft). The dolomite member has produced in several wells in the North Thackerville field.

Oil Creek Formation.—The Oil Creek Formation consists of nearly 1,000 ft of shale, thin-bedded limestone, and sandstone. According to Womack (1956, p. 381), the upper 800 ft is mostly green shale and thin-bedded limestone in the Aylesworth field. The shales (in contrast to the emerald-green shales in the McLish Formation) are dull gray-green and can be identified by the ubiquitous ostracode *Aparchites* (J. M. Westheimer, personal communication, 1977). The limestones are white to brown, fine- to medium-grained, and slightly dolomitic and sandy. The basal 200 ft consists of medium-grained quartz sandstone with well-rounded grains and calcareous cement, changing to sandy limestone in the upper 25 ft.

In the Cumberland field (Cram, 1948, p. 347), the upper part of the Oil Creek Formation comprises 465 ft of coarse-grained limestone and green shale. Underlying this upper part is the first Oil Creek sand, which averages 180 ft in thickness and commonly carries oil and gas shows. Below the first Oil Creek sand is a 30-ft limestone, which overlies a 30-ft bed of tight, calcareous sandstone. The second Oil Creek sand is 210 ft thick; it is composed of well-rounded quartz grains and is an important oil producer. In the Pure 2 Little 210 well, (SW¼SE¼NW¼ sec. 34, T5S, R7E), the Oil Creek Formation comprises 890 ft of limestone, green shale, and sandstone.

The basal sandstone of the Oil Creek Formation is the most important producing zone in Love County (Westheimer, 1965, p. 51–52), where it ranges from 0 to >100 ft in thickness. It appears to represent a beach deposit of a transgressive sea and is limited to easternmost Love County. It is overlain by 800 ft of dull-green shales and thin beds of chalky limestone with abundant *Aparchites*. The uppermost 150 ft of the Oil Creek comprises an oolitic limestone member overlain by the dense "birdseye"-type limestone.

In the South Powell field, in southern Marshall County, the American Quasar Petroleum 1-11 Federal well (sec. 11, T8S, R4E) was completed as a gas well in a 90-ft section of basal Oil Creek sandstone.

McLish Formation.—The McLish Formation is 475–575 ft thick. In the Cumberland field, the upper 400 ft comprises finely crystalline, light-brown limestones and coarsely crystalline, gray-white limestones interbedded with streaks of fine, tight, calcareous, glauconitic sandstone. The basal McLish sandstone makes up the lower 100 ft of the formation; it is one of the main producing zones in the field (Cram, 1948, p. 347). In the Pure Oil Co. 2 Little 210 well, the McLish includes 497 ft of calcareous sandstone, green shale, and limestone, with 114 ft of oil-productive sandstone at the base.

In the Aylesworth field, the McLish is 575 ft thick. The upper 450 ft comprises thin, interbedded, white or gray to brown limestones; green shales; and fine-grained, tight to loosely cemented, argillaceous sandstone. The lower 125 ft is a fine- to medium-grained, porous, massive sandstone, with minor thin streaks of green shale (Womack, 1956, p. 381); this is the "basal" McLish sandstone. The limestones in the McLish Formation are generally coarser-grained than those in formations above and below (J. M. Westheimer, personal communication, 1977).

Gahring (1959, p. 281–282) described the McLish as comprising 475 ft of limestone, shale, and sandstone in the North Madill field. There, a 20-ft, finely crystalline, ostracode-bearing limestone is underlain by 360 ft of white or gray to brown limestones and green shale. A fine-grained sandstone occurs 160 ft below the top of the formation in some wells, where the basal McLish sandstone is a fine-grained, porous, shaly sandstone that carries oil stain.

The basal McLish sandstone produces oil in the North Madill, Southeast Mannsville, and Cumberland fields, but is water-bearing at Aylesworth (Godfrey, 1956, p. 120). At Southeast Mannsville, five wells produced 347,000 bbl from the basal McLish sand in 12 yr (Merritt, 1978, p. 22).

Tulip Creek Formation.—The Tulip Creek Formation averages 315 ft in thickness in the Aylesworth field, where it was described by Womack (1956, p. 380). There the upper 110 ft comprises green shales and interbedded limestones, which overlie a 65- to 135-ft sandstone known as the "second Bromide sand." The second Bromide sand is fine- to medium-grained and subangular; it is interbedded with subordinate amounts of green shale and carries oil shows in several fields. Directly below the second Bromide sand is a dense, white to buff, slightly dolomitic limestone that is 5–50 ft thick. Below this limestone is the "third Bromide sand" ("Tulip Creek sand"), which is a major producing zone. It is described as a fine- to medium-grained, tightly to poorly cemented, sandstone with subangular to rounded grain, carrying oil shows and interbedded with green shale. The third Bromide or Tulip Creek produces oil and gas in the Aylesworth and Cumberland fields.

Bromide Formation.—The Bromide Formation is ~350 ft thick in the Aylesworth field (Womack, 1956, p. 380), where it comprises three units (descending order): a white to buff limestone commonly referred to as the "Bromide dense" (Pooleville Member; 100 ft); green, waxy shales and dense to coarsely crystalline, white to brown limestone that is locally sandy (upper Mountain Lake Member; 150–250 ft); fine-grained, oil-stained sandstone interbedded with green shale ("first Bromide sand," or lower Mountain Lake Member; 125–135 ft).

Bromide–Tulip Creek (Undifferentiated).—In many oil fields in southern Oklahoma, operators make little or no attempt to separate the Tulip Creek and Bromide Formations. In the Cumberland field, Cram (1948, p. 345,346) described the "Bromide" as comprising 630 ft of limestone, shale, and sandstone. He described the upper 280 ft as limestones interbedded with green shale and sandy limestones. The 350-ft-thick lower part of the "Bromide" contains three sands, which produce oil in the Cumberland field. The first Bromide sand, a fine- to medium-grained sandstone with subangular grains, is 110 ft thick. The second Bromide sand averages 135 ft in thickness and consists of fine to medium, subangular to rounded sand grains. The third Bromide sand averages 105 ft in thickness and is a fine- to medium-grained, tight sandstone composed of subangular to rounded grains. In the Pure Oil Co. 2 Little 210 well (Cumberland field), the combined thickness of the Bromide and Tulip Creek Formations is 486 ft.

In the North Madill Field, Gahring (1959, p. 281) described the "Bromide" as comprising 675 ft of limestone, shale, and sandstone. There, the top is a gray to buff, dense limestone (15 ft) known as the "Bromide dense." Beneath this is 50 ft of white, coarsely crystalline limestone; 70 ft of smooth green shale; 90 ft of coarsely crystalline limestone; and the first Bromide sand zone, comprising two sands separated by 30 ft of green shale. The second Bromide sand is 175 ft below the top of the first Bromide sand, the interval between being composed of green shale and thin-bedded limestone. The second Bromide sand is about 80 ft thick and consists of fine- to medium-grained, tight to porous sandstone. Beneath the second Bromide sand is 25 ft of dense limestone underlain by 20 ft of green shale with thin limestone interbeds. The Tulip Creek sand (third Bromide sand) is composed of 120 ft of fine-grained, well-cemented, slightly porous, iron-stained sandstone.

In Love County (Westheimer, 1965, p. 54), the "Bromide" consists of 700 ft of fine-grained, calcareous sandstones; emerald-green shales; arenaceous, ostracode-bearing limestones; and light-gray, dense limestone.

In the South Powell Field, in southern Marshall County, the American Quasar Petroleum 1-11 Federal well (sec. 11, T8S, R4E) drilled 730 ft of Bromide.

Viola Group

The Viola (= "Viola Limestone" or "Viola Formation" of previous reports) was raised to group rank and divided into two formations, an upper Welling Formation (= "Fernvale") and a lower Viola Springs Formation (= "Viola Trenton") by Amsden (1983, p. 1).

The Welling Formation or "Fernvale" limestone is a coarsely crystalline, fossiliferous limestone that is 25–37 ft thick in northwestern Bryan County (Huffman and others, 1978). Beneath the Welling is 500–600 ft of limestone of the Viola Springs Formation, a fine- to medium-grained, off-white to brown, dolomitic limestone with beds of tan to brown chert. The lower 150 ft is differentiated from the rest of the Viola Springs by its dark-brown color (Cram, 1948, p. 345). In the Cumberland Field, the Viola Group is 444–550 ft thick. In the Southeast Aylesworth field, it is ~575 ft thick, in the Aylesworth ~625 ft, and in the North Madill 630 ft. In Love County and elsewhere in southern Oklahoma, an aggregate thickness of 950–1,000 ft has been reported (Westheimer, 1965, p. 54).

Sylvan Shale.—The Sylvan Shale ranges in thickness from 280 ft in the Cumberland field (Cram, 1948, p. 345) to 330 ft in the Aylesworth field (Womack, 1956, p. 379). The upper 175 ft is a pale-gray-green, nonsandy shale, whereas the lower 125 ft is light- to dark-brown, dolomitic shale containing a 20- to 30-ft-thick bed of finely crystalline, graptolitic dolomite near the base (Womack, 1956, p. 378). In the Pure Oil Co. 2 Little 210 well (sec. 34, T5S, R7E) in the Cumberland field, 235 ft of Sylvan was logged.

Silurian–Devonian Rocks

Hunton Group

The Hunton Group, comprising four formations, is 0–300 ft thick. It is divided into the basal Chimneyhill Formation (30 ft), Henryhouse Shale (25 ft), Haragan Marlstone (145 ft), and Bois d'Arc Limestone (100 ft). Isopach studies by Godfrey (1956, pl. 2) indicate a maximum thickness of slightly more than 300 ft in the Cumberland area. The Hunton is thin or missing along the axis of the Mannsville–Madill–Aylesworth flexure as a result of pre-Woodford erosion.

The Chimneyhill Formation includes a basal oolitic member (5 ft), a middle glauconitic member (10 ft), and an upper pink, crinoidal member (20 ft), for a total of 35 ft. The Henryhouse Formation comprises 25 ft of gray, argillaceous limestone and red, finely crystalline limestone, the upper parts having been removed by pre-Haragan erosion. The Haragan Formation is a green to gray, argillaceous limestone or marlstone (100 ft), which is overlain by the Bois d'Arc Formation, which comprises ~100 ft of coarsely crystalline, gray to white, glauconitic and cherty limestone.

Woodford Formation.—The Woodford Formation overlies the Hunton Group in normal sequence. The upper part of the Woodford comprises 70 ft of hard, dark-brown shale with thin interbeds of dark-brown chert. The underlying 280 ft comprises hard, coffee-brown shale with abundant "spores" (probably the alga *Tasmanites*). The basal 40 ft is green, silty shale (Gahring, 1959, p. 280). The Woodford Formation has a thickness of 236 ft in the Pure Oil Co. 2 Little 210 well, in the Cumberland field; 380 ft in the Aylesworth field (Womack, 1956, p. 379); and 390 ft in the North Madill Field (Gahring, 1959, p. 280).

On the northeast flank of the Madill–Aylesworth structure, the "Mannsville" dolomite occurs beneath the Woodford shale and carries oil in an updip wedge-out (Beckman and Sloss, 1966, p. 1359). According to J. M. Westheimer (personal communication, 1977), the "Mannsville" dolomite commonly is a conglomerate composed of chert pebbles (not Woodford) and coarse, rounded quartz grains. It appears to have been deposited during the erosional interval between the Woodford and the underlying Hunton (or Sylvan, where the Hunton is missing); it may be similar to the "Misener" clastic sequence, which occurs in parts of Oklahoma north of the Arbuckle Mountains.

Mississippian Rocks

Sycamore Limestone.—The Sycamore Limestone conformably overlies the Woodford Shale. The Sycamore includes 175–275 ft of light-brown, finely crystalline, highly silty, micaceous limestone or calcareous siltstone, often referred to by subsurface geologists as the "Mayes." In the Aylesworth field, the Sycamore is 60–225 ft thick (Womack, 1956, p. 378). The Sycamore is 247 ft thick in the Pure Oil Co. 2 Little 210 well, in the Cumberland field.

Cram (1948, p. 343) noted an average thickness of 260 ft for the Sycamore in the Cumberland field. The upper four-fifths of the formation was described as light-brown, calcareous, micaceous, siliceous siltstone. A persistent, light-brown, dense limestone member (20 ft) occurs 50–60 ft above the base. Below this member is a tight, calcareous, glauconitic siltstone that commonly carries a gas odor. A 5-ft bed of pale-green shale marks the base of the formation.

"Caney" (Delaware Creek) Shale[6].—The "Caney" shale is a brownish-black, fissile shale, 200–500 ft thick, averaging 400 ft. It is currently assigned to the Meramecian and Chesterian Series (Mississippian). Godfrey (1956, p. 119) noted a glauconitic zone near the top and described the basal beds as silty.

In the Pure Oil Co. 2 Little 210 well, in the Cumberland field, the "Caney" is 335 ft thick and comprises interbedded black shale and thin limestones. In other wells in the Cumberland field, the "Caney" is 405 ft thick. It is 500 ft thick in the North Madill Field and reaches a thickness of 655 ft in the Southeast Aylesworth field (Merritt, 1978, p. 33).

"Springer"–Goddard Shale[7].—Lying above the "Caney" shale is a sequence of dark-gray to brown, sideritic shales and lenticular sandstones 0–2,500 ft thick. Geologists have assigned these beds variously to the "Caney," Goddard, and "Springer" and placed them in both the Mississippian and Pennsylvanian Systems. The Goddard embraces those shales below the first sandstone marker bed at the base of the "Springer" (restricted), and overlying beds have been termed "Springer." In the Ardmore basin, the Rod Club Sandstone Member is placed at the base of the "Springer."

The Goddard Shale is now assigned to the Late Mississippian Chesterian Series. The overlying "Springer" formation has been assigned to the Mississippian by some and to the Pennsylvanian by others. Beckman and Sloss (1966) postulated a major unconformity and channeling at the base of the Goddard and assigned thicknesses of ~4,000 ft to the Goddard. Other geologists do not accept this interpretation and attribute this abnormal thickness to structural complications.

In the Cumberland field, the "Springer"–Goddard sequence is 1,800–2,800 ft thick, the thickest parts being on the flanks of the structure. According to J. M. Westheimer (personal communication, 1977), Morrowan shales may overlie the Goddard in the Cumberland field, and the "Springer" equivalents are missing. For the North Madill field, Gahring (1959, p. 280) assigned a thickness of 700–1,200 ft to the Goddard formation, which he described as gray, fine-textured shale with interbeds of gray, fissile shale and siderite concretions. He assigned 1,200–1,300 ft of light-gray shale to the "Springer" formation. Godfrey (1956) recognized 2,000 ft of Goddard in the Aylesworth field.

[6]The Delaware Creek shale generally is recognized by the Oklahoma Geological Survey; it replaces the "Caney."

[7]The validity of the term "Springer" is questioned by the Oklahoma Geological Survey.

Pennsylvanian Rocks

Lower Dornick Hills Group

Golf Course Formation.—The lower Dornick Hills Group has been recognized by several writers. In the Ardmore basin, the lower Dornick Hills is the equivalent to the Golf Course Formation, which includes the Lake Ardmore Sandstone Member, Primrose Sandstone Member, Jolliff and Otterville Limestone Members, and associated unnamed shales. North of the Arbuckle Mountains, the Union Valley and Wapanucka Formations are correlated with the Golf Course Formation and are assigned to the Morrowan Series.

Gahring (1959, p. 276) described the lower Dornick Hills Group as comprising 700–1,700 ft of light-gray, fine-textured shales with thin beds of siderite and a thick bed of glauconitic shale near the base. According to Godfrey (1956, p. 117), the lower Dornick Hills reaches a thickness of 4,000 ft on the northeast side of the Madill–Aylesworth anticline and is present in the southwest part of the Cumberland field. The sequence also has been recognized in wells in northwestern Bryan County (secs. 20 and 24, T6S, R8E; Huffman and others, 1978, p. 57).

In Love County, Westheimer (1965, p. 57) recognized 3,200–3,300 ft of Dornick Hills sediments (corrected for dip). There, the lower Dornick Hills is represented by the Joliff Limestone Member and overlying beds (1,100 ft) of sandy limestones, cherty shale, and oolitic limestones of the Wapanucka facies.

Upper Dornick Hills Group

Lake Murray and Big Branch Formations.—In the Ardmore basin, the Lake Murray Formation comprises the Bostwick Conglomerate Member, the Davis Sandstone Member, the Lester Limestone Member, the Frensley Limestone Member, and unnamed shales, with a total thickness of ~2,000 ft. The Big Branch Formation includes the Pumpkin Creek Limestone Member and associated shales, with a thickness of ~680 ft (Lang, 1966, p. 15–17).

In Love County, Westheimer (1965, p. 57–58) recognized 2,135 ft of upper Dornick Hills, including an 800-ft section of shale and conglomerate (Bostwick Conglomerate Member); 325 ft of gray shale; a 110-ft zone of thin sandstones and intercalated shales ("micaceous sand," or "Davis sand"); 200 ft of arenaceous, oolitic, brown limestone (Lester Limestone Member); 700 ft of fine-grained sandstones, gray and maroon shales; and two limestone members, the Frensley and Pumpkin Creek.

In Marshall County, the upper Dornick Hills (Godfrey, 1956, p. 117) includes 2,100 ft of fine- to medium-grained, calcareous sandstone alternating with gray, calcareous, silty, micaceous shale and a few beds of gray-brown, fossiliferous limestone. Dornick Hills rocks appear to be present on both flanks of the Madill–Aylesworth anticline, in the Cumberland syncline, and in the Kingston syncline. Equivalent beds are present in the South Powell and Southwest Isom Springs fields of southern Marshall County and in the Handy field of northern Grayson County, Texas.

Upper Dornick Hills strata are believed to be present in wells in northwestern Bryan County, Oklahoma (secs. 20 and 24, T6S, R8E).

Deese Group

The Deese Group (Desmoinesian) reaches a maximum thickness of 8,000 ft in the Ardmore basin, where it is divided into the Millsap Lake and West Arm Formations. Prominent named members include (in ascending order) the Devils Kitchen Conglomerate, Arnold Limestone Member, Rocky Point Conglomerate Member, Williams Member, and Natsy Sandstone Member.

Many important oil-producing sands occur in the Deese. These include the "Tussy sands," the "*Fusulina* sands," and the "Culberson sand," which are equivalent to the "Hewitt sands" of the Hewitt field. The "Hewitt sands" are divided into the "fourth Hewitt sand" ("lower Lone Grove"), "third Hewitt sand" ("upper Lone Grove"), "second Hewitt sand" ("Norris"), and "first Hewitt sand" ("Chubbee"). Other names have been applied to equivalent sands in other fields of southern Oklahoma.

Following other workers in southern Oklahoma, Westheimer (1965, p. 58–59) divided the Deese in Love County into the Millsap Lake and West Arm Formations. The Millsap Lake Formation ("maroon Deese") is composed of maroon and greenish clay and shale, gray shale, and numerous conglomerates. Some of the shales are conglomeratic. Individual oil- and gas-producing members include the Hudspeth ("Rocky Point conglomerate") and the Bruhlmeyer ("Lone Grove" equivalent). Above the Millsap Lake Formation lies 600–900 ft of gray shales, sandstones, conglomerates, thin limestones, and arenaceous, oolitic limestones. Near the top of the West Arm Formation is the "Chubbee sand," which comprises 100–400 ft of medium- to coarse-grained sandstone. Lower Deese beds (pre-Millsap Lake) include 1,000–1,800 ft of shales.

In northern Grayson County, Texas, and in the southern tip of Marshall County, Oklahoma, Desmoinesian strata are assigned to the Strawn Group. The lower Strawn, commonly known as the "gray Strawn," includes a maximum of 1,500 ft of gray shales, thin limestones, and sandstone. Important sands in the "gray Strawn" are the "Foster sand" and "Handy sand." The overlying "red Strawn" includes approximately 4,000 ft of maroon shales and sandstones. A basal shale section (600–1,200 ft) is succeeded by the "Ramsey–Best sand zone" (150–200 ft), followed by a maroon-shale section (2,000 ft) and the "Bruhlmeyer sand zone" (500 ft). Above the "Bruhlmeyer sand zone" is a gray-shale section (250–400 ft), which is overlain by the McMenamy Limestone (25–30 ft).

Deese sediments have been recognized in the Cumberland and Kingston synclines both northeast and southwest of the Madill–Aylesworth anticline (Godfrey, 1956, pl. 3), where the Deese consists of fine- to coarse-grained, calcareous, glauconitic sandstone alternating with gray, calcareous, micaceous, silty shale.

Hoxbar Group

The Hoxbar Group (Missourian) includes a maximum of 4,000 ft of gray to greenish-gray shales and thin limestone beds. A few thin sandstone beds, conglomerates, and coals are present in places. Included in the Hoxbar are the beds between the base of the Confederate Limestone and the unconformity at the base of the conglomerates of the Vanoss (Pontotoc) Group. The Hoxbar Group includes five persistent, named members, the Confederate Limestone, Crinerville Limestone, Anadarche Limestone, Daube Limestone, and Zuckerman Limestone. A coal bed in the Daube Member has been mined. The famous oil sands of the Healdton field also occur within the Hoxbar Group (Lang, 1966, p. 16).

Sedimentary rocks of Hoxbar age were identified in Love County by Westheimer (1965, p. 60), who described them as 1,600–2,000 ft of gray to greenish-gray shales containing four or five individual limestone zones, several thin sandstones, and a few conglomerates. The top of the Hoxbar was subjected to pre-Cisco (Virgilian) erosion; at places the upper beds have been eroded to considerable depth.

Operators have identified Hoxbar rocks in two wells in western Marshall County. The Parker 1 McKenzie well (sec. 26, T6S, R4E), found Cretaceous rocks resting on the Hoxbar at +333 ft and the top of the Deese at −2,157 ft, for a total thickness of 2,490 ft. The Union of California 1 Woody well found the Trinity (Antlers) resting on the Hoxbar at +335 ft.

Virgilian (Cisco) Rocks

Sedimentary rocks assigned to the Cisco Group in Love County (Westheimer, 1965, p. 60) attain a thickness of 2,600 ft in deeper parts of the Marietta basin, where they are composed of gray, greenish-gray, and maroon shales and cherty, conglomeratic sandstones. These beds are known as the "Vanoss Formation" in the Arbuckle Mountains and are included in the Pontotoc Group by some geologists.

The "Vanoss conglomerate" (Cisco Group) has not been reported in Marshall County, although it may be present in deeper parts of the Kingston syncline.

Ouachita Rocks

The Ouachita deep-water flysch facies is represented by a sequence of metamorphosed beds that were thrust onto the Arbuckle facies and overlapped by Cretaceous strata. Ouachita rocks are present in southern Bryan County and in southeastern Marshall County, where they occupy a structural belt between the Madill–Aylesworth anticline and the Sherman anticline in Texas. Wrench faulting along preexisting growth faults allowed the Bryan salient to move northwestward to its present position east of the Kingston fault. Earlier movement in the Bryan basin (Desmoinesian and later) had produced uplifts that supplied chert pebbles for the Devils Kitchen and Rocky Point Conglomerates and higher beds in the Hoxbar in the Ardmore basin (R. O. Fay, personal communication, 1978).

The Ouachita facies, where completely developed, includes the Womble Shale, Bigfork Chert, and Polk Creek Shale of Ordovician age; the Missouri Mountain Shale and Arkansas Novaculite of Silurian–Devonian–Mississippian age; and the Stanley Group, Jackfork Group, Johns Valley Shale, and "Atoka" formation of Mississippian and Pennsylvanian age. Harlton (1966, p. 1372, fig. 4) correlated Ouachita rocks with those in the Arbuckle Mountains; these correlations remain somewhat tentative, inasmuch as structural and stratigraphic relations of the Arbuckle facies and the Ouachita facies are not clearly understood, especially in the Ardmore basin.

Wells drilled in southeastern Marshall County pass directly from basal Cretaceous sands into the Stanley Group shales and chert. The Stanley is underlain by the Arkansas Novaculite, the Missouri Mountain Shale (or Slate), the Polk Creek Shale, the Big Fork Chert, and the Womble Shale. Recent discoveries in the Isom Springs area (T7–8S, R5–6E) have been completed by Westheimer and Neustadt in the Big Fork, Arkansas Novaculite, and Stanley chert section (Fig. 30).

Cretaceous System

Lower Cretaceous Rocks

Lower Cretaceous strata comprise (in ascending order) the Antlers Formation (200–600 ft); Goodland Limestone (15–25 ft); Kiamichi Formation (32–40 ft); Duck Creek Member of the Caddo Formation (110–130 ft); Fort Worth Member of the Caddo Formation (40 ft); Bokchito Formation, including the Denton Clay, Soper Limestone, Weno Clay, McNutt Limestone, and Pawpaw Sandstone Members (140 ft); Bennington Lime-

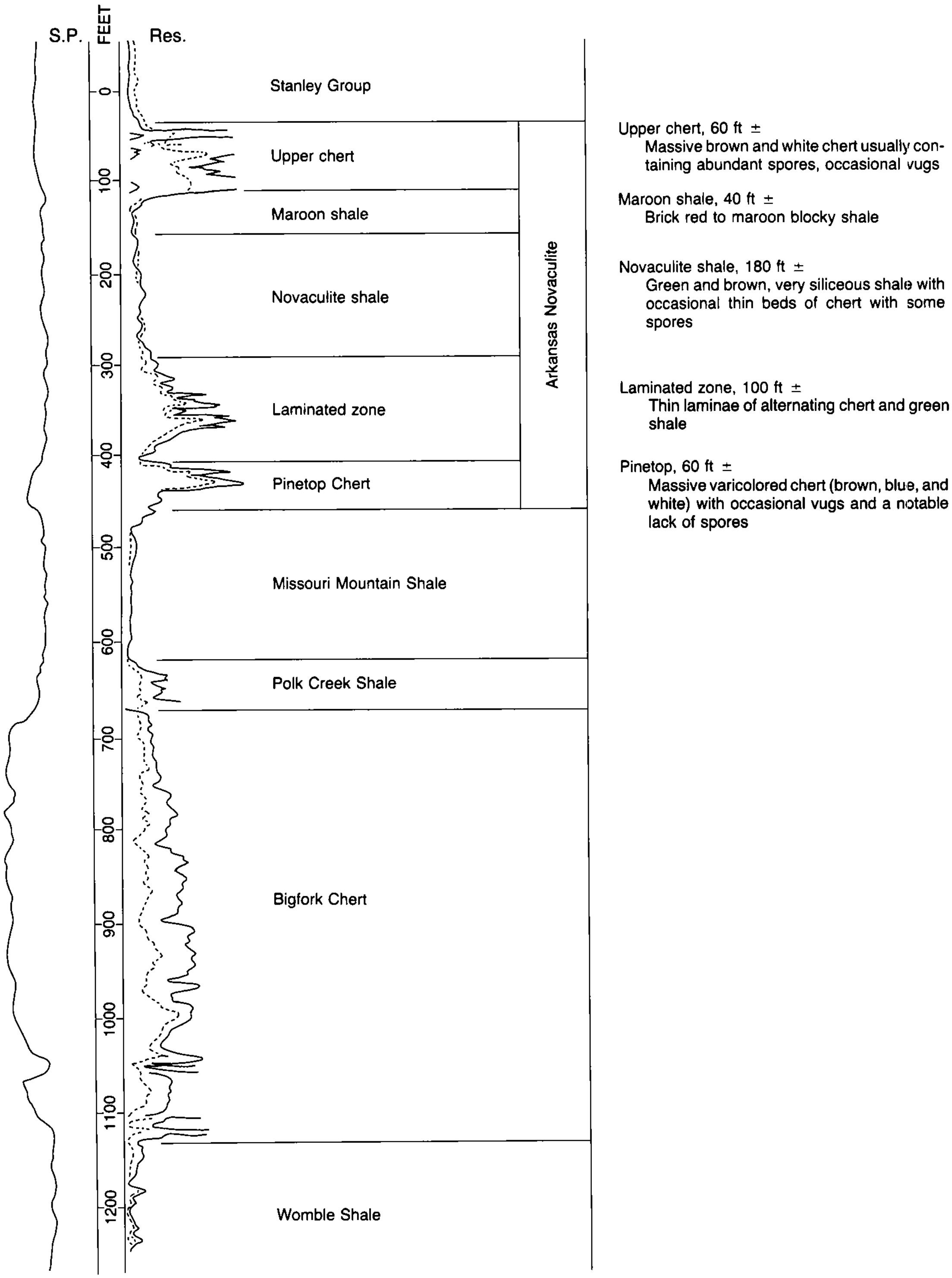

Figure 30. Composite log of Ouachita rocks in Bryan and Marshall Counties, Oklahoma, and Grayson County, Texas. (After Morrison, 1980, fig. 7.)

stone (1.5–2.5 ft); and Grayson Marlstone (0–15 ft).

Upper Cretaceous Rocks

Upper Cretaceous strata in Marshall County include only the basal member of the Woodbine Formation, the Dexter, a sandstone that attains a thickness of ~35 ft.

The distribution of pre-Cretaceous units is shown in Figure 31, a paleogeologic (subcrop) map.

Quaternary System

Pleistocene and Holocene Deposits

Cretaceous strata are overlain by various thicknesses of Pleistocene clay, sand, and gravel belonging to three distinct levels of terrace deposits and Holocene alluvium. (See Part I.)

SURFACE STRUCTURE

Major Tectonic Elements

The subsurface structure that affects the Paleozoic rocks and controls the accumulation of hydrocarbons beneath the onlapping Cretaceous is highly complicated, consisting of a series of NW-trending folds and faults extending from the Arbuckle Mountains, Ardmore basin, and Meers Valley–Criner Hills–Wichita complex and passing beneath and possibly into the Ouachita facies.

The major regional tectonic features, as well as those reflected in exposed Cretaceous strata, are discussed in Part I of this report and are not repeated here; this part of the report is restricted to those structures that relate specifically to oil and gas production in Marshall County. The regional tectonics have been discussed in other articles, namely those by Ham and others (1964), Harlton (1966), and Huffman and others (1978).

Tectonic features of importance to oil and gas production in Marshall County (Fig. 32) are (1) the Ravia block and associated nappes, (2) the Cumberland fault, (3) the Cumberland anticline, (4) the Cumberland syncline, (5) the Mannsville–Madill–Aylesworth fault system, (6) the Mannsville anticline, (7) the Madill anticline, (8) the Aylesworth anticline (9) the Kingston syncline, (10) the Bryan fault, (11) the Preston anticline, (12) the Overbrook thrust, (13) the Criner block, (14) the Bryan salient of the Ouachita system, and (15) the Bryan horst block.

Ravia Fault Block and Associated Nappes

The Ravia Fault block is a slender fault slice lying between the Washita Valley and Cumberland faults. The Washita Valley fault bounds the Ravia Block on the northeast, bringing Precambrian granites to rest on limestone of the Arbuckle Group. The Washita Valley fault is a high-angle reverse fault that extends southeastward from the southwest corner of T1N, R1W, in the western Arbuckle Mountains, to the southeast corner of T7S, R12E, where it passes beneath the Ouachita thrust sheet. The Ravia Fault block is bounded on the southwest by the Cumberland Thrust fault.

The Ravia block is ~35 mi long (Harlton, 1966, p. 1371) and 1–2 mi wide, except in the areas directly southeast and northwest of the Cumberland anticline, where the Cumberland fault flattens and two nappes (Ravia nappe and Sand Canyon nappe) bring sheets of Arbuckle and Simpson rocks over the "Springer"–Goddard sequence. Wells drilled in the Ravia Block encounter a section of lower Paleozoic rocks beneath the Cretaceous and above the Tishomingo Granite. Basement rocks in the Ravia block lie 5,000–8,000 ft below the surface.

Directly southeast of the Cumberland field, the Ravia nappe incorporates a large block of Arbuckle limestone that has been thrust several miles across the "Springer"–Goddard shales (Huffman and others, 1978). The Ravia nappe is nearly 5 mi long and 3 mi wide, situated mostly in Bryan County. Wells drilled in the Ravia nappe go from Cretaceous into lower Paleozoic rocks, usually the Arbuckle Group limestone, cross the Cumberland Fault into the "Springer"–Goddard sequence, and thence downward through a normal section of Paleozoic rocks, including the "Caney" shale, Sycamore Limestone, Woodford Formation shale, Hunton Group limestone, Sylvan Shale, Viola Group limestone, Bromide–Tulip Creek Formations, McLish Formation, Oil Creek Formation, and Joins Formation, into the Arbuckle limestone. The Sand Canyon nappe, named by Merritt, (1978) and noted earlier by Godfrey (1956), lies directly northwest of the Cumberland field and extends from northeastern Marshall County into southern Johnston County. In the Caraway B-1 Rutherford well (NW¼SE¼ sec. 32, T4S, R4E), the Arbuckle limestone was drilled directly below the Cretaceous. The Arbuckle limestone rests on truncated Mississippian and Pennsylvanian beds ("Springer"–Goddard and possibly Dornick Hills). The Sand Canyon nappe is ~2 mi long and ~1 mi wide.

Whether these two nappes are bounded by tear faults, as suggested by Merritt (1978, p. 40), or are erosional remnants of a much larger sheet of rocks that was thrust across the Cumberland structure, as suggested by Godfrey (1956, p. 123), is conjectural.

Cumberland Fault

The Cumberland fault bounds the Ravia block on the southwest, paralleling the Washita Valley fault for >35 mi. It merges with the Washita Val-

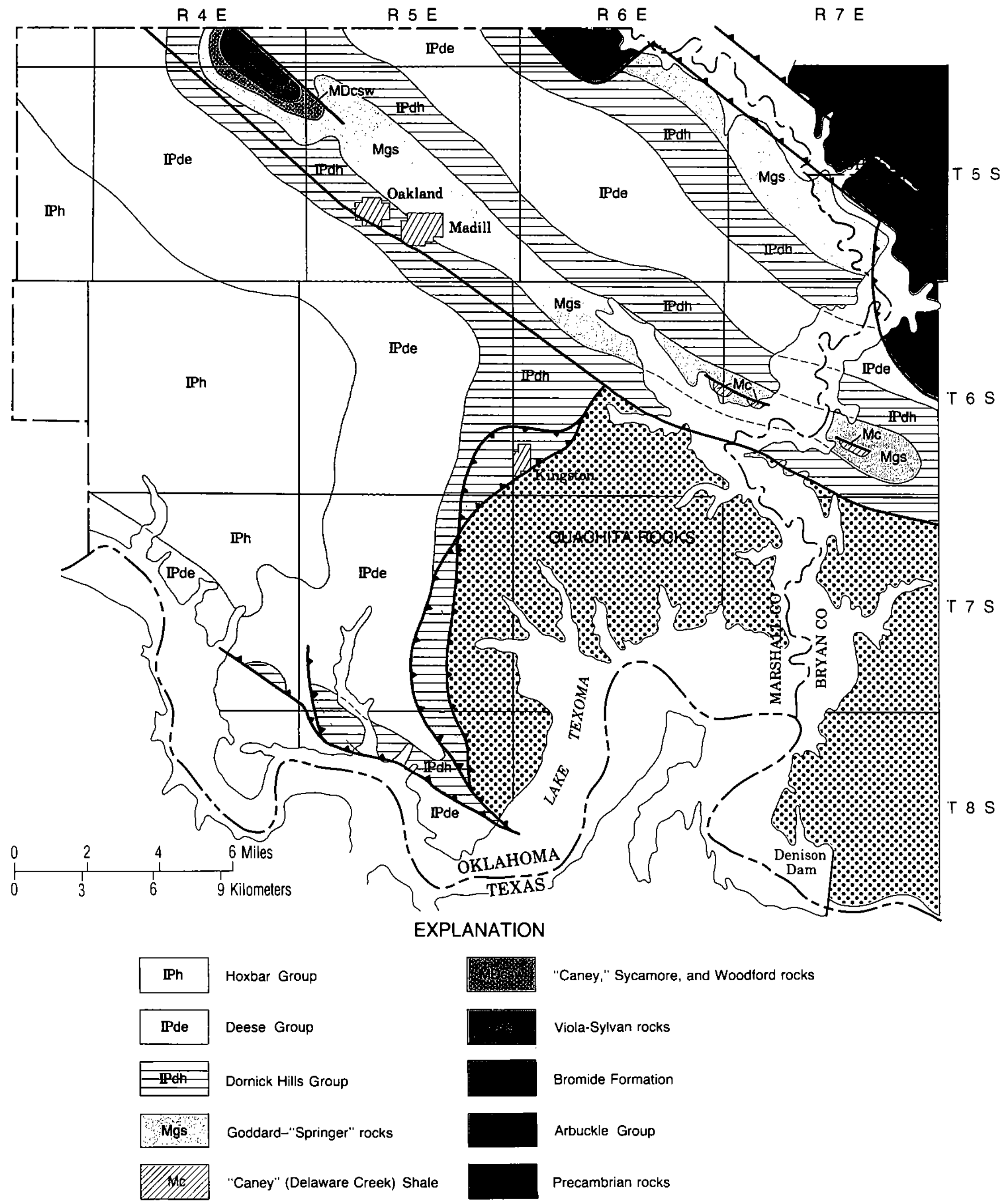

Figure 31. Pre-Cretaceous paleogeologic (subcrop) map of Marshall County and areas bordering on the east.

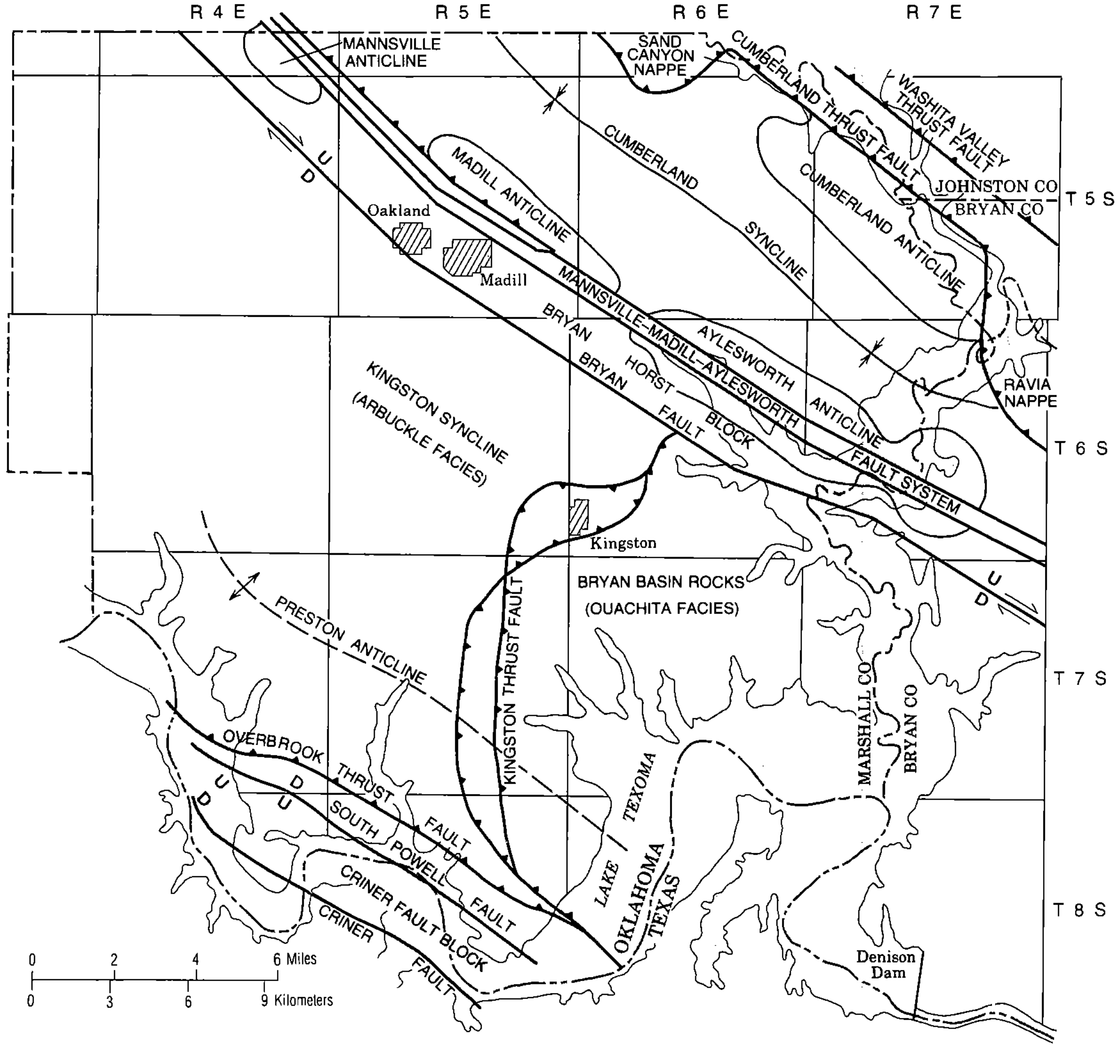

Figure 32. Principal subsurface structural features in Marshall County and areas bordering on the east.

ley Fault in T4S, R5E (Ham and others, 1964, pl. 2) and extends southeastward into T7S, R12E, where it passes beneath or possibly cuts strata of the Ouachita facies. The Cumberland fault is a high-angle reverse fault that dips northeastward beneath the Ravia block. Locally, as beneath the Ravia and Sand Canyon nappes, the fault plane flattens and becomes the sole of the thrust plate. The Cumberland fault lies directly northeast of the Cumberland field along the northeast corner of Marshall County.

Cumberland Anticline

The Cumberland anticline lies southwest of the Cumberland Thrust fault. It is a nearly symmetrical anticline ~4.5 mi long and ~2 mi wide. The axis extends from sec. 18, T5S, R7E, to sec. 34, T5S, R7E. Structural closure increases from 250 ft at the top of the "Caney" shale to 500 ft on top of the Viola Group to 550 ft or more at the top of the Bromide Formation. Cram (1948, fig. 4) mapped several cross faults at the southeastern end of the anticline. Oil accumulation is anticlinal, and >70 million bbl of crude have been produced from the sandstones in the Simpson Group.

Cumberland Syncline

The Cumberland syncline is broad and nearly symmetrical, occupying a 4-mi-wide belt between the Cumberland anticline and the Mannsville–Madill–Aylesworth flexure. The axis, traced at the top of the Viola Group limestone, trends NW through T6S, R7E, thence diagonally across T5S, R6E, into T4S, R5E (Fig. 32). Pennsylvanian beds of the Deese Group occupy the center of the syncline and subcrop beneath the Cretaceous. The Ravia and Sand Canyon nappes, previously discussed, have been thrust southwestward onto the northeast flank of the Cumberland syncline. Basement rocks in the Cumberland syncline are believed to lie at depths of –16,000 ft (Ham and others, 1964, pl. 2).

Mannsville–Madill–Aylesworth Fault System

The Mannsville–Madill–Aylesworth fault system extends diagonally southeastward from the vicinity of Mannsville (T4S, R4E, Johnston County), past the north side of Madill, through the Madill and Aylesworth fields, across Lake Texoma, and through the Southeast Aylesworth Field in Bryan County—a distance of ~25 mi. The fault system consists of two (and in places, three) subparallel faults. In the Aylesworth and Southeast Aylesworth fields, two parallel faults control the hydrocarbon accumulation and have a total displacement of 2,000–3,000 ft. The faults appear to be high-angle normal faults through the producing section, but are believed to curve with depth to become thrust faults (Fig. 38). In the North Madill field, a third major fault is upthrown on the northeast, with a displacement of nearly 2,000 ft. This fault controls accumulation, which is limited to the northeast block; the fault has been interpreted as a high-angle reverse fault, as depicted in a geophysical profile across the field (Fig. 42). The fault system trends NW through the Mannsville anticline, where three faults are believed to be present. The two faults on the southwest side of the structure are believed to be high-angle normal faults, which here also curve downward to become reverse faults. The northeast fault is believed to be a high-angle reverse fault. The central downthrown block forms a typical ramp; the Viola limestone is at a depth of –10,519 ft in the Sun 1 Lewis well.

Mannsville Anticline

The Mannsville anticline is a tightly folded and faulted, slightly asymmetrical anticline associated with the Mannsville–Madill–Aylesworth fault system. The anticline is ~2 mi long and ~1 mi wide. It is interrupted by the westernmost of the three faults described above. The upthrown (western) block has been exhumed by erosion, forming an inlier along Turkey Creek (secs. 34 and 35, T4S, R4E), where Viola through Sycamore beds are exposed beneath the Cretaceous Trinity Group (Antlers Formation). Paleozoic rocks on the southwest limb of the faulted anticline dip SW at 40–60°. The northeast side of the structure is faulted, and beds beneath the Cretaceous are concealed. The northeast fault is believed to be a high-angle reverse fault dipping NE, with the upthrown block on the northeast side.

Madill Anticline

The Madill anticline is an elongate, asymmetrical uplift whose axis lies along a major fault zone. Three major northwest-trending faults, two upthrown to the southwest and one upthrown to the northeast, and several small cross faults cut the structure. The North Madill field is on the northeast side of the fault system, and the East Madill field is on the southwest. Structural closure in the North Madill field ranges from 1,500 ft on the "Caney" to more than 2,000 ft on the Bromide. Closure in the East Madill field is ~1,500 ft at the top of the Viola limestone. The original Madill field produced from shallow (probably Pennsylvanian) sands on the northeast flank of the structure.

The North Madill field is bounded on the southwest by a major thrust fault, which dips NE. Two additional faults, which at depth dip SW, bound the resulting ramp on the southwest. The Tesoro Petroleum 1-22 Reynolds well, (SW¼NE¼NE¼ sec. 22, T5S, R5E) was drilled between these faults, reaching the Viola limestone at –10,053 ft.

Aylesworth Anticline

The Aylesworth anticline is an elongate, slightly asymmetrical uplift ~10 mi long and ~2 mi wide. It extends northwestward from sec. 36, T6S, R7E, in Bryan County to a point in sec. 4, T6S, R6E, in Marshall County. Two NW-trending, NE-dipping faults extend the entire length of the structure. The major fault is downthrown on the northeast, with displacement of 2,000–3,000 ft. The second fault, also downthrown on the northeast, has a displacement of 300–900 ft. Both faults are interpreted as normal through the producing section, but they may curve with depth to become thrust faults. Production southwest of the fault system is from the Simpson Bromide; that northeast of the fault zone is from the Simpson Group and the Woodford–"Misener"–Hunton and Sycamore intervals. A shallow syncline divides the Aylesworth Anticline into two smaller structures, on which Aylesworth and Southeast Aylesworth fields are located.

Bryan Fault

Huffman and others (1978, p. 62) named the Bryan fault, which is a major wrench fault that separates rocks of typical Arbuckle facies from rocks of the Ouachita facies in western Bryan County. The Bryan fault trends NW across Marshall County, parallel to the Mannsville–Madill–

Aylesworth fault system, forming a prominent horst, which encompasses the towns of Oakland and Madill. Vertical displacement at the top of the Viola Group is ~6,000 ft in T5S, R4E, and nearly 10,000 ft in T5S, R5E. This fault can be projected southeastward across western Bryan County to the eastern edge of T7S, R9E, and northwestward beneath the alluvium of the Washita River in T2S, R2E, Carter County, where it may join the Washita Valley fault system of the western Arbuckle Mountains. Apparent lateral displacement of the Ouachita front in Bryan and Marshall Counties is ~36 mi; this displacement could be explained by deposition of Ouachita-facies rocks of the Bryan basin along a major normal growth fault, and it is perhaps necessary to invoke only a few miles of lateral movement along the Bryan fault.

Kingston Syncline

The Kingston syncline is a broad, shallow structure lying between the Bryan fault and the Preston anticline. The axis of the syncline, as delineated by surface exposures, passes through a row of hills capped by strata of the Woodbine Formation in T7S, R6–7E. The axis extends northwestward through T6S, R5–6E, 3–4 mi southwest of the Mannsville–Madill–Aylesworth flexure.

In the subsurface, the axis of the syncline probably lies in the area where Hoxbar sediments are preserved below the Cretaceous. The deepest part, as indicated by structure contours on the Viola Group, is in T6S, R4–5E, where the Viola top is at −24,000 ft. The Kingston syncline is faulted and gently folded (Pl. 2); it passes northwestward into the Ardmore basin.

Preston Anticline

The Preston anticline is a prominent structural feature in the Cretaceous rocks of southern Oklahoma and bordering Texas. It extends from the southeastern part of Love County, into southern Marshall County north of the Red River, and into Texas to the vicinity of Gober, in Fannin County. The Preston anticline, known primarily from its effects on Cretaceous rocks, lies generally northeast of the Meers Valley–Criner Hills line of folding and faulting. The crest is north of the Overbrook fault system, which controls entrapment in the Handy field of Texas and extends into southern Marshall County, Oklahoma.

In the subsurface, the Ouachita rocks of the Bryan basin have been thrust against the Preston anticline and the Kingston syncline as a series of sheetlike plates, with local overturning. Oil accumulation in the Ouachita chert facies in the Enos–Isom Springs area is believed to be related to structures formed as the Ouachita rocks were thrust across the Preston anticline.

Overbrook Fault

West of Marshall County, the Overbrook thrust fault can be traced from sec. 3, T5S, R1E, southeastward to sec. 25, T6S, R2E, flanking the Overbrook anticline on the east and dipping NE (Harlton, 1976). The Overbrook anticline is a long, plunging fold cut by numerous cross faults. The Overbrook fault system passes southeastward through the West Enville field in eastern Love County and through the Handy field of northern Texas. It extends into and through southern Marshall County, controlling entrapment in the South Powell field (Harlton, 1976, p. 48–49). The South Powell structure comprises two elements, a southeastward extension of the Handy block and a steeply dipping, faulted anticline that contains the productive "Handy sand" of Deese age. It is believed that the Overbrook block and associated faults extend through southern Marshall County, controlling accumulation in the Southwest Isom Springs field in T8S, R5E.

Criner Block

The Meers Valley–Criner Hills line of folding and faulting enters Oklahoma from the Texas Panhandle, trends southeastward along the frontal Wichita Mountains through the Duncan area and the Criner Hills, and continues southeastward through Love County into the southern tip of Marshall County in T8S, R4E.

The Criner uplift in T5S, R1E, Carter County, was described by Harlton (1976, p. 47) and Reed (1959, p. 134–138). It is a complexly folded and faulted structure bounded on the southwest by the Meers Valley–Criner fault. The Kirby fault and the Rock Crossing fault divide the Criner block into triangular wedges. The southwest Ardmore fault lies east of the Rock Crossing fault and controls accumulation in the Southwest Ardmore field (Hale, 1959, p. 263–273).

The Criner block and associated faults continue through eastern Love County and provide entrapment in the North Marietta, Northeast Marietta, and Southeast Enville fields. The Southwest Enville field and associated structures have been discussed by Westheimer (1965, p. 65–67). Additional faulting southwest of the Criner fault controls accumulation in the Southeast Marietta field (Westheimer, 1965, pl. 2). Deep production in the South Powell field of Marshall County is from the Criner block, which is bounded on the north by the south Powell fault and on the south by the Criner fault. Production from the Viola Group and Oil Creek Formation is related to anticlinal closure on the Criner block.

Bryan Salient of the Ouachita System

A large body of Ouachita-facies rocks lies south of the Madill–Aylesworth anticline and the Bryan fault in southern Bryan County and extends westward into eastern Marshall County and southward into Texas. This body of rocks is extremely complex, comprising a series of imbricate thrust slices that lie east of the frontal thrust (Kingston fault). These rocks were uplifted in Desmoinesian time and were thrust northwestward in late Virgilian time. The total displacement has not been determined, although the Ouachita front may have been moved many miles in Bryan and Marshall Counties.

Kingston Thrust Fault

The Kingston thrust fault separates rocks of the Ouachita facies from those of the Arbuckle facies. It extends southward from the Bryan fault in T6S, R6E, to the southern part of T8S, R5E, where it passes beneath Lake Texoma and continues into Texas. Two fault slices appear to lie adjacent to the main fault (Figs. 31,32). Rocks of the Arbuckle facies occupy both thrust slices. The vertical displacement of the Viola limestone in the thrust slice near Kingston approaches 20,000 ft along the axis of the Kingston syncline.

Bryan Horst Block

The Bryan horst block extends southeastward across Marshall County for a distance of nearly 30 mi. It is bounded on the southwest by the Bryan fault, which has a vertical displacement on the Viola Group of 6,000–10,000 ft. It is bounded on the northeast by two normal faults, both downthrown on the northeast, with a vertical displacement of nearly 4,000 ft. The west flanks of the Aylesworth, Madill, and Southeast Mannsville fields are on this horst block.

HISTORY OF OIL AND GAS PRODUCTION

The history of development of oil and gas production in Marshall County has been summarized by Bullard (1926), Godfrey (1956), Womack (1956), Huffman and others (1978), and Merritt (1978). The following is a brief summary of the production history to date.

Oil and gas seeps had long been known to exist in the region north of Madill, where "Seneca Oil" was bottled from an oil spring on Oil Creek (SE¼ sec. 34, T4S, R5E); production was from 10 ft below the base of the Goodland Limestone in what is now known as the Antlers sandstone (Hutchison, 1911, p. 64). The presence of oil seeps led to the drilling of the first commercial attempt in 1906. In March 1909, the Mal-Millan Oil Co. 1 Arbuckle well (SW¼ sec. 25, T5S, R5E) was completed in the "Arbuckle sand" (of Cretaceous age). By April 1909, eight wells had been drilled, four of which were productive. The largest well in the field produced >400 bbl/day of oil. This field, the Arbuckle, was later incorporated in the Madill field. Subsequent drilling in secs. 13 and 24, T5S, R5E, and sec. 30, T5S, R6E, led to completion of more than 50 wells on the flank of the Madill anticline from a lenticular sand (possible Deese) of Pennsylvanian age. This was sometimes referred to as the "Shoe String field" or "Bilbo field."

The next major discovery was the Enos field, ~7 mi south of Kingston. Production was from the Cretaceous (Antlers) sandstone near the crest of the Preston anticline at depths of 500–1,480 ft (Bullard, 1926, p. 55–57). The field was discovered in 1916, and by 1918 more than a dozen wells had been completed. Twenty-four wells were still producing in 1961, when the field was combined with Isom Springs field. Recent drilling has established deep production in the Arkansas Novaculite.

The Isom Springs field produces from the basal Cretaceous (Antlers sandstone) and underlying Paleozoic strata. Approximately 60 wells have been drilled, of which 44 were producing in December 1971. Recent drilling has established production in the Stanley Formation, the Arkansas Novaculite, and the Bigfork Chert (Ouachita facies) in the Enos–Isom Springs field.

The Kingston field, ~2 mi southeast of Kingston, in secs. 3, 4, 10, and 11, T7S, R6E, was discovered in 1932 and abandoned in 1962. Approximately 32 wells were drilled; nine were completed as oil wells, and five as gas wells. Production was from the basal Cretaceous Antlers sandstone.

Deeper drilling began in 1939 in the Aylesworth area, when Johnson and Kemnitz drilled the 1 Neff–Godfrey well (SW¼SE¼NW¼ sec. 14, T6S, R6E) to the top of the Arbuckle limestone (Godfrey, 1956, p. 116). Shows of gas and oil were found in the Simpson Group. This led to the drilling in 1942 of the discovery well of the Aylesworth field, the Samedan 1 Neff–Godfrey (SW¼ sec. 13, T6S, R6E). Approximately 86 wells have produced >10 million bbl of crude oil from the Bromide sand on the Madill–Aylesworth anticline. Production on the northeast flank is from the "Misener(?) dolomite." The Aylesworth field was extended northwestward into secs. 4 and 10, T6S, R6E (Northwest Aylesworth field, now incorporated with the Aylesworth).

In 1945, production was extended southeastward into Bryan County by the discovery of the Southeast Aylesworth field (secs. 27 and 28, T6S, R7E), where the Bromide Formation produces on the southwest flank of the faulted Aylesworth anticline. Production was established on the northeast flank in 1957 from the "Springer," Sycamore, Woodford–"Misener"–Hunton, Bromide, and McLish. Production in the narrow fault block in the center of the field (in sec. 21, T6S, R7E) was established in 1976 in sandstone of the Oil Creek.

The Cumberland field was discovered by the Pure Oil Co. in its 1 Little 100 well (SE¼ sec. 28, T5S, R7E). The well flowed oil on a drill-stem test in sandstone of the Bromide (Cram, 1948, p. 341). Production was found on an elongate anticline in April 1940, the structure having been located by reflection-seismograph surveys.

In 1951, the Texas Co. drilled the 1 Chapman (SW¼NW¼SE¼ sec. 35, T4S, R4E), the discovery well of the Southeast Mannsville field. This accumulation was located by surface work in an area of exposed Paleozoic rocks in the Turkey Creek inlier. Production was from the McLish Formation (Godfrey, 1956, p. 116). The Southeast Mannsville field was abandoned in 1965.

The North Madill field was discovered in 1954 by Sinclair in its 1 Griffin well, (SE¼NE¼NE¼ sec. 16, T5S, R5E), as a result of extensive seismic and subsurface work (Godfrey, 1956, p. 116). Production is from sandstones of the Bromide and McLish on the northeast flank of the faulted Madill anticline.

The East Madill field was discovered in 1952. The original well, the Powell 1 Godfrey–Welch (NE¼NE¼NW¼ sec. 31, T5S, R6E) was drilled to test the Bromide, but was unsuccessful (Godfrey, 1956, p. 116). A good show of oil in the Primrose Sandstone led to the drilling of a second well, the Powell 2 Godfrey–Welch, which was completed in a "Springer" sandstone. Subsequent drilling established production in the Bromide. The East Madill field has been combined with the Madill field.

The South Powell field was discovered in 1958 by the Shell 1 Dickerson (sec. 35, T7S, R4E). Several wells were completed in 1958 and 1959 in various sandstones in the Deese Group (Desmoinesian). Renewed activity in 1967 through 1969 established production in the "Handy sand" and "P sand" in secs. 2 and 3, T8S, R4E. A step-out well, the Magna 1 Foster–Davis (NE¼SW¼NW¼ sec. 33, T7S, R4E) completed in the "Handy sand" (5,210–5,257 ft), extended the Handy field of Grayson County, Texas, into Marshall County, Oklahoma. Deep drilling in the South Powell field began in 1977 with the completion of the American Quasar Petroleum 1 Groff (CSE¼NW¼ sec. 2, T8S, R4E) as a gas well in the Viola limestone. A subsequent well, the American Quasar Petroleum 1 Beard (SE¼SE¼SE¼ sec. 3, T8S, R4E), was completed as a gas-condensate well in April 1979.

The Southwest Isom Springs field is a small four-well field in secs. 10 and 15, T8S, R5E. It was discovered in June 1958 by the Shell 1 Little well. Production has come from various sandstones in the Deese Group (Desmoinesian). Cumulative production as of January 1, 1985, was 416,845 bbl.

During recent years, attention has been focused on new discoveries in the Ouachita facies, especially in the Enos–Isom Springs area, where Westheimer–Neustadt has established production in the Mississippian cherts (Stanley), the Arkansas Novaculite, and the Bigfork Chert. Entrapment seems to be controlled by a series of thrust faults, causing repetition of the section and resulting in overturning of some of the principal producing zones. Reservoir rocks are fractured along the crests of the resulting anticlines.

DESCRIPTIONS OF INDIVIDUAL OIL FIELDS

Introduction

Maps and cross sections have been constructed to illustrate the subsurface structures responsible for the trapping of hydrocarbons in Marshall County. In addition to subsurface maps drawn on the top of the Viola limestone for the Cumberland, Aylesworth and Southeast Aylesworth, Madill and East Madill, North Madill, Southeast Mannsville, and South Powell fields, cross sections have been drawn at right angles to the Cumberland, Aylesworth, and Overbrook trends to complete the depiction of the third dimension. A general description of each major field is included, along with a discussion of the pertinent map and cross section. Additional maps include a pre-Cretaceous subcrop or paleogeologic map (Fig. 31) and a Viola structure map of the county (Pl. 2).

Cumberland Field

Location and Description

The Cumberland field was discovered by Pure Oil Co. in 1940, when production was established from the Bromide sandstone on an elongate, NW-trending anticline detected by the reflection seismograph method (Cram, 1948, p. 341). In all, 150 oil wells, one gas well, and nine dry holes were drilled during field development (Cram, 1948, p. 358).

The Cumberland anticline is on the downthrown side (southwest) of the NW-trending Cumberland thrust fault. The fold is ~3 mi long and ~3 mi wide; production is from an area 3 mi by 1 mi. Seismic records indicate a closure of more than 1,000 ft, with effective closure at the top of the Bromide Formation of 550 ft (Cram, 1948, p. 348). The anticline is nearly symmetrical, with the steeper limb on the northwest side. One or more cross faults with 200–300 ft of displacement cut the southern end of the anticline.

The oil reservoirs are sandstones of the Bromide, McLish, and Oil Creek Formations of the Simpson Group (Middle Ordovician). Three producing sandstones are present in the lower part of the Bromide; each one is >100 ft thick. The basal McLish sand is 100 ft thick, the first Oil Creek sand is 185 ft thick, and the second Oil Creek sand is 210 ft thick. Original bottom-hole pressures represented normal hydrostatic pressures: 2,210 psi at 4,800 ft in the Bromide, 2,542 psi at 5,300 ft in the McLish, and 2,940 psi at 6,200 ft in the second Oil Creek. The gravity of the oil is 35° API. According to Cram (1948, p. 355–358), the Bromide produced oil from 1,250 acres in 41 wells; the McLish produced from 2,000 acres in 74 wells, with a 320-acre gas cap; the first Oil Creek produced from <2,000 acres in five wells; and the second Oil Creek produced from 600 acres in 31 wells. In 1977, gas production was established in the West Spring Creek Formation (Arbuckle Group) in the Union Oil Co. 104-14 Chrisman well (sec. 20, T5S, R7E). Several wells have been plugged back and recompleted as producers in the Sycamore, Woodford, Hunton, and Viola.

Production figures of January 1, 1985, indicate that 81 wells are producing and that cumulative production through December 1984 was 72,042,054 bbl of oil. Production for 1984 was 166,849 bbl. Gas production in 1983 (Table 3) was 1,995,318 Mcf and in 1984 was 3,424,965 Mcf. Approximately two-thirds of the wells in the Cumberland field are in Marshall County; the remainder are in Bryan County.

Structure-Contour Map and Cross Section

The Cumberland anticline is an elongate, nearly symmetrical fold, with structural closure of >1,000 ft (Figs. 33,34). The axis trends NW and is doubly plunging. Northeast of the Cumberland field, the Cumberland and Washita thrust faults strike NW and parallel the axis of the fold, suggesting a genetic relationship. The northeastern limb of the anticline dips more steeply than the southwestern and may be faulted. Several small faults were mapped across the southeastern end by Cram (1948, p. 349–350); only the larger of these has been shown in Figure 33. Directly southeast of the Cumberland anticline is the Ravia nappe, a body of rock that has been thrust southwestward >3 mi. A second but smaller nappe, the Sand Canyon nappe, has been identified northwest of the Cumberland anticline (Merritt, 1978, p. 40). These two nappes may be remnants of a much larger thrust sheet that covered the Cumberland anticline and were isolated by post-Pennsylvanian–pre-Cretaceous erosion. An alternative suggestion is that the two nappes are bounded laterally by tear faults.

The Pure 1 Stewart 113 well (sec. 33, T5S, R7E) was drilled on the southwest flank of the structure (Figs. 33,34). The test encountered a normal section of pre-Goddard sedimentary rocks topping the Viola limestone at 4,578 (−3,952) ft. It failed to establish production in the Simpson sands. The Pure 1 Little 100 (sec. 28, T5S, R7E) and the Pure 2 Little 208 (sec. 27, T5S, R7E) were completed as oil wells in the Bromide and McLish sands. The Pure 1 Thompson (sec. 27, T5S, R7E) was too low on the structure to establish production. A small fault is believed to separate this well from producing wells in the Cumberland field; however, its position can be explained by a slightly steeper dip on the northeast limb of the anticline. In all four wells, Cretaceous strata rest unconformably on shales of the "Springer"–Goddard sequence (Upper Mississippian and/or Lower Pennsylvanian). An electric log illustrating the normal sequence in the Cumberland field is shown in Figure 35.

In the Texaco 1 Snodgras well (sec. 23, T5S, R7E), Cretaceous rocks rest on the Arbuckle limestone. This well encountered the Joins Formation at 3,284 (−2,516) ft, and the Oil Creek Formation 340 ft below. The Oil Creek, which is normally ~700 ft thick, was drilled from 3,625 (−2,857) ft to a total depth of 7,016 (−6,248) ft, indicating a nearly vertical dip (Fig. 34). The Cumberland thrust fault is believed to bring the Arbuckle limestone in the thrust block to lie upon the upturned edges of strata ranging in age from Joins (Ordovician) to "Springer"–Goddard (Upper Mississippian and/or Lower Pennsylvanian). These strata are vertical to slightly overturned beneath the Cumberland Thrust. This interpretation has been confirmed by a series of cross sections drawn at right angles to the Cumberland thrust fault between the Cumberland field and the Durant east field in northwestern Bryan County (Huffman and others, 1978, p. 62–72).

Aylesworth and Southeast Aylesworth Fields

Location and Description

The Aylesworth and Southeast Aylesworth fields are on the Madill–Aylesworth flexure, an elongate, faulted anticline extending >25 mi across Marshall and Bryan Counties (Figs. 36–38). Five oil fields—Aylesworth, Southeast Aylesworth, North Madill, East Madill, and Southeast Mannsville—are on this structure.

The first two wells drilled on the Aylesworth anticline were the Johnson–Kemnitz 1 Neff–Godfrey (SW¼SE¼ sec. 14, T6S, R6E; total depth 5,860 ft in Arbuckle limestone) in 1939, and the Marshall–Kubat 1 McCormick (SE¼SE¼ sec. 4, T6S, R6E) in 1942. Both wells were abandoned after encountering numerous oil and gas shows in sandstones of the Simpson Group (Womack, 1956, p. 376).

The discovery well of the Aylesworth field, the Samedan 1 Neff–Godfrey (NE¼SW¼ sec. 13, T6S, R6E), was completed in 1942 for 100 bbl/day from the Bromide sand. Approximately 78 wells were drilled, and production was established from 1,800 acres extending from sec. 4, T6S, R6E, to sec. 21, T6S, R7E, on the upthrown block southwest of the Aylesworth fault zone. The field is terminated northwestward in sec. 4, T6N, R6E, by closure against the major fault, and southeastward by a saddle that separates it from the Southeast Aylesworth field (Fig. 36). Production on the southwest flank comes primarily from the second and third

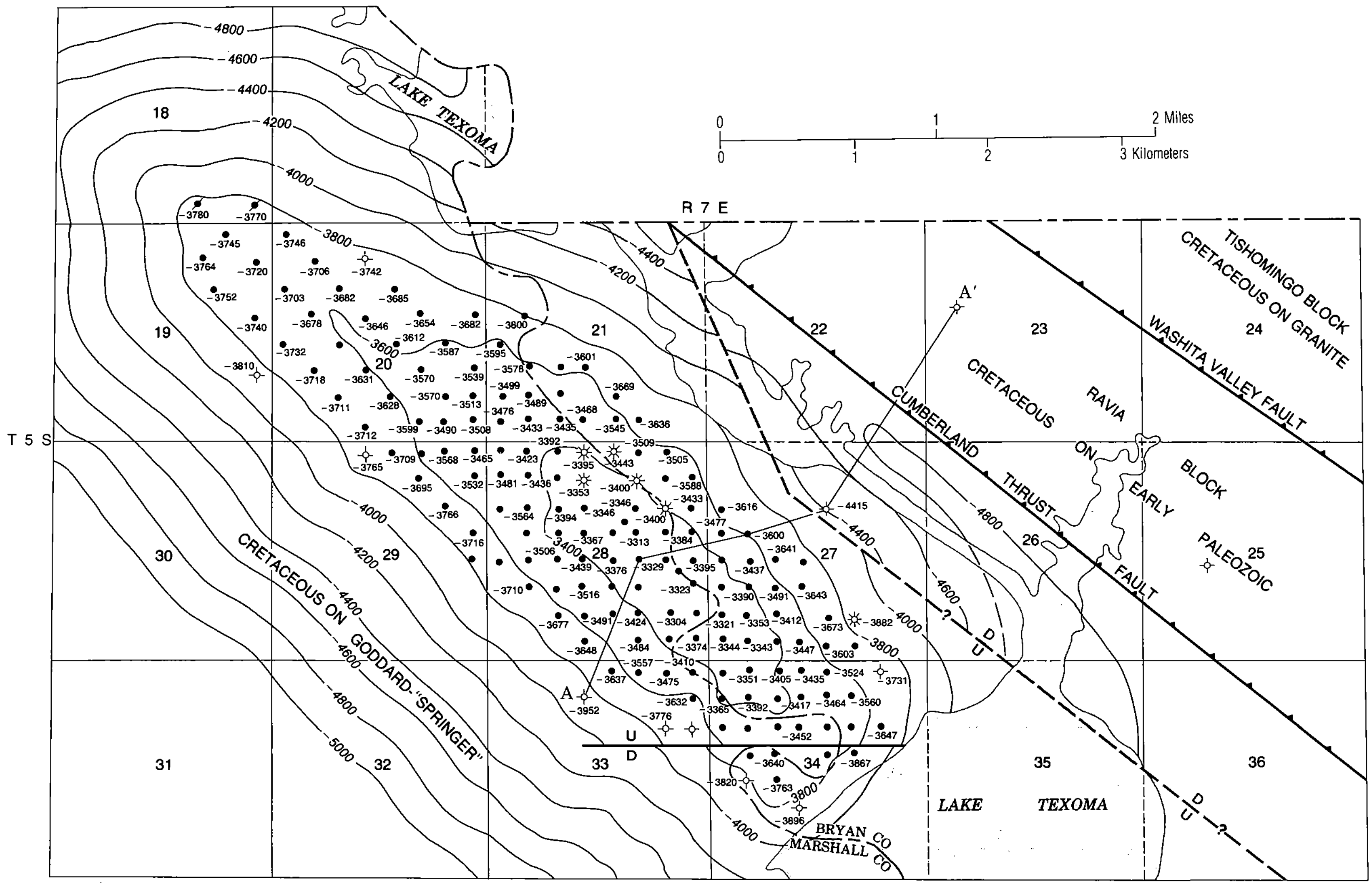

Figure 33. Structure-contour map of the top of the Viola Group in the Cumberland field, Marshall and Bryan Counties. Cross section *A–A'* is shown in Fig. 34. (After Huffman and others, 1978, fig. 44.)

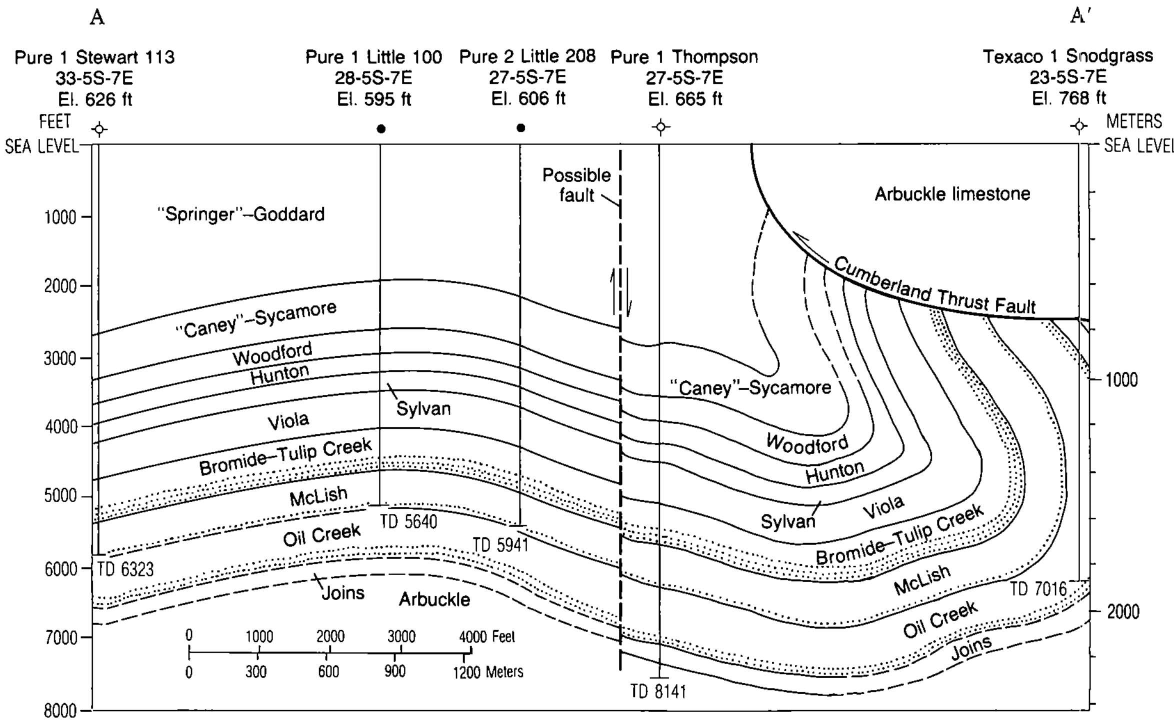

Figure 34. Cross section of the Cumberland field, Marshall and Bryan Counties. Line of cross section is shown in Figure 33. (After Huffman and others, 1978, fig. 36.)

Bromide or Tulip Creek sands. The McLish and Oil Creek sands produced salt water during tests. Approximately 1,200 ft of closure is present against the Aylesworth fault. The stratigraphic sequence and electric-log characteristics of Oil Creek through Goddard–"Springer" strata are shown in Figure 39.

The northeast segment of the Aylesworth field was developed from 1957 to 1959, with production in the Woodford–"Misener" zone and in the Sycamore Limestone. Twenty-nine oil wells and one gas well (Simpson) were drilled east of the Aylesworth fault zone. Two major faults, both downthrown on the northeast, have a combined displacement of as much as 3,000 ft or more along the crest of the Aylesworth anticline.

Eighty-two oil wells and two gas wells were producing in the Aylesworth field in 1984; all are in Marshall County. Oil production for 1984 was 62,270 bbl; cumulative production to January 1, 1985, was 10,800,678 bbl. Gas production in 1983 was 800,770 Mcf, and in 1984 it was 829,840 Mcf. (See Table 3).

The Southeast Aylesworth field is in western Bryan County, on the Madill–Aylesworth flexure. Here again, the major anticlinal structure is cut by two high-angle normal faults, both downthrown on the northeast, with a maximum combined displacement of ~3,000 ft. Production on the southwest side of the fault zone is from the Bromide sands. Production on the northeast side was established in 1957, when oil and gas were found in the "Springer," Sycamore, Woodford–"Misener"–Hunton, Bromide, and McLish zones. Production in the narrow fault block in the center of the field was established by the Cleary 1 Hanover well (sec. 21, T6S, R7E) and the Hanover 1 State well (sec. 27, T6S, R7E).

The discovery well for the Southeast Aylesworth field was completed in April 1945, establishing production from the Simpson Group on the southwest side of the flexure. Today, 18 wells produce oil and five produce gas in the Southeast Aylesworth field. Production for 1984 (Table 3) was 31,604 bbl; cumulative production to January 1, 1985, was 2,202,726 bbl. Gas production in 1983 was 1,451,820 Mcf; gas production in 1984 was 1,270,114 Mcf.

Structure-Contour Map and Cross Sections

The Aylesworth and Southeast Aylesworth fields are typical anticlinal flexures cut by two high-angle faults with curving surfaces that make up the Mannsville–Madill–Aylesworth fault system (Figs. 36–38). The faults are basically normal

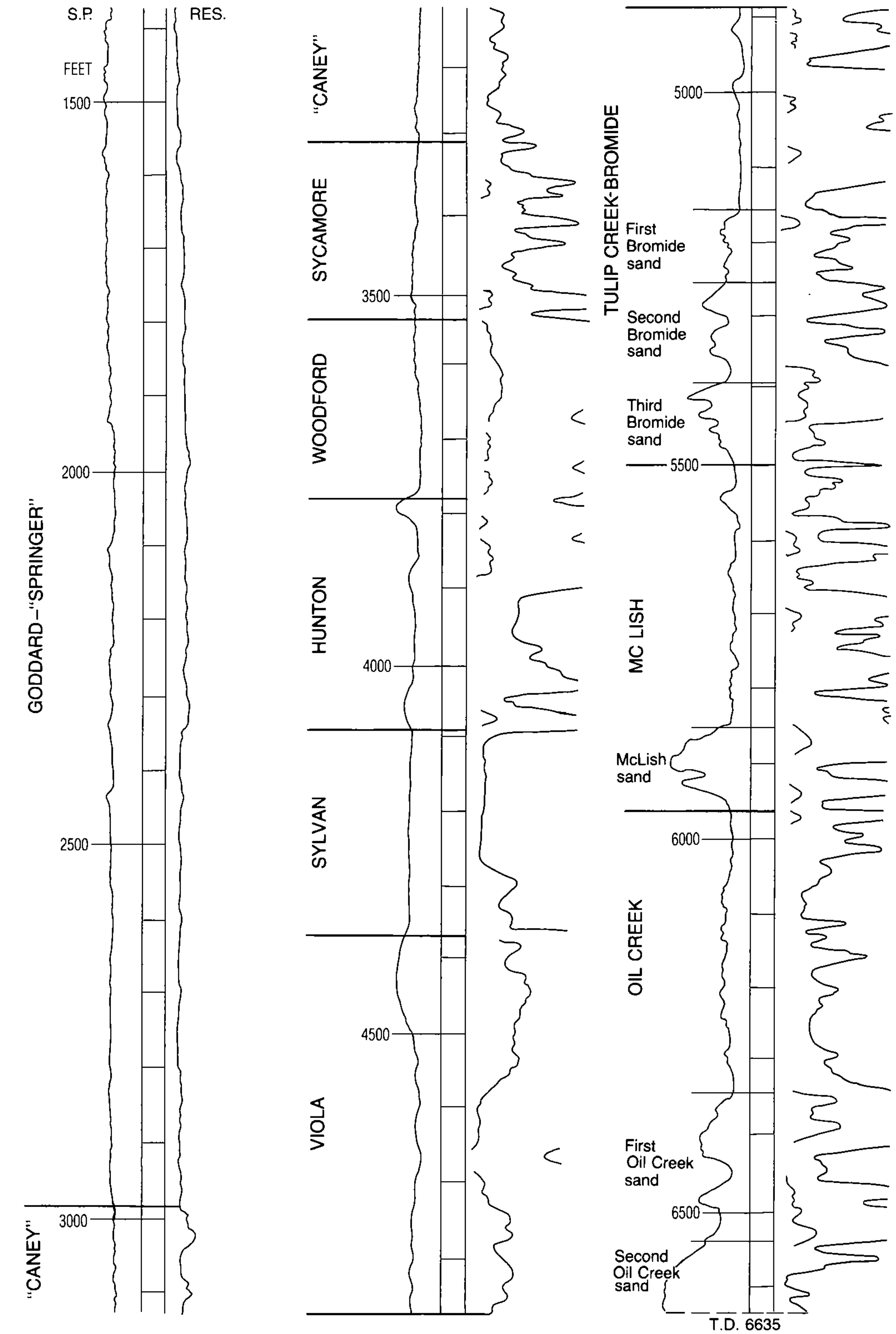

Figure 35. Electric log showing stratigraphic sequence in the Pure 4 Meyers 110 well (sec. 34, T5S, R7E), Cumberland field, Marshall and Bryan Counties. (After Huffman and others, 1978, fig. 45.)

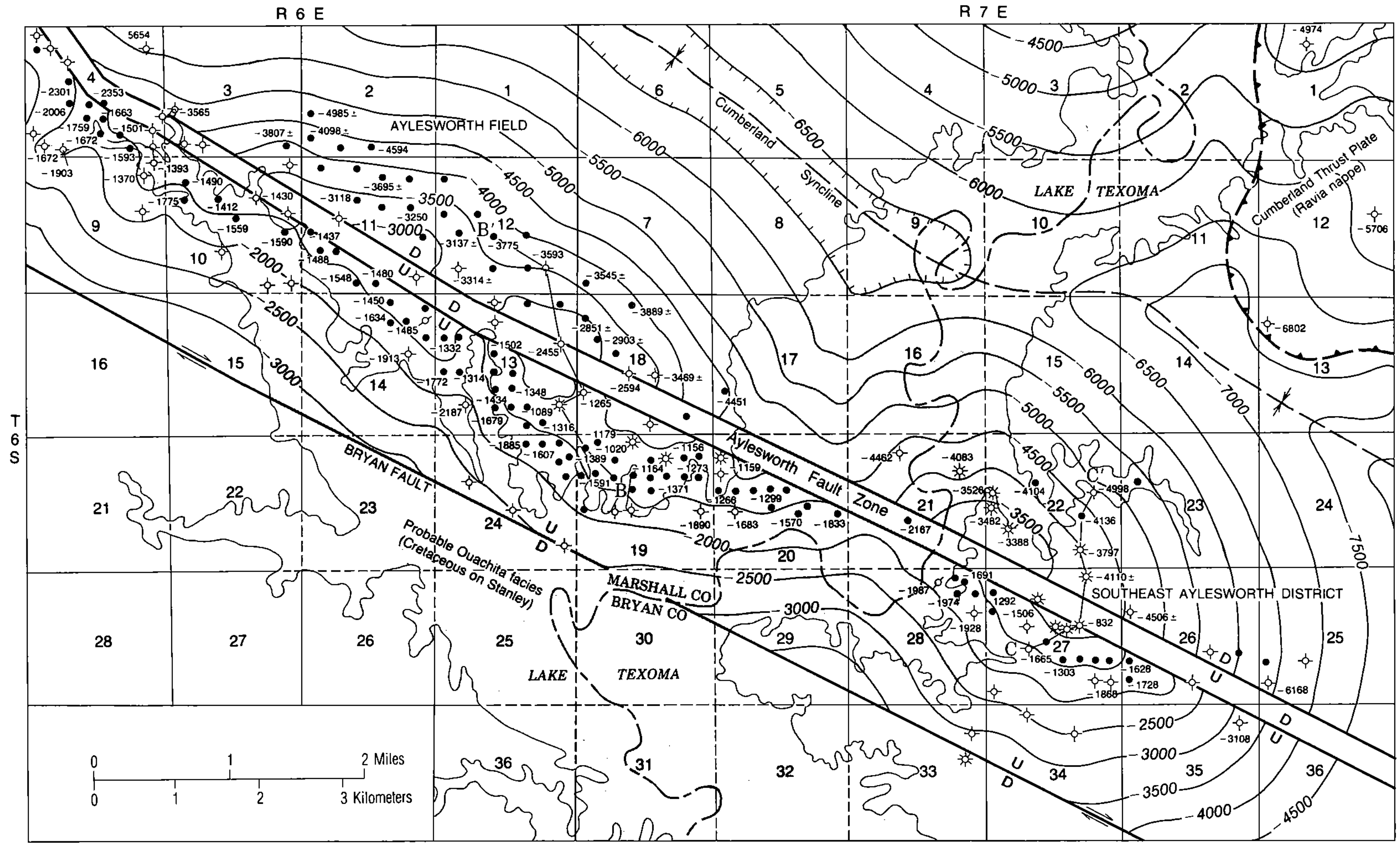

Figure 36. Structure-contour map of the top of the Viola Group in the Aylesworth and Southeast Aylesworth fields, Marshall and Bryan Counties. Cross sections *B–B′* and *C–C′* are shown in Figures 37 and 38. (After Huffman and others, 1978, fig. 46.)

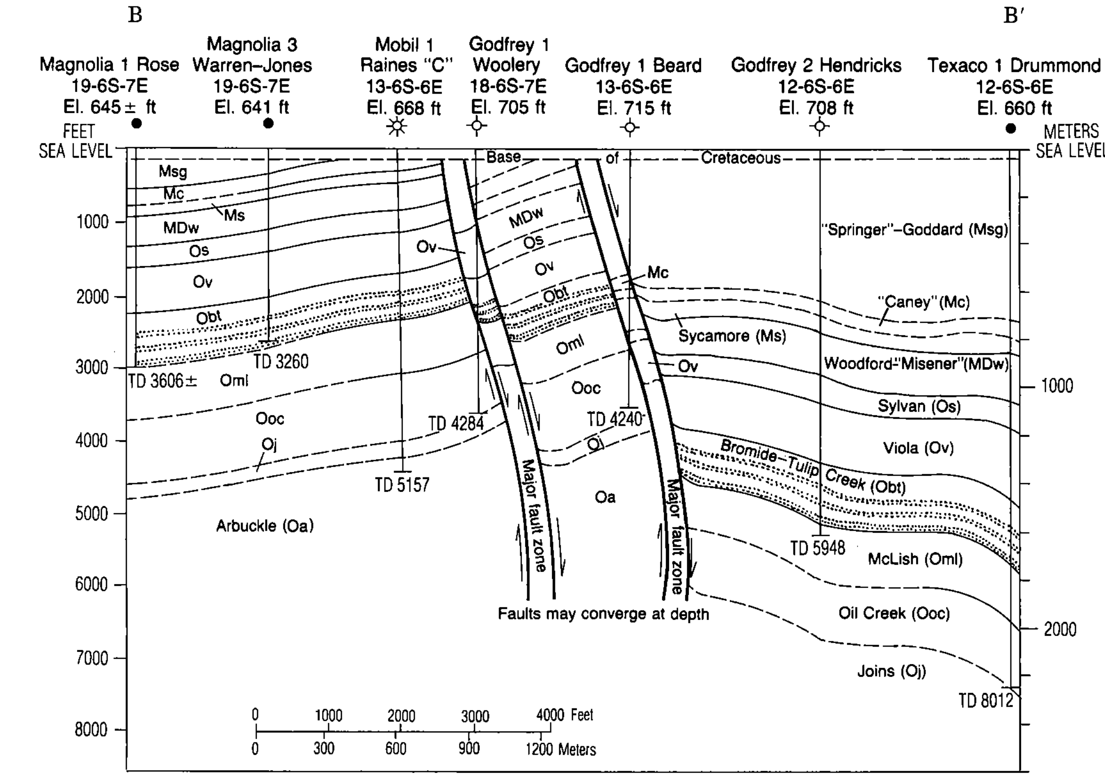

Figure 37. Cross section of the Aylesworth field, Marshall County. Line of cross section is shown in Figure 36.

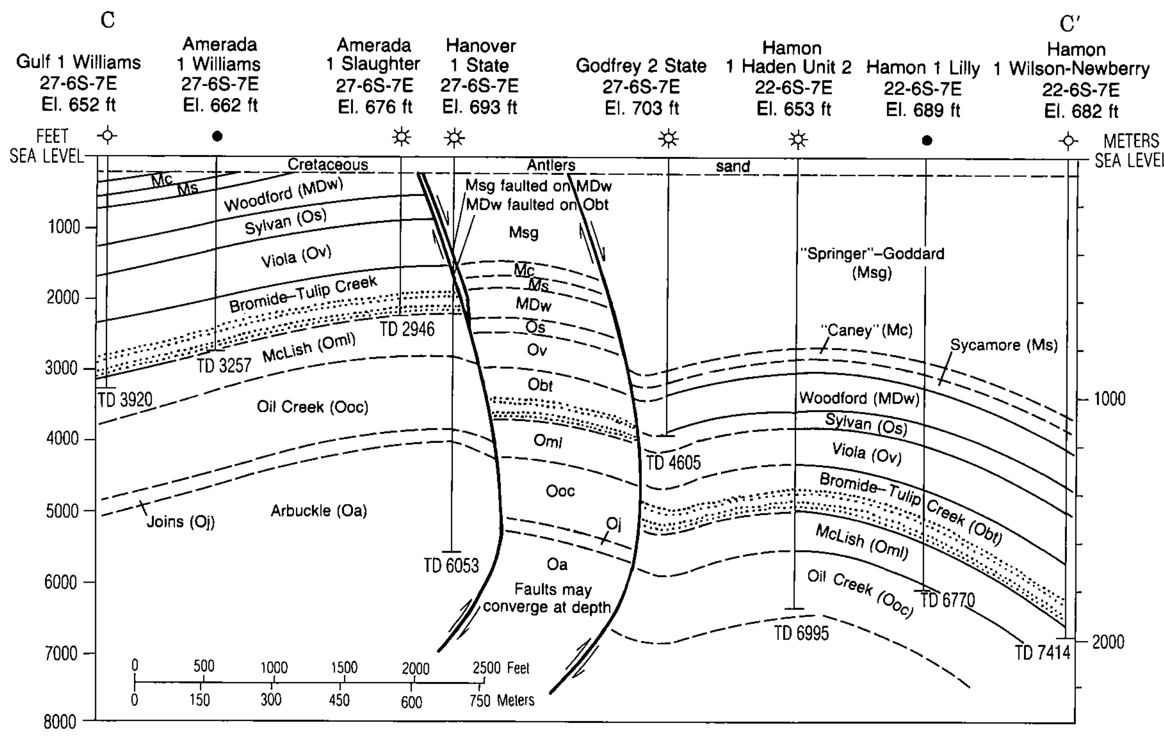

Figure 38. Cross section of the Southeast Aylesworth field, Bryan County. Line of cross section is shown in Figure 36. (Modified from Merritt, 1978, fig. 11.)

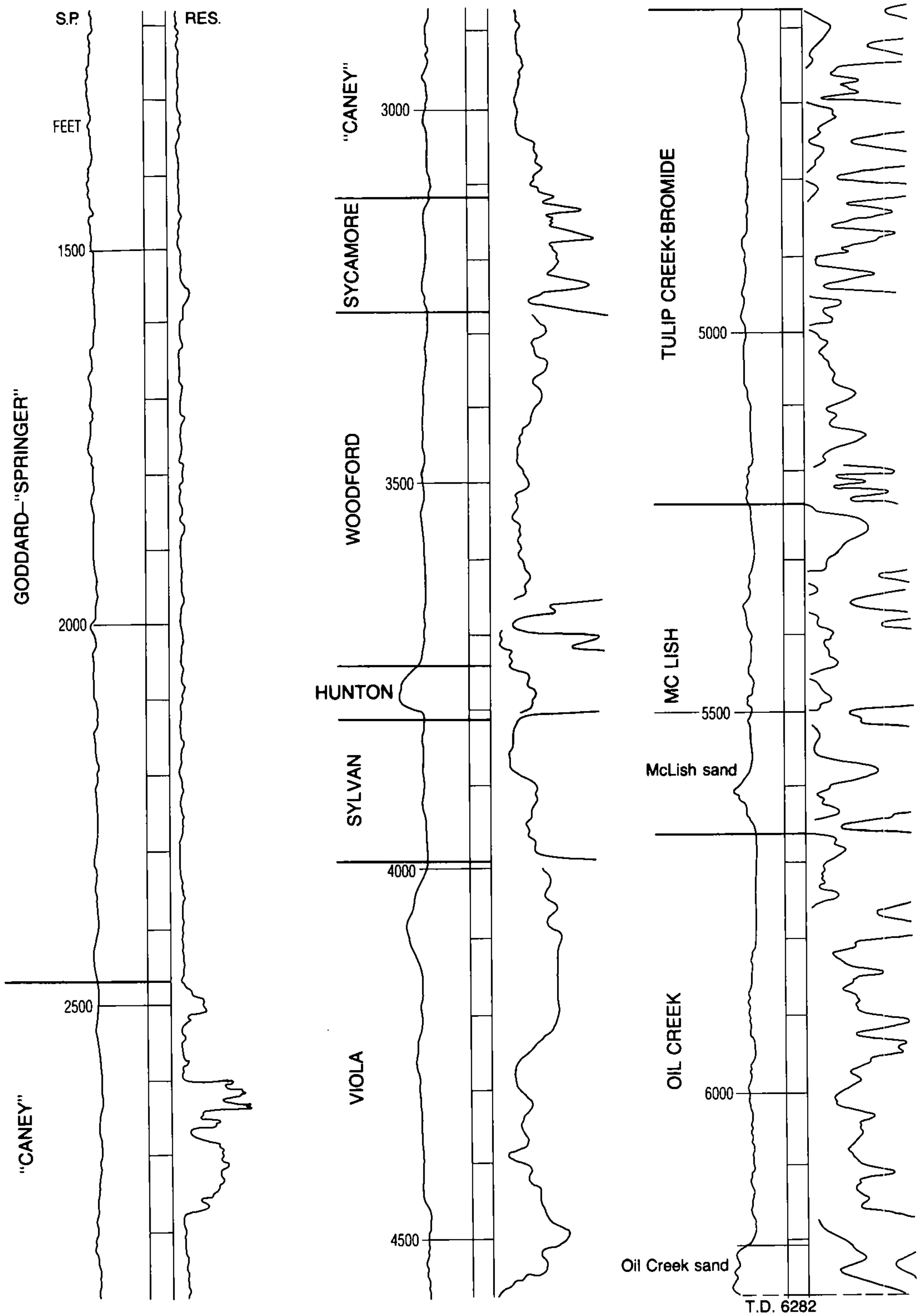

Figure 39. Electric log showing stratigraphic sequence in the Amerada 1 Neff–Godfrey well (sec. 22, T6S, R7E), Southeast Aylesworth field, Bryan County. (After Huffman and others, 1978, fig. 47.)

faults that are downthrown on the northeast, with a combined stratigraphic displacement of ~3,000 ft. The curvature of the fault surfaces and reversal of dip along the faults may indicate thrusting at depth. At places, the faults bifurcate, so that the same fault zone can cut a well bore in more than one place (Figs. 37,38).

The Aylesworth field is on the faulted Aylesworth anticline. Production on the southwest flank is from the second and third Bromide sands, with an effective closure of ~1,200 ft against the fault. Production on the northeast flank has been established in the Sycamore, Woodford–"Misener"–Hunton, Bromide, and McLish.

Two wells shown in cross section B–B′ (Figs. 36,37) cross the major fault zones. The Magnolia 1 Rose well (NE¼SE¼NW¼ sec. 19, T6S, R7E) was drilled to a total depth of ~3,600 ft; the top of the Woodford Formation was found at 1,506 (−861) ft, the Sylvan at 1,901 (−1,256) ft, the Viola at 2,236 (−1,591) ft, the Bromide at 2,906 (−2,261) ft, the first Bromide sand at 3,276 (−2,631) ft, the second Bromide sand at 3,411 (−2,766) ft, and the third Bromide sand at 3,539 (−2,894) ft.

The Magnolia 3 Warren–Jones well (NW¼NW¼NW¼ sec. 19, T6S, R7E) was drilled to a total depth of 3,260 ft and bottomed in the Bromide–Tulip Creek Formation. The top of the Woodford was placed at 1,360 (−719) ft, the Sylvan at 1,723 (−1,082) ft, the Viola at 2,030 (−1,389) ft, and the Bromide at 2,660 (−2,019) ft. The well was completed in the first and second Bromide sands.

The Mobil Oil 1 Ward Raines "C" well (NE¼SE¼SE¼ sec. 13, T6S, R6E) was drilled to a total depth of 5,157 ft and bottomed in Arbuckle limestone. In this well, the basal Cretaceous Trinity Group (Antlers sandstone) rests on the Mississippian "Caney" at 770 (−102) ft. The top of the Sycamore was called at 1,000 (−332) ft, the Woodford at 1,110 (−442) ft, the Viola at 1,757 (−1,089) ft, the Bromide at 2,350 (−1,682) ft, the McLish at 3,012 (−2,344) ft, and the Arbuckle limestone at 4,930 (−4,262) ft. The Bromide and Tulip Creek sands were logged at depths of 2,605 (−1,937), 2,771 (−2,103), and 2,873 (−2,205) ft. McLish sand zones were encountered at 3,125 (−2,457) and 3,175 (−2,507) ft. Originally completed as a gas well in the Tulip Creek (third Bromide) sand, the well was reworked and completed for oil production in the Viola. No faults were observed in this well.

The Godfrey 1 Woolery well (SW¼NW¼SW¼ sec. 18, T6S, R7E) was drilled to a total depth of 4,284 ft and bottomed in the Joins Formation. The well cut a fault near the top of the Viola at 1,970 (−1,265) ft and entered the Bromide Formation at 2,428 (−1,723) ft. The well crossed a second fault, passing into the McLish Formation at 2,920 (−2,215) ft; the Oil Creek at 3,354 (−2,649) ft, and the Joins at 4,274 (−3,569) ft (Fig. 37). The test was dry and abandoned.

The Godfrey 1 Beard well (SE¼NE¼ sec. 13, T6S, R6E) crossed a fault at 2,500 (−1,785) ft, in the "Springer"–Goddard section. The "Caney" shale was encountered at 2,540 (−1,825) ft, the Sycamore at 2,586 (−1,871) ft, the Woodford–"Misener" at 2,665 (−1,950) ft, the Sylvan Shale at 3,073 (−2,358) ft, and the Viola Group at 3,170 (−2,455) ft. The borehole crossed a second fault in the McLish Formation at 3,230 (−2,515) ft and found the Oil Creek Formation at 3,413 (−2,698) ft. The hole was plugged after numerous drill-stem tests in the Woodford, McLish, and Oil Creek indicated no commerical production.

The Godfrey 2 Hendricks well (NW¼SE¼SE¼ sec. 12, T6S, R6E) was drilled to a total depth of 5,948 ft where it was abandoned in the McLish as a dry hole. The Mississippian "Caney" was found at 2,903 (−2,195) ft, the Sycamore at 3,112 (−2,404) ft, the Woodford at 3,258 (−2,550) ft, the "Hunton" at 3,785 (−3,077) ft, the Sylvan at 3,855 (−3,147) ft, the Viola at 4,301 (−3,593) ft, and the Bromide at 5,236 (−4,528) ft. The first Bromide sand was drilled at 5,753 (−5,045) ft, and the second Bromide sand was topped at 5,853 (−5,145) ft. No tests were made, and no cores were taken.

The Texaco #1 Drummond well (NE¼NE¼SW¼ sec. 12, T6S, R6E) found the Sycamore Limestone at 3,281 (−2,621) ft, the Woodford at 3,396 (−2,736) ft, the Sylvan at 4,020 (−3,360) ft, the Viola at 4,435 (−3,775) ft, the Bromide at 5,580 (−4,920) ft, the McLish at 6,444 (−5,784) ft, and the Oil Creek Formation at 7,110 (−6,450) ft. The Tulip Creek sand was logged at 6,385 (−5,725) ft and the Oil Creek sand at 7,905 (−7,245) ft. The well was completed for a small producer in the "Misener" zone (basal Woodford).

Cross section C–C′ (Figs. 36,38) depicts an anticlinal fold cut by two high-angle faults. Both faults are downthrown on the northeast, with a total displacement of ~3,000 ft. The southwest fault has a stratigraphic displacement ⩾800 ft; the northeast fault has a vertical displacement ⩾1,600 ft. The fault surfaces are thought to curve, indicating thrusting at depth. Production on the southwest flank is from the Bromide sands, while production on the northeast flank is from the "Springer," Woodford–"Misener"–Hunton, Bromide, and McLish zones.

The Gulf 1 Williams well (NW¼NE¼SW¼ sec. 27, T6S, R7E) was drilled to a total depth of 3,920 ft and was abandoned in the McLish Formation. The top of the Woodford was logged at 1,340 (−688) ft, the "Hunton" at 1,857 (−1,205) ft, the Sylvan at 1,887 (−1,235) ft, the Viola at 2,310 (−1,658) ft, the Bromide at 3,000 (−2,348) ft, the second Bromide sand at 3,402 (−2,750) ft, the Tulip Creek at 3,420 (−2,768) ft, the Tulip Creek sand at 3,714 (−3,062) ft, and the McLish Formation at 3,760 (−3,108) ft.

The Amerada 1 Williams well (NE¼NE¼SW¼ sec. 27, T6S, R7E) penetrated the basal

Cretaceous Antlers sandstone resting on the Mississippian "Caney" shale at a depth of 830 (−168) ft. The top of the Sycamore was logged at 930 (−268) ft, the Woodford at 1,040 (−378) ft, the Sylvan at 1,642 (−980) ft, the Viola at 1,966 (−1,304) ft, the Bromide at 2,594 (−1,932) ft, and the McLish at 3,230 (−2,568) ft. Bromide sands were found at 2,976 (−2,314), 3,080 (−2,418), and 3,172 (−2,510) ft.

The Amerada 1 Slaughter well (SE¼SW¼NE¼ sec. 27, T6S, R7E) was drilled to a total depth of 2,946 ft in the top of the McLish Formation. The Cretaceous Antlers sandstone is in contact with the Woodford Formation. The top of the Sylvan was picked at 1,220 (−544) ft, the Viola limestone at 1,508 (−832) ft, and the Bromide sand at 2,670 (1,994) ft. The well was completed as a gas producer.

The Hanover Petroleum 1 State of Oklahoma well (SW¼NE¼ sec. 27, T6S, R7E) was drilled to a total depth of 6,053 ft, and bottomed in the Arbuckle limestone. The Cretaceous Antlers sandstone rests unconformably on the "Springer"–Goddard shales. The well crossed a small fault at 2,253 (−1,560) ft, going from "Springer"–Goddard to Woodford. A second fault at 2,350 (−1,657) ft brought the Woodford in contact with the Ordovician Bromide Formation. The second Bromide sand was logged at 2,597 (−1,904) ft, the McLish Formation at 2,840 (−2,147) ft, the basal McLish sand at 3,361 (−2,668) ft, the Oil Creek Formation at 3,455 (−2,762) ft, the Joins Formation at 4,550 (−3,857) ft, and the Arbuckle limestone at 4,700 (−4,007) ft. The well was originally pronounced dry and abandoned, but it was reworked in 1975 and completed for 1,905 Mcf/day of gas and 39 bbl/day of oil from the Oil Creek sand and the Arbuckle limestone. Production is on the upthrown side of the southwest fault. The second northeast fault of the Aylesworth system passes ~800 ft northeast of the well at the pre-Cretaceous surface.

The Roy A. Godfrey 2 State of Oklahoma well (N½NE¼ sec. 27, T6S, R7E) was drilled to a total depth of 4,605 ft in the Sylvan Shale. The Trinity Group (Antlers sandstone) of Cretaceous age rests on the "Springer"–Goddard shale. The well found the "Caney" shale at 3,708 (−3,005) ft, the Sycamore at 3,778 (−3,075) ft, the Woodford at 3,976 (−3,273) ft, and the Sylvan at 4,520 (−3,817) ft. Sylvan dolomite was drilled at 4,585 (−3,882) ft. The top of the Viola limestone was estimated at 4,813 (−4,110) ft. The well was completed for 6,402 Mcf/day of gas from the "Misener" (basal Woodford).

The Hamon 1 Haden Unit 2 well (SW¼SE¼ sec. 22, T6S, R7E) found the base of the "Springer"–Goddard section resting on the "Caney" shale at 3,542 (−2,889) ft. The top of the Woodford was called at 3,740 (−3,087) ft, the Sylvan at 4,266 (−3,613) ft, the Viola at 4,450 (−3,797) ft, the Bromide at 4,992 (−4,339) ft, the McLish at 5,632 (−4,979) ft, and the Oil Creek at 6,104 (−5,451) ft. The second and third Bromide (Tulip Creek) sands were found at 5,344 (−4,691) and 5,514 (−4,861) ft, respectively. The first Oil Creek sand occurred at 6,660 (−6,007) ft, and the second Oil Creek sand at 6,924 (−6,271) ft. The total depth was 6,995 ft in the Oil Creek Formation. The well was completed in the second Bromide and McLish sands.

The Hamon 1 Lilly well (NW¼SE¼ sec. 22, T6S, R7E) was drilled to a total depth of 6,770 ft and completed as an oil well in the Bromide and McLish Formations. The top of the Woodford was picked at 4,018 (−3,329) ft, the Sylvan at 4,548 (−3,859) ft, the Viola at 4,825 (−4,136) ft, the Bromide at 5,458 (−4,769) ft, and the McLish at 6,223 (−5,534) ft. The second Bromide sand at 5,878 (−5,189) ft, the third Bromide sand at 6,080 (−5,391) ft, and the basal McLish sand at 6,684 (−5,995) ft.

The Hamon 1 Wilson–Newberry "A" Unit well (SW¼SE¼NE¼ sec. 22, T6S, R7E) was dry and abandoned at a total depth of 7,414 ft. The top of the "Caney" was picked at 4,320 (−3,638) ft, the Sycamore at 4,550 (−3,868) ft, the Sylvan at 5,293 (−4,611) ft, the Viola at 5,680 (−4,998) ft, the Bromide Formation at 6,432 (−5,750) ft, the first Bromide sand at 6,854 (−6,172) ft, the second Bromide sand at 6,988 (−6,306) ft, and the third Bromide sand at 7,262 (−6,580) ft.

North Madill Field

Location and Description

The North Madill field is ~2 mi north of the town of Madill. The discovery well, the Sinclair 1 Griffin (SE¼NE¼NE¼ sec. 16, T5S, R5E) was drilled on the basis of detailed seismograph exploration by Sinclair (Gahring, 1959, p. 276); it was completed in the first Bromide sand and the basal McLish sand.

The field is ~3 mi long and >1 mi wide. It is on an anticline on the upthrown (northeast) side of a major thrust fault, which is part of the Mannsville–Madill–Aylesworth structure (Figs. 40,41). A high-angle reverse fault is thought to bound the field on the northeast side (Figs. 41,42). Originally, 10 wells were completed in the first Bromide sand, and 60 were completed in the basal McLish sand; none were completed in the basal Oil Creek sand.

The combined thickness of the Bromide sands averages 160 ft. Porosity is 1.2–17%, averaging 14%; permeability is 0.1–799 mD, averaging 109 mD (Gahring, 1959, p. 286). The original reservoir pressure was ~2,350 psi, and the gravity of the oil is 33–39°API. Bromide sands produced from ~1,340 acres, with 2,160 ft of closure.

The basal McLish sand produced in 13 wells from 260 acres. The sand thickness averages 99 ft, 63 ft having permeability (Gahring, 1959, p. 286).

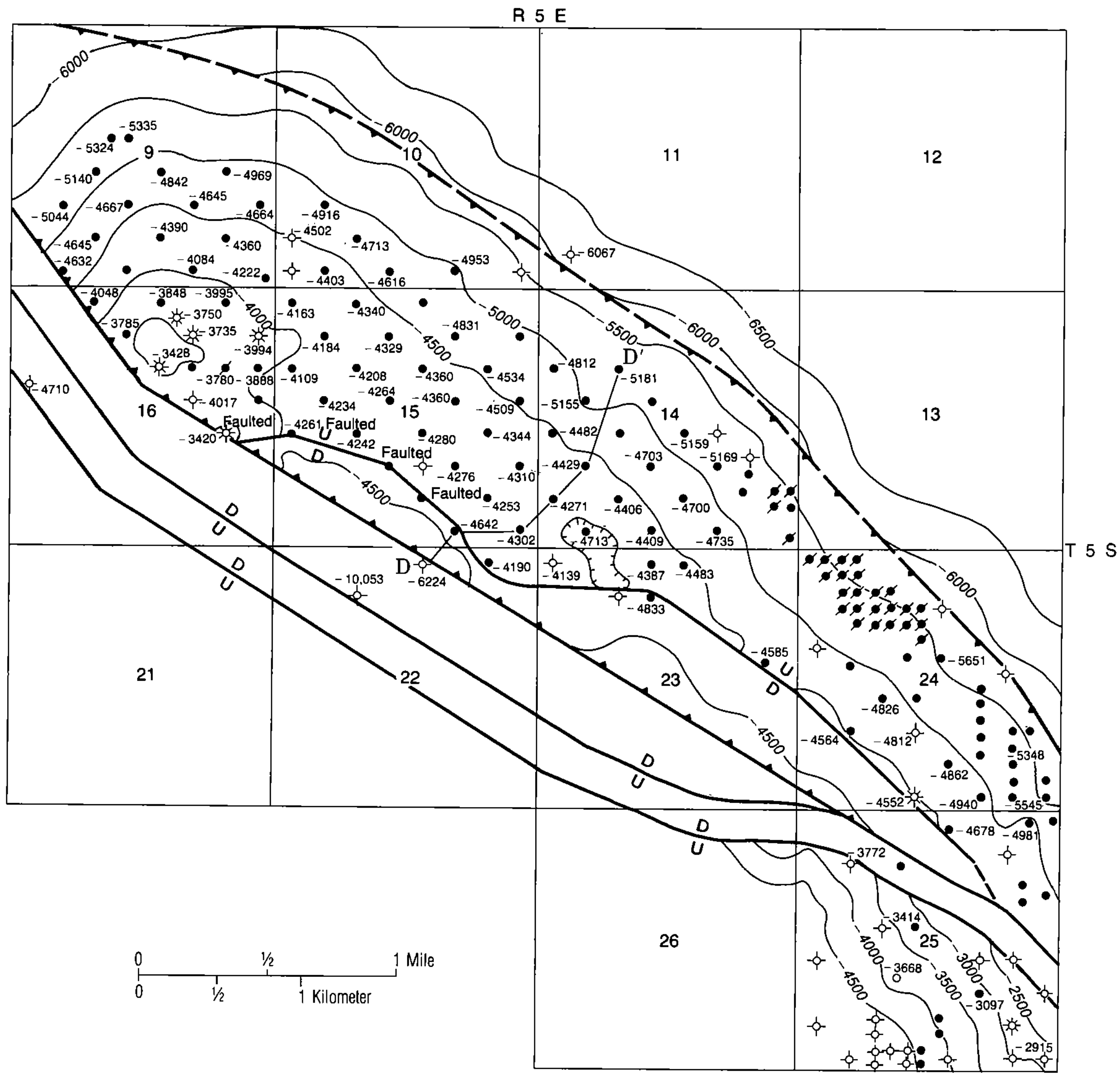

Figure 40. Structure-contour map of the top of the Viola Group in the North Madill field, Marshall County. Cross section *D–D'* is shown in Figure 41.

Porosity is 2.6–25.3%, averaging 16%; permeability is 1.1–714 mD, and averaging 96 mD. The original reservoir pressure was 2,450 psi, and the gravity of the oil ranges from 37–39° API.

The North Madill field produced a cumulative total of 1,259,209 bbl of oil and 622,160 Mcf of gas from the time of discovery to January 1, 1975. Production figures for the North Madill, Madill, and East Madill fields are now combined. Production in 1984 from 108 wells was 81,048 bbl, and cumulative production to January 1, 1985, was 15,298,335 bbl. 1984 gas production was 1,595,973 Mcf.

Structure-Contour Map and Cross Section

The North Madill field is northeast of the major fault zone that controls production along the Mannsville–Madill–Aylesworth flexure. Two major high-angle normal faults are downthrown on the northeast; a third fault is a reverse fault upthrown on the northeast (Fig. 40). Two wells, the Tesoro Petroleum 1 Reynolds (SE¼SW¼NW¼ sec. 22, T5S, R5E) and the Texaco 1 Hilburn (NW¼NE¼NE¼ sec. 22, T5S, R5E), were drilled in the downdropped ramp between these major faults, reaching the Viola limestone at depths of

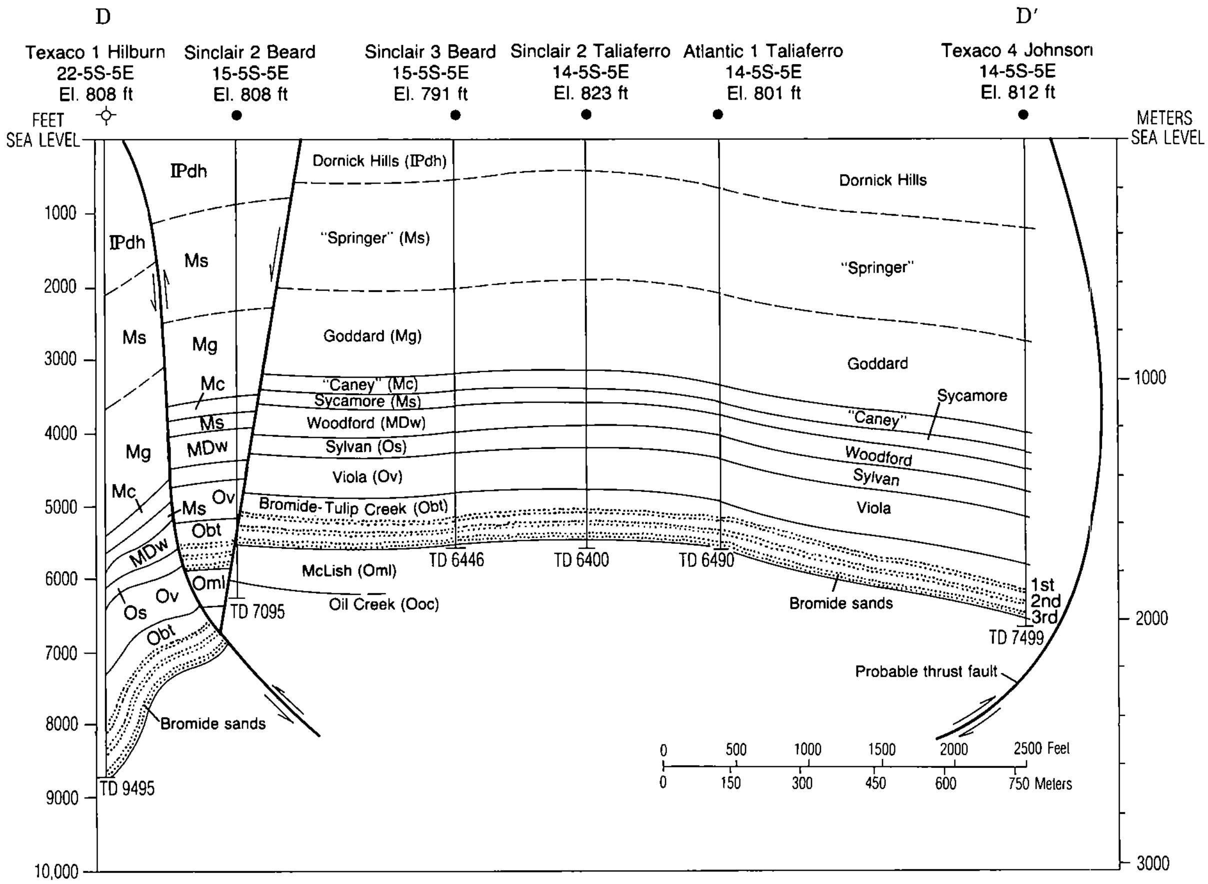

Figure 41. Cross section of the North Madill field, Marshall County. Line of cross section is shown in Figure 40.

~10,830 (−10,053) ft and 7,032 (−6,224) ft, respectively. A small fault, downthrown to the southwest, lies just north of the reverse fault (Figs. 40,41). Additional small cross faults were noted by Gahring (1959, p. 284). Approximately 2,000 ft of closure is present against the major fault on the southwest flank of the structure. Production is from the first, second, and third Bromide sandstones and the basal McLish sandstone. The basal Oil Creek sandstone is not productive. A small thrust fault is thought to border the field on the northeast.

The Texaco 1 Hilburn well (Fig. 41) was drilled to a total depth of 9,495 ft, where it penetrated the basal Bromide–Tulip Creek section. The test encountered Antlers sandstone lying on Dornick Hills shales. The top of the Mississippian "Caney" shale was drilled at 6,220 (−5,412) ft, the Sycamore at 6,400 (−5,592) ft, the Woodford at 6,672 (−5,864) ft, the Sylvan at 6,872 (−6,064) ft, the Viola at 7,032 (−6,224) ft, and the Bromide at 8,020 (−7,212) ft. Three Bromide sandstones were penetrated at depths of 8,950 (−8,142), 9,140 (−8,332), and 9,320 (−8,512) ft. This dry hole is believed to be on the downthrown side of the major thrust fault, which has ~1,750 ft of displacement on the Viola limestone.

The Sinclair 2 Beard well (SE¼SW¼SE¼ sec. 15, T5S, R5E) was drilled to a total depth of 7,095 ft and completed as an oil well in the second and third Bromide sandstones. The well found the top of the "Caney" shale at 4,360 (−3,552) ft, the Sycamore at 4,692 (−3,884) ft, the Woodford at 4,936 (−4,128) ft, the Sylvan at 5,335 (−4,527) ft, the Viola at 5,450 (−4,642) ft, the McLish at 6,360 (−5,552) ft, and the Oil Creek Formation at 6,843 (−6,035) ft. Three Bromide sands were drilled at depths of 6,042 (−5,234), 6,178 (−5,370), and 6,279 (−5,471) ft. The well is believed to have crossed a fault in the Bromide–Tulip Creek section and to have entered the Bromide sands on the upthrown side (Fig. 41). The well was completed in the second and third Bromide sands.

The Sinclair 3 Beard well (SE¼SE¼SE¼ sec. 15, T5S, R5E) bottomed in the McLish Formation at a total depth of 6,446 ft. The top of the "Caney"

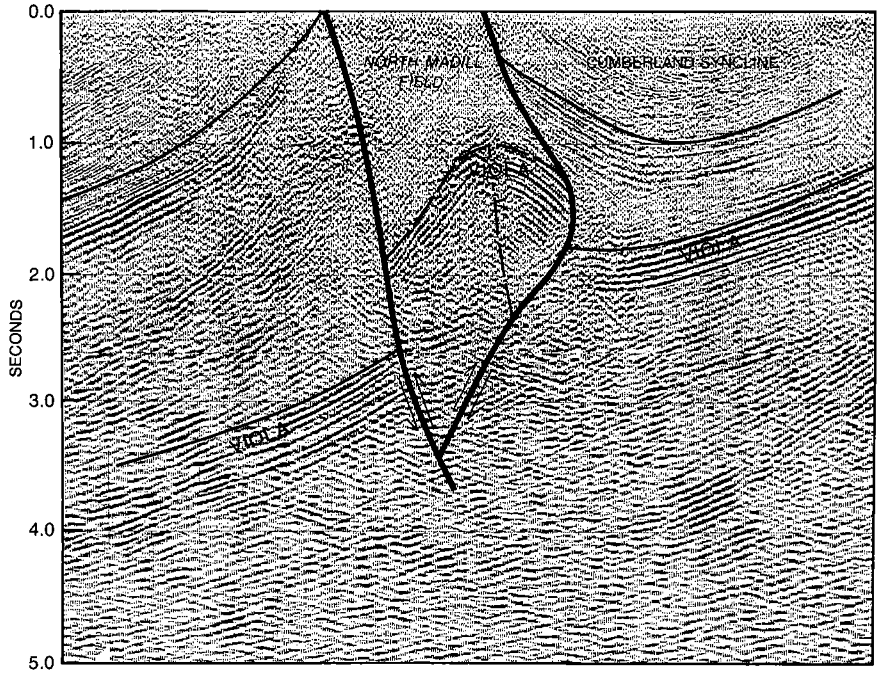

Figure 42. Seismic section across North Madill field. (Courtesy of Lawrence S. Morrison.)

shale was drilled at 4,050 (−3,259) ft, after the well penetrated ~3,500 ft of Dornick Hills, "Springer," and Goddard beds. The top of the Sycamore was picked at 4,232 (−3,441) ft, the Woodford at 4,462 (−3,671) ft, the Sylvan at 4,820 (−4,029) ft, the Viola at 5,093 (−4,302) ft, the Bromide at 5,654 (−4,863) ft, and the McLish at 6,426 (−5,635) ft. The three Bromide sands were encountered at depths of 5,942 (−5,151), 6,136 (−5,345), and 6,280 (−5,489) ft.

The Sinclair 2 Taliaferro well (NW¼SW¼SW¼ sec. 14, T5S, R5E) produces oil from the Bromide sands. The total depth is 6,400 ft. The top of the "Caney" was logged at 4,032 (−3,209) ft, the Sycamore at 4,278 (−3,455) ft, the Woodford at 4,459 (−3,636) ft, the Sylvan at 4,801 (−3,978) ft, the Viola at 5,094 (−4,271) ft, the Bromide at 5,714 (−4,891) ft, and the McLish at 6,328 (−5,505) ft. The Bromide sands were found at depths of 5,966 (−5,143), 6,138 (−5,315), and 6,248 (−5,425) ft.

The Atlantic 1 Taliaferro well (SE¼NW¼SW¼ sec. 14, T5S, R5E), originally completed in the Bromide Formation, was reworked and completed in the Viola limestone. After drilling ~3,500 ft of the Dornick Hills, "Springer," and Goddard shales, the well penetrated the top of the Mississippian "Caney" at 4,250 (−3,449) ft. The Sycamore was encountered at 4,368 (−3,567) ft, the Woodford at 4,582 (−3,781) ft, the Sylvan at 4,926 (−4,125) ft, the Viola at 5,230 (−4,429) ft, the Bromide at 5,845 (−5,044) ft, and the McLish at 6,451 (−5,650) ft. Bromide sands were reported at depths of 6,111 (−5,310), 6,278 (−5,477), and 6,385 (−5,584) ft. No faulting was observed in this well. The total depth was 6,490 ft.

The Texaco 4 Johnson well (NW¼SE¼NW¼ sec. 14, T5S, R5E) was drilled to a total depth of 7,499 ft in the McLish Formation. The Goddard top was called at 3,095 (−2,283) ft, the Mississippian "Caney" at 4,820 (−4,008) ft, the Sycamore at 5,096 (−4,284) ft, the Woodford at 5,321 (−4,509) ft, the Sylvan at 5,665 (−4,853) ft, the Viola at 5,993 (−5,181) ft, the Bromide at 6,692 (−5,880) ft, and the McLish at 7,400 (−6,588) ft. Bromide sands were logged at depths of 7,037 (−6,225), 7,172 (−6,360), and 7,294 (−6,482) ft.

A seismic cross section of the North Madill field (Fig. 42) indicates that two thrust faults cut the section and that the Viola is displaced and arched upward between the two faults to form a bubble-like structure.

Madill and East Madill Fields

Location and Description

The Madill Field originally was called the "Arbuckle field," the name having been derived from the farm on which the discovery well (Mal–Millan Oil Co. 1 Arbuckle; sec. 25, T5S, R5E) was drilled. Subsequent drilling in secs. 24 and 13, T5S, R5E, extended the "Arbuckle field" northward until more than 50 shallow wells had been drilled into what is thought to be a lenticular sand in the Pennsylvanian Deese Group. The name East Madill was given to a new discovery in 1952 in sec. 31, T5S, R6E, where production was established from the Primrose Sandstone in the Pennsylvanian Dornick Hills Group. Gradually the two fields merged in sec. 25, T5S, R5E, and the term Madill was applied to both. Later they were incorporated with the North Madill field, so that production reports for 1978 combine the Madill, East Madill, and North Madill fields into a single Madill field.

Structure-Contour Map

The Madill and East Madill fields lie along the the Mannsville–Madill–Aylesworth fault system and associated anticlinal uplifts. The old Madill field produces from erratic sand lenses, often referred to as the "Arbuckle sand" or "Bilbo sand," which are variously assigned to the basal Cretaceous, Trinity (Antlers), or to the Deese (Pennsylvanian). Trapping is stratigraphic and is contained in a lenticular sand on the flank of the Madill anticline (Fig. 43). The East Madill field is on the southwest side of the Mannsville–Madill–Aylesworth fault system, with closure against the southwesternmost fault. Production is from the Primrose Sandstone (basal Dornick Hills Group) and from the Bromide and McLish sands.

Southeast Mannsville Field

Location and Description

The Southeast Mannsville field was discovered by the Texaco 1 Chapman well (SW¼NE¼SE¼ sec. 35, T4S, R4E). The field is in an area where Paleozoic rocks are exposed, and its discovery was the result of surface work (Godfrey, 1956, p. 116). Production was from the McLish sand. The field was discovered in 1951, and through 1952 five wells had a cumulative production of 102,490 bbl. By 1964, only three wells were producing, and cumulative production was 347,493 bbl. The field was abandoned in 1965.

The field is terminated on the northeast by the Mannsville–Madill–Aylesworth fault system. Strata on the southwest flank dip steeply SW. The faulted anticline has been breached by erosion, and Cretaceous beds lie variously on the Bromide, Viola, Sylvan, Hunton, Woodford, and Sycamore, as well as on younger beds.

Structure-Contour Map and Cross Section

The Southeast Mannsville Field is on the southwest flank of a faulted anticline (Figs. 44,45). Three high-angle faults appear to cut the structure. The two southwesternmost faults are upthrown on the southwest. They appear to be normal faults through the producing section, but are believed to curve with depth to become thrust faults (Fig. 45). The northeastern fault is a thrust fault which dips NE and is upthrown on the northeast. Hydrocarbon accumulation is limited to the southwest flank of the anticline, where erosion in places has cut as deep as the Bromide. The Viola limestone is exposed at places along Turkey Creek, but occurs at −10,519 ft in the Sun 1 Lewis (sec. 6, T5S, R5E). A small "nosing" southeast of the field is the locus of a small, one-well field. The Bryan fault is ~2 mi southwest of the Southeast Mannsville field.

The Hughes Drilling Co. well (NE¼SE¼ sec. 11, T5S, R4E) found Cretaceous strata resting on Pennsylvanian (Fig. 45). The top of the Goddard was called at 2,529 (−1,731) ft, the "Caney" at 3,625 (−2,827) ft, the Woodford at 4,720 (−3,922) ft, the "Hunton" at 5,121 (−4,323) ft, the Sylvan at 5,388 (−4,590) ft, the Viola at 5,447 (−4,649) ft, and the Bromide at 6,075 (−5,277) ft. The test was completed as a dry hole at a total depth of 7,110 ft.

The Texaco 1 Neff–Rollins well (NE¼NE¼NE¼ sec. 12, T5S, R4E) encountered the basal Cretaceous Trinity lying unconformably on the "Springer" shale. The top of the Woodford was reported at 1,085 (−227) ft, the Sylvan at 1,685 (−827) ft, the Viola at 1,701 (−843) ft, the Bromide at 2,430 (−1,572) ft, and the McLish sandstone at 3,665 (−2,807) ft. Commercial production was not established, and the test was abandoned at a total depth of 3,739 ft.

The Sohio 1 Goldfeder "A" well (SW¼SW¼ sec. 6, T5S, R5E) was drilled to a total depth of 3,870 ft in the Oil Creek Formation. This test found the Antlers sandstone overlying the "Springer"–"Caney" shale section. The well encountered the top of the Sylvan at 1,383 (−493) ft, the Viola limestone at 1,393 (−503) ft, the Bromide at 1,928 (−1,038) ft, the McLish at 2,505 (−1,615) ft, and the Oil Creek at 3,035 (−2,145) ft. Shows of oil were encountered in the third Bromide (Tulip Creek) sandstone, but commercial production was not established.

The Godfrey 2 Waggoner well (NE¼SE¼SW¼ sec. 6, T5S, R5E) crossed a fault at 2,750 (−1,852) ft, passing from "Springer"–Goddard shales into the Middle Ordovician Oil Creek Formation. The Oil Creek sandstone, at 3,346 (−2,448) ft, contained gas, but not in quantities sufficient to make a commercial well.

A nearby well (the Godfrey 1 Lewis "A", NE¼SW¼SW¼ sec. 6, T5S, R5E, not shown in Fig. 45) crossed the fault at 1,210 (−305) ft, passing from "Pennsylvanian" shale into the Woodford Formation. Continued drilling encountered the Sylvan dolomite at 1,430 (−515) ft, the Viola limestone at 1,430 (−525) ft, the Bromide at 1,905 (−905) ft, and the McLish Formation at 2,408 (−1,503) ft. The hole was pronounced dry and abandoned after several drill-stem tests recovered only traces of gas and gas-cut mud.

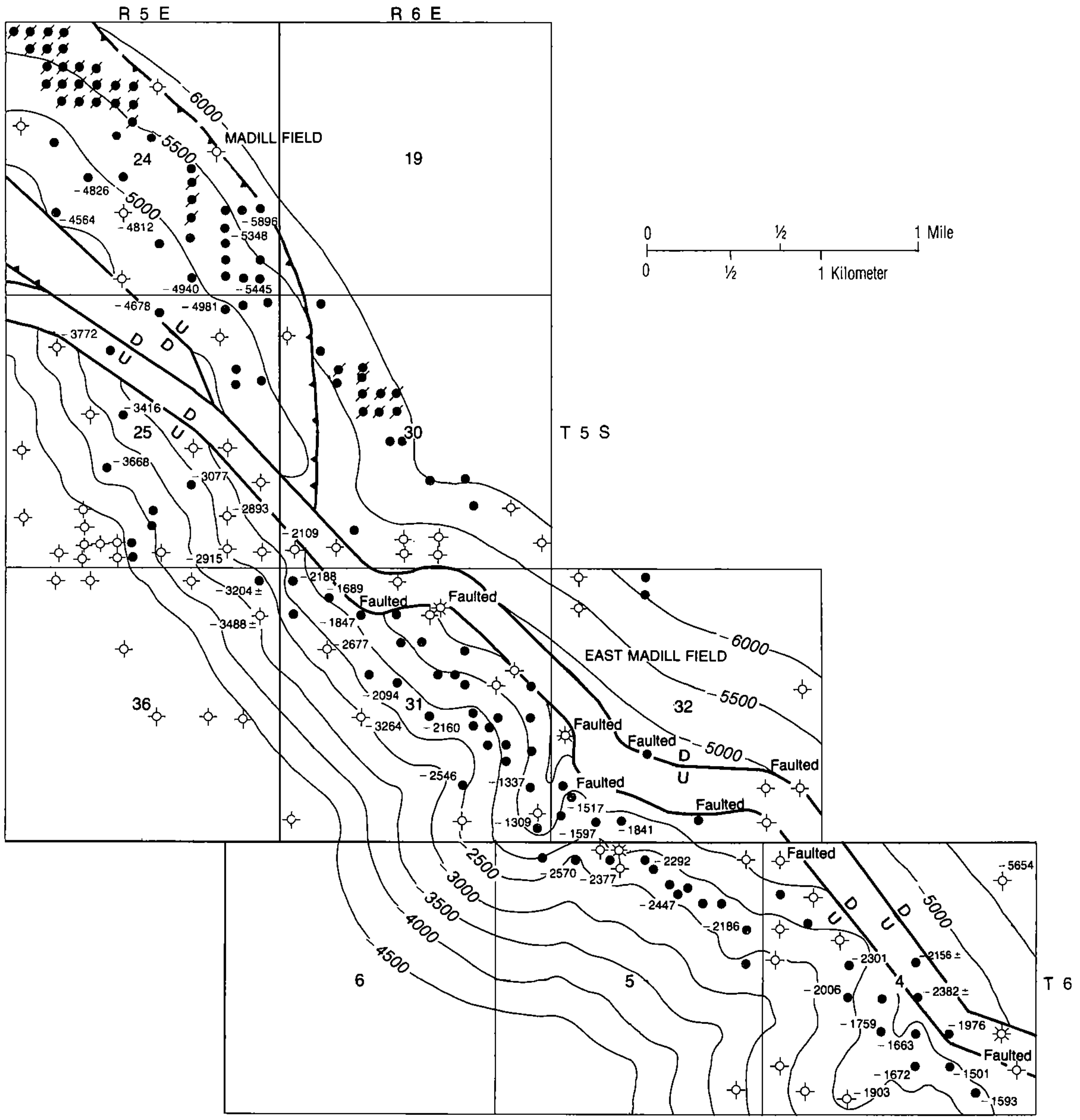

Figure 43. Structure-contour map of the top of the Viola Group, Madill and East Madill fields, Marshall County.

The Sun Oil Co. 1 Lewis well (NE¼NW¼ sec. 6, T5S, R5E) reached a total depth of 14,090 ft in the Oil Creek Formation. The Cretaceous Trinity (Antlers sandstone) lies unconformably on the Pennsylvanian Deese Group. The "Springer" formation was reported at 5,714 (−4,861) ft, the "Caney" at 10,153 (−9,300) ft, the Sycamore at 10,538 (−9,685) ft, the Woodford at 10,786 (−9,933) ft, the Sylvan Shale at 11,126 (−10,273) ft, the Viola limestone at 11,372 (−10,519) ft, the Bromide "dense" at 12,032 (−11,179) ft, the McLish Formation at 12,758 (−11,905) ft, and the Oil Creek Formation at 13,962 (−13,109) ft. The well was abandoned after several drill-stem tests failed to recover commercial quantities of hydrocarbons. The Sun 1 Lewis well is believed to be in a ramp between the two SE-trending thrust faults that cut the Mannsville anticline.

Enos and Isom Springs Fields

Location and Description

The Enos and Isom Springs fields are small, shallow fields producing from basal Cretaceous

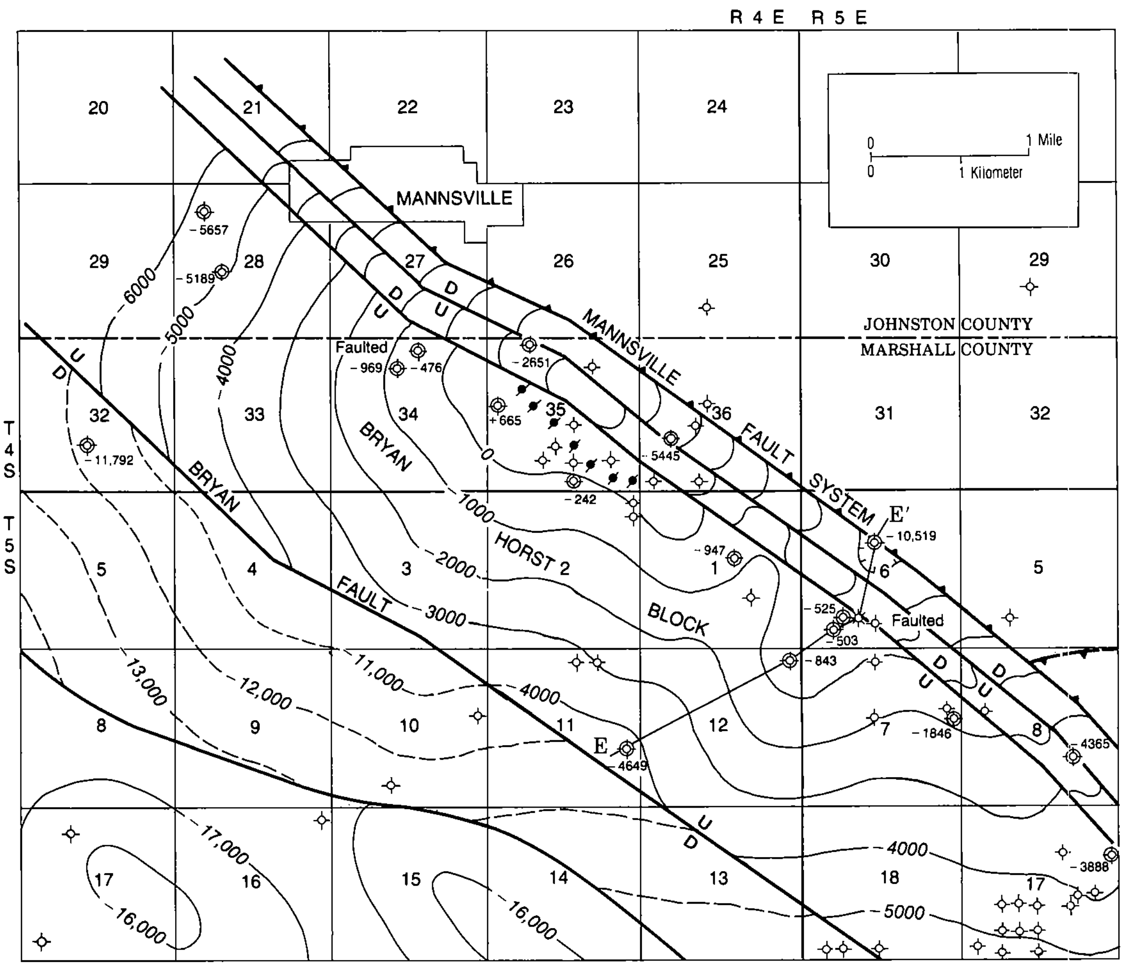

Figure 44. Structure-contour map of the top of the Viola Group, Southeast Mannsville field, Marshall County. Cross section *E–E'* is shown in Figure 45.

Trinity (Antlers) sands at depths of 500–1,500 ft. The fields are in southern Marshall County on the crest of the Preston anticline (Fig. 28). Hydrocarbons are thought to have migrated upward from the underlying Paleozoic rocks along various faults and fractures in rocks of the Ouachita facies. These fields are located along the western margin of the Ouachita thrust belt (Figs. 31,32,46). In 1984, 100 wells produced 109,024 bbl of oil, with a cumulative total (1-1-85) of 3,725,130 bbl (Table 3).

Deeper drilling has recently established production in the Ouachita facies well below the Cretaceous strata, where a series of thrust faults and overturned beds have formed oil traps in the Arkansas Novaculite.

Enos–Isom Springs Novaculite Production

Background

[Note: This section has been taken largely from Morrison (1980) and from an unpublished report made available by Westheimer–Neustadt Corp., Ardmore, Oklahoma.]

In February 1977, the Westheimer–Neustadt Corp., together with the Daube Exploration Co. and a group represented by George Ramsey of Ardmore, drilled the 1 Wallace well in the NE¼SW¼NE¼ sec. 2, T8S, R5E (Figs. 47,48). Drilling of the discovery well was prompted by shows of oil reported by Henry McCool in a stratigraphic test (SE¼SW¼NE¼ sec. 2, T8S,

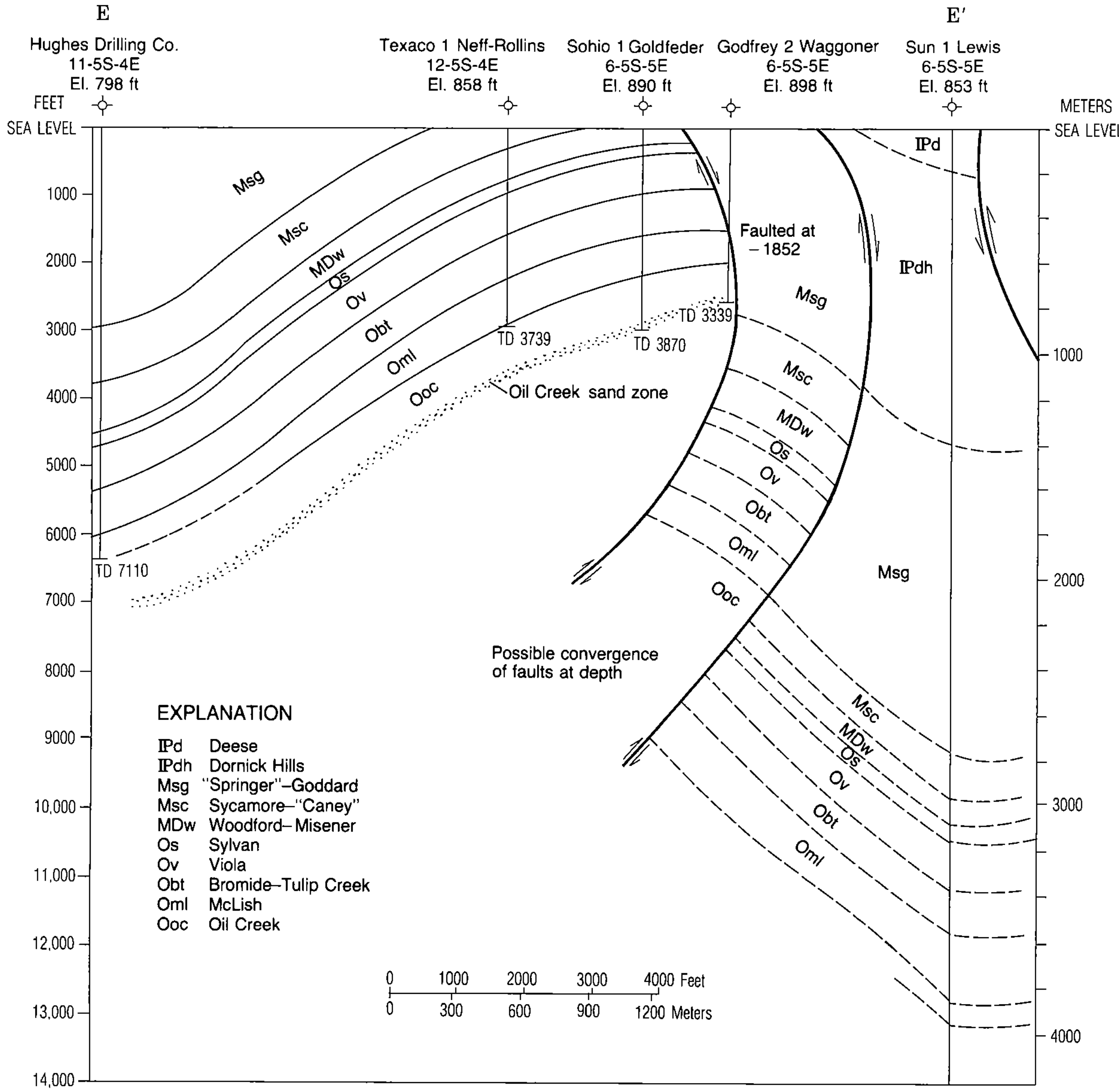

Figure 45. Cross section of the Southeast Mannsville field, Marshall County. Line of cross section is shown in Figure 44.

R5E) drilled by the Atlantic Richfield Co. in May 1969 (Morrison, 1980, p. 20).

The 1 Wallace well encountered a show in the upper chert zone of the Arkansas Novaculite and made gas on a drill-stem test at 2,116–2,249 ft. A second drill-stem test, taken in the laminated zone at 2,770–2,931 ft, flowed at the rate of 645 bbl of 43°-gravity oil per day. The well was completed in the lower laminated zone through perforations at 3,426–3,440, 3,415–3,420, 3,403–3,409, and 3,390–3,393 ft; it flowed at the rate of 250–300 bbl/day. Cumulative production through September 1980 was 180,000 bbl.

Following completion of the 1 Wallace, more than 65 additional wells were drilled and completed, with cumulative production from the Arkansas Novaculite through September 1980 >1,500,000 bbl (Morrison, 1980, p. 20–21). Fifty of the first 59 wells were producers; nine were dry holes.

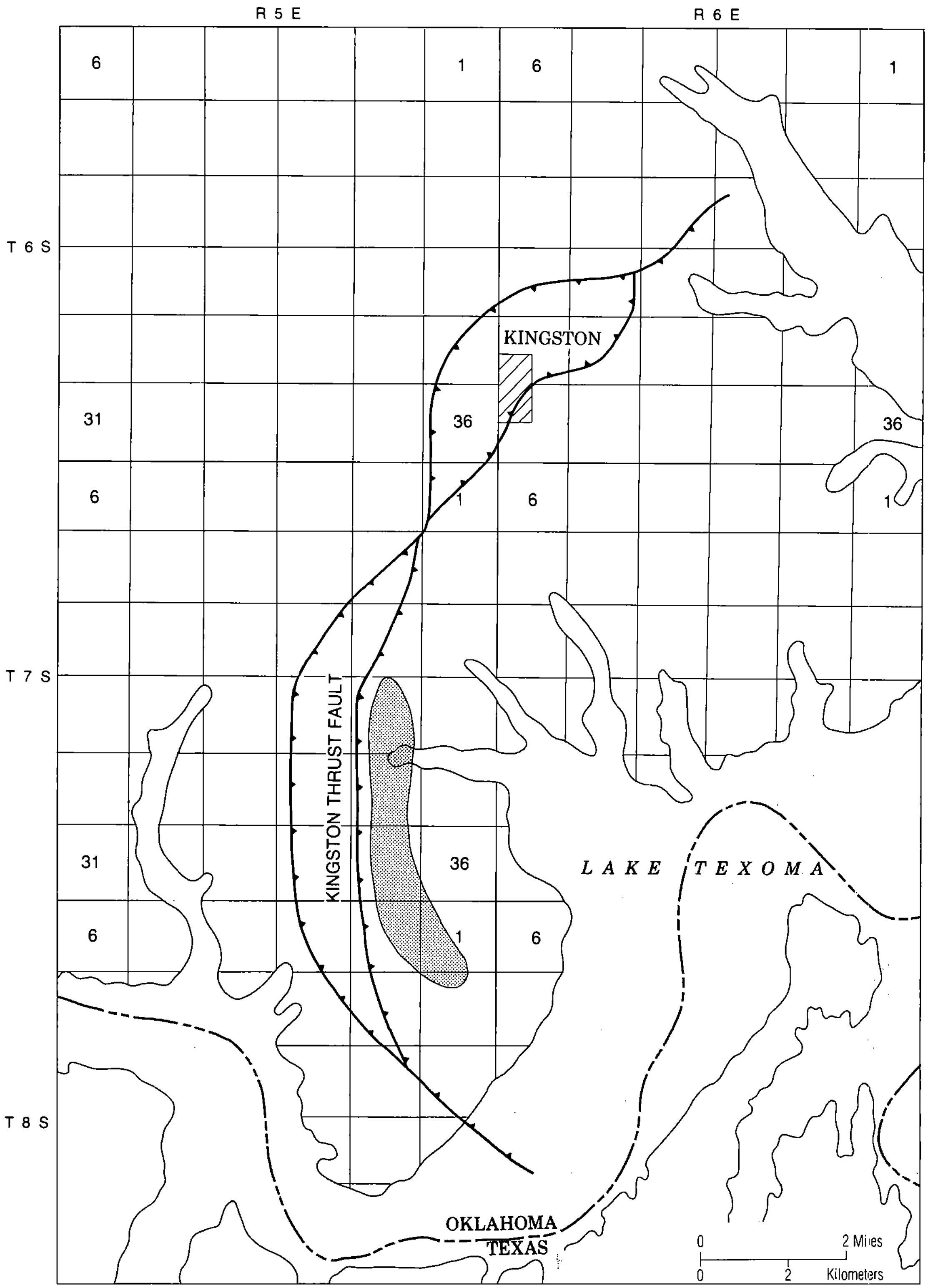

Figure 46. Area of Arkansas Novaculite production (stippling), Enos and Isom Springs fields, Marshall County. (Redrawn from Morrison, 1980, fig. 1.)

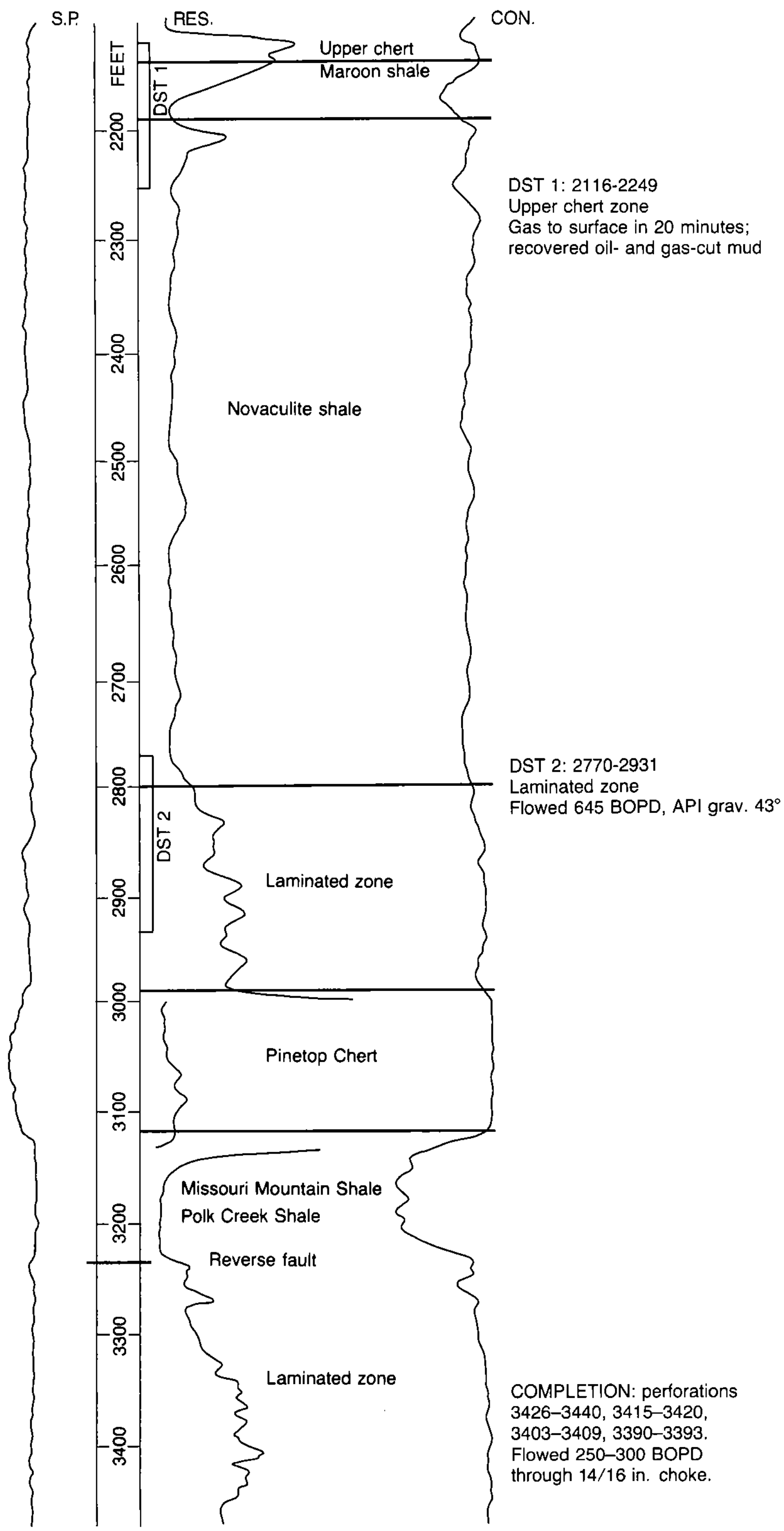

Figure 47. Electric log of the Westheimer–Neustadt 1 Wallace well (sec. 2, T8S, R5E), the discovery well for production from the Arkansas Novaculite in the Enos and Isom Springs field, Marshall County. (Redrawn from Morrison, 1980, fig. 2.)

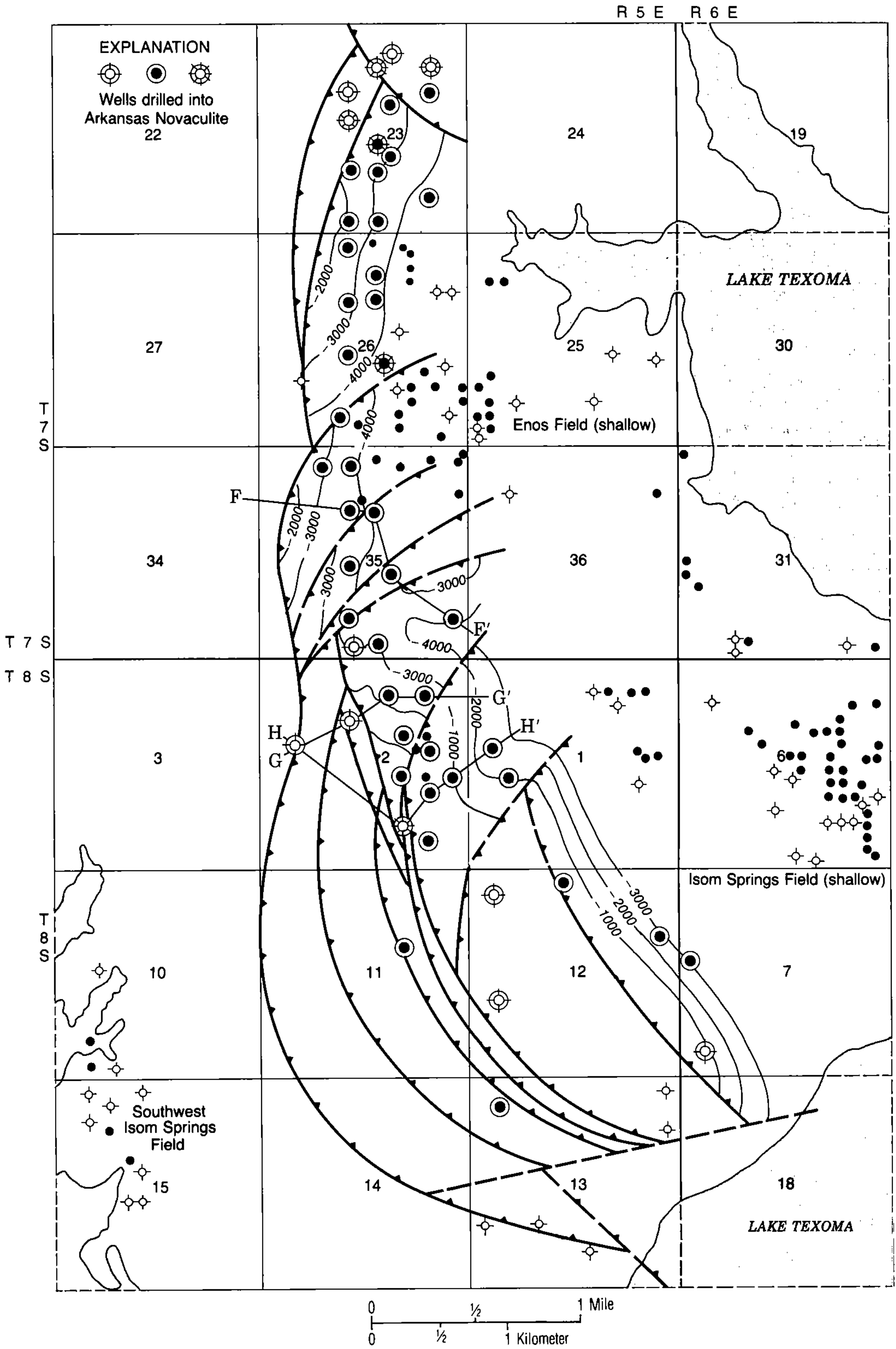

Figure 48. Structure-contour map of the top of the Arkansas Novaculite in the productive area, Enos and Isom Springs fields. (Redrawn from an unpublished map furnished by Westheimer–Neustadt Corp., Ardmore, Oklahoma.) Cross sections *F–F′*, *G–G′*, and *H–H′* are shown in Figures 49–51.

Structure-Contour Map and Cross Sections

The structure of the Isom Springs novaculite reservoir is highly complex. Production is confined to the overthrust block (Figs. 48–51) east of the Ouachita frontal thrust zone (Kingston fault of this report). Structures along the frontal thrust are characterized by imbricate thrusting with associated folding and fracturing. Fracturing is essential to the generation of permeability in the novaculite sequence. The Ouachita rocks are thrust upon rocks of the Arbuckle facies ("Springer" and Dornick Hills) and are overlain unconformably by the basal Cretaceous Antlers sandstone.

The Isom Springs novaculite field is ~5 mi long (Fig. 48). The trap is a complexly thrust-faulted anticline. The beds dip ~35° eastward and are overturned toward the west.

The stratigraphic section below the Cretaceous consists of shale of the Stanley Group; the Arkansas Novaculite (350 ft), divided into the upper chert (60 ft), the maroon shale (40 ft), the novaculite shale (180 ft), and the laminated zone (100 ft); the Pinetop Chert, which is included by some in the basal part of the Arkansas Novaculite (50 ft); the Missouri Mountain Shale (170 ft); the Polk Creek Shale(?) (50 ft); the Bigfork Chert (450 ft); and the Womble Shale (150 ft). The stratigraphic section for the Enos–Isom Springs novaculite production is shown in Figure 30 (adapted from Morrison, 1980, fig. 7). The Womble Shale is correlated with the Simpson Group of the Arbuckle facies, the Bigfork Chert with the Viola Group (Trenton), the Polk Creek Shale with the Sylvan Shale, the Missouri Mountain Shale with the Lower Silurian (Chimneyhill), the Arkansas Novaculite with the Woodford and Sycamore, and the Stanley Group with the "Caney" and Goddard. The Jackfork Group (if present) is now considered Lower Pennsylvanian (Morrowan) by the Oklahoma Geological Survey.

Discovery of oil in fractured Arkansas Novaculite in the Enos–Isom Springs area of Marshall County, Oklahoma, and the subsequent discovery of oil at McKay Creek in the Caballos Formation in Terrel County, Texas, may have opened a petroleum province extending some 640 mi from the Ouachita Mountains of Oklahoma to the Marathon Mountains of southern Texas, including a belt some 30 mi wide along the frontal thrust belt, (Morrison, 1980, p. 30).

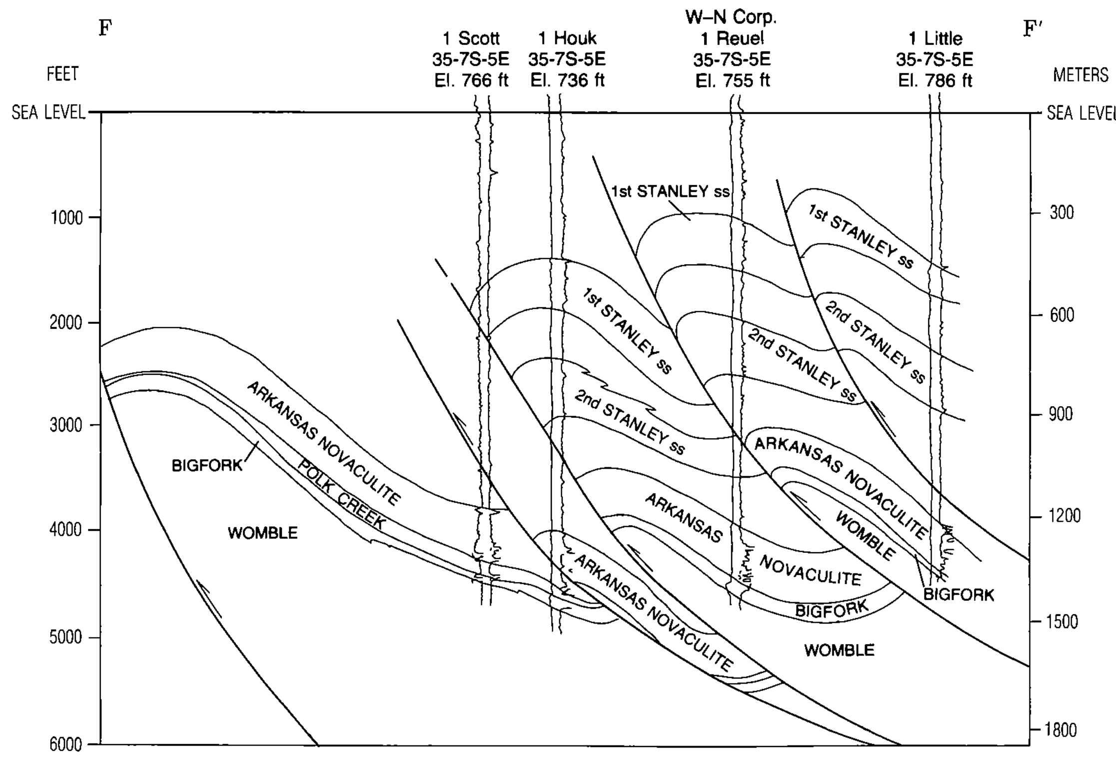

Figure 49. Cross section of the Enos–Isom Springs field. (Courtesy of Westheimer–Neustadt Corp.) Line of cross section is shown in Figure 48.

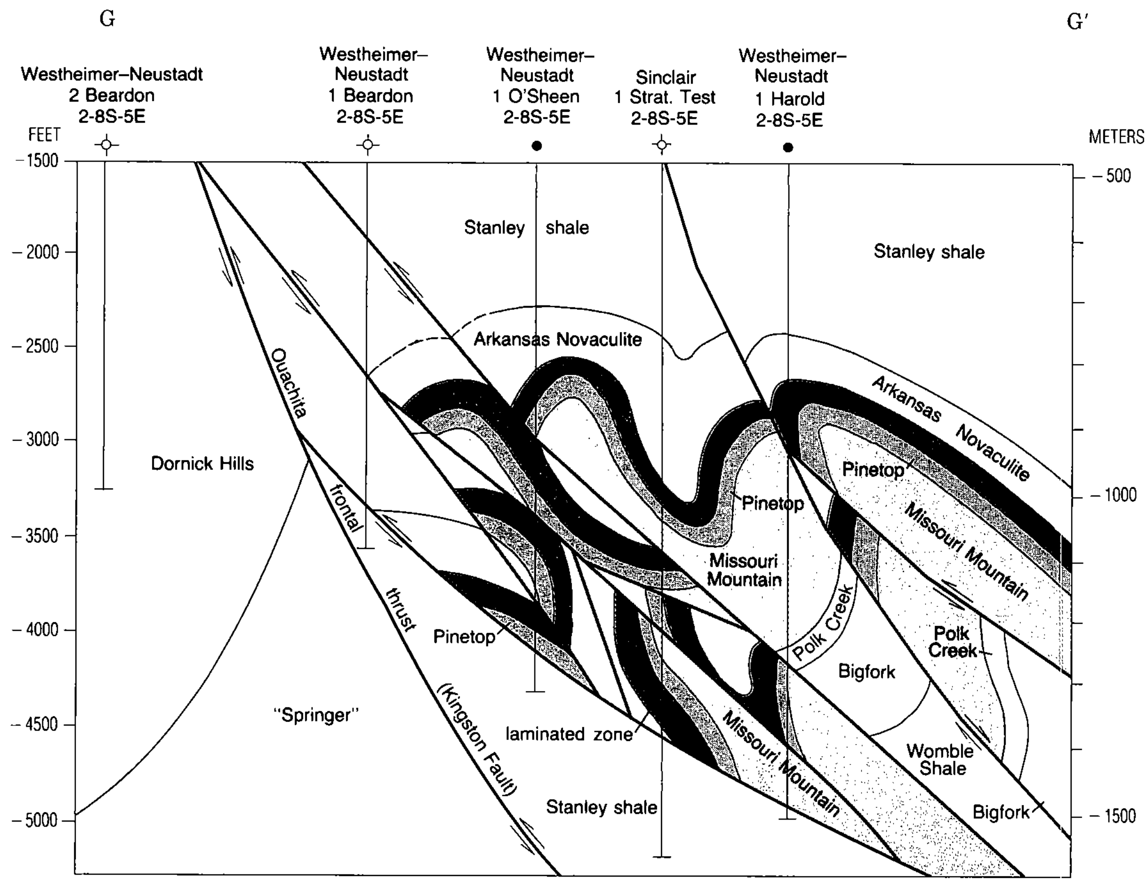

Figure 50. Cross section of the Enos–Isom Springs field, showing structures that control Arkansas Novaculite production. (Redrawn from Morrison, 1980, fig. 6.) Line of cross section is shown in Figure 48.

Handy and Southeast Handy Fields

[Note: This section has been taken largely from Henry (1968).]

Location and Description

The Handy field, in Grayson County, northern Texas, was described by Henry (1968). Production was established high on the south flank of the Overbrook anticline (Fig. 52), the most northerly ridge of the Criner Hills anticlinorium. Production is from the lower "gray Strawn" and the lower "red Strawn" (both Desmoinesian) and the occurrence of hydrocarbons is controlled largely by flank pinchouts on the Overbrook structure. Thrusting along the Overbrook fault pushed "Springer" and "Morrow" beds from the northeast over the younger producing zones in the Strawn, and there is local overturning beneath the thrust sheet.

The Handy field was discovered by Texaco in 1946 as the result of test drilling along the Criner Hills trend. Texaco's 2 J. R. Handy, the discovery well, flowed 500 bbl/day from the "Handy sand" (lower "gray Strawn") at 1,670 ft. Two additional wells were completed in this zone, and development was halted. In 1953, Howell, Holloway, and Howell completed a southeast stepout, the 2-A Hutchison, which discovered the Southeast Handy field. Subsequent drilling and development led to the completion of some 73 wells, which produced more than 5 million bbl of 40°-gravity oil through September 1968.

Drilling and development of the field were made difficult by the complicated structure along the Overbrook fault, by heaving shales in the "Morrow"–"Springer" on the upthrown side of the fault, and by construction of Lake Texoma, whose waters cover much of the producing area. Consequently, many of the holes were directionally drilled.

Reservoir rocks include (in descending order) the "H-1 sand," "H-2 sand," "Handy sand," "H-3 sand," "N sand," "O sand," "P sand," and "Q sand" (Fig. 52). The "Handy sand" is described as the best reservoir rock in the field, having an average

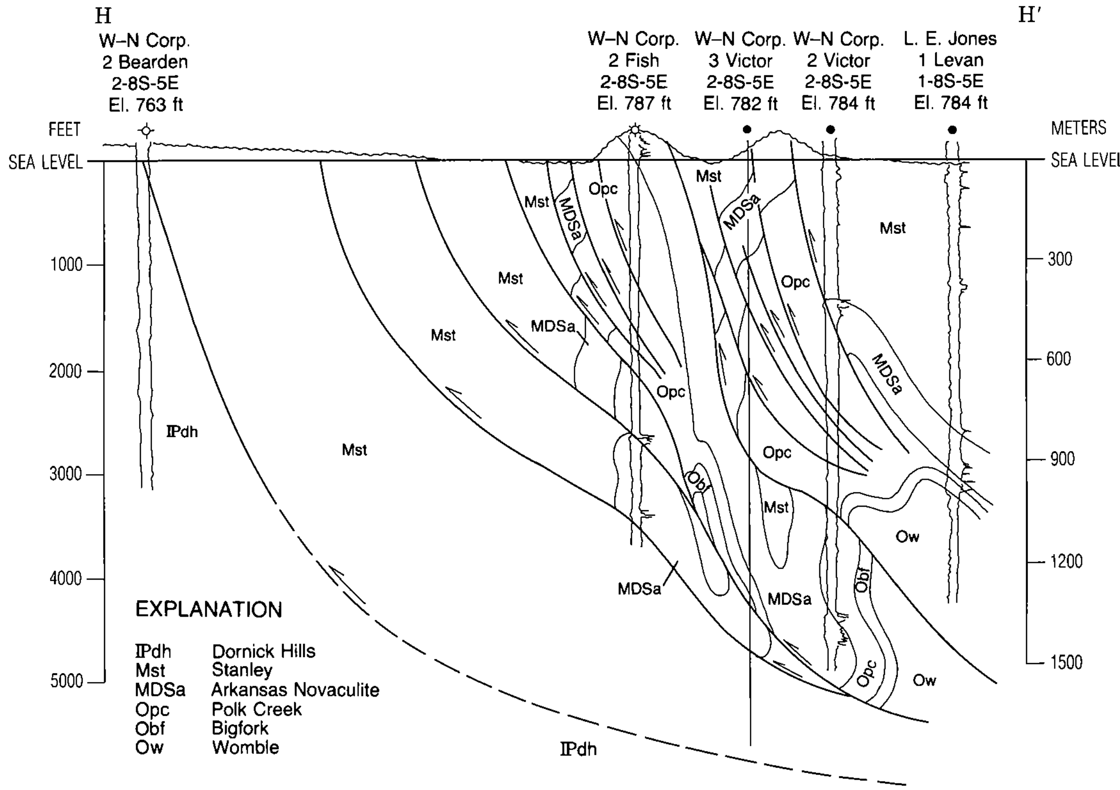

Figure 51. Cross section of the Enos–Isom Springs field. (Courtesy of Westheimer–Neustadt Corp.) Line of cross section is shown in Figure 48.

thickness of 50 ft, a porosity of 20%, a permeability of 200 mD, and a water saturation <10%. A maximum oil column of 2,000 ft is present on the Handy Unit lease. The "H-2 sand" is similar to the "Handy sand," but is limited in extent. The "H-3 sand" has lower porosity, more shale, and 25% water saturation. The "P sand" and "Q sand" are tighter than the younger sandstones, having 14% porosity and 17% water saturation.

The Southeast Handy field was extended into sec. 33, T7S, R4E, in Marshall County, Oklahoma, by the Magna 1 Foster–Davis well, which was completed in the "Handy sand" (3-28-67) through perforations at 5,210–5,257 ft for 110 bbl of 39°-gravity oil per day.

Southwest Isom Springs Field

The Southwest Isom Springs is a small field producing from relatively shallow Pennsylvanian sands of the Deese Group (Desmoinesian). Five wells drilled on the southwest side of a fault have a cumulative production to January 1, 1985, of 416,845 bbl. Production for 1984 was 8,727 bbl.

South Powell Field

Location and description

The South Powell field is on a structural block that is a southeastward extension of the Handy and Southeast Handy block in Grayson County, Texas, and the Criner block in Oklahoma (Figs. 29,32).

The discovery well, the Shell Oil Co. 1 Dickerson "C" (SW¼SW¼ sec. 35, T7S, R4E) was spudded December 29, 1957, and completed April 17, 1958. Originally drilled to a depth of 6,090 ft, the well was plugged back to 1,742 ft and completed in a stray sand in the upper Dornick Hills Group (Desmoinesian) through perforations at 1,451–1,630 ft, for an initial production of 61 bbl/day of 32.7°-gravity oil. The top of the Atoka(?) was logged at 1,665 (−942) ft, and the borehole crossed the Overbrook fault at 4,050 (−3,327) ft, which brings the Dornick Hills section against the Deese (or Strawn) (Fig. 53). Wells on the northeast side of the Overbrook fault (upthrown block) pass from basal Cretaceous into upper Dornick Hills.

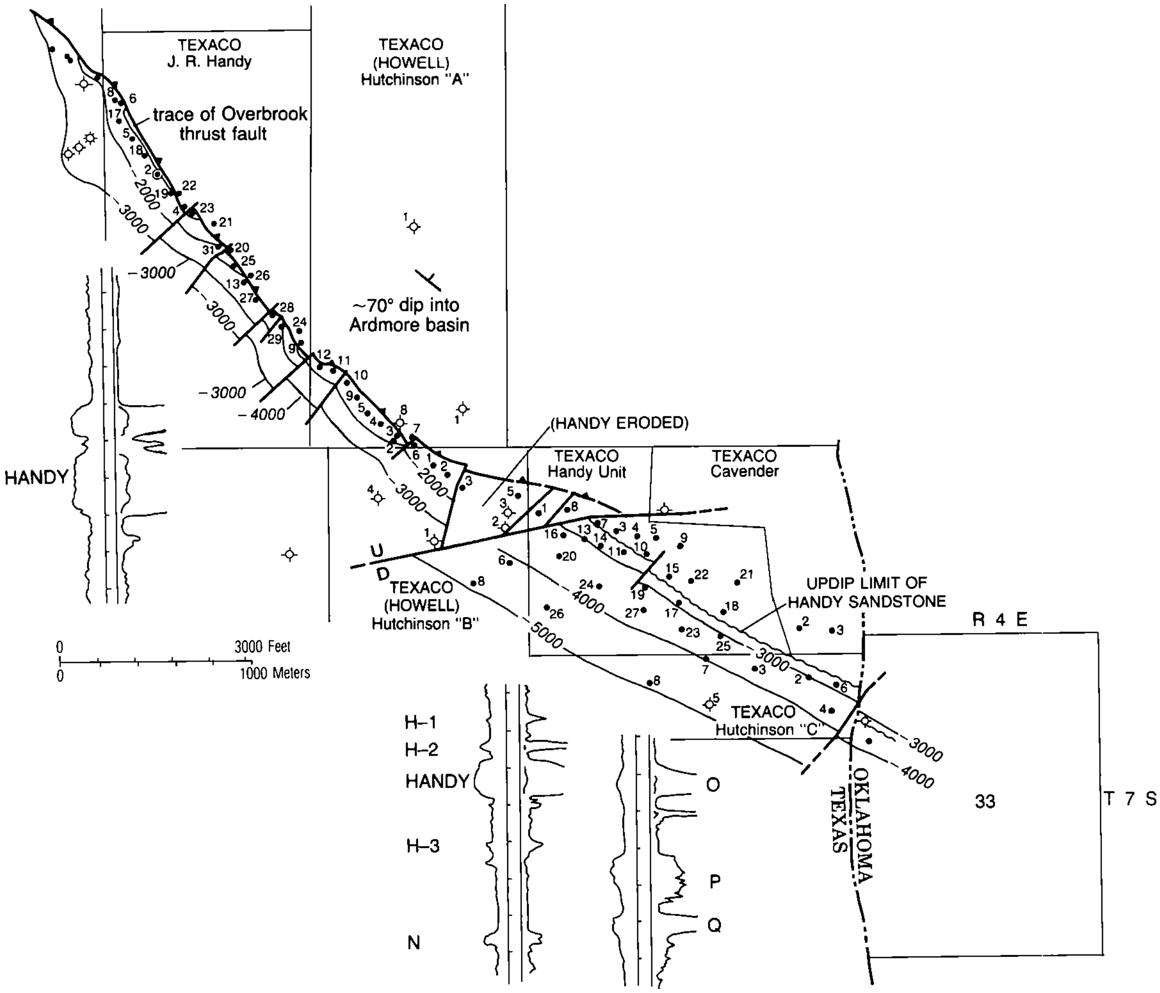

Figure 52. Structure-contour map of the top of the "Handy sand," Handy and Southeast Handy fields, Grayson County, Texas, and Marshall County, Oklahoma. Producing zones are indicated on typical electric logs. (After Henry, 1968, fig. 2.)

Wells drilled on the southwest side of the Overbrook fault pass from the Cretaceous Trinity (Antlers) sand into the "red Strawn" (Deese Group). Fusulinids in a limestone at 1,280 ft and in a sandy limestone at 3,120 ft in the discovery well support the assignment of the upthrown section to the Dornick Hills Group.

Succeeding tests found production in the "Handy sand," the "P sand," and unnamed sands of the Desmoinesian Series. This shallow accumulation is controlled by structure and by lensing of the reservoir sands. The structure is a NW-trending anticline whose northeast flank is cut by the Overbrook fault (Figs. 53–55). The most prolific zone is the "Handy sand," which tends to "shale out" near the top of the structure. The "Handy zone" lies beneath the lower "gray Strawn" (Deese). Twenty oil wells and nine dry holes were drilled during the development stage.

The Overbrook thrust fault separates very shallow production on the southwest side. Several of the wells were directionally drilled in order to produce beneath the waters of Lake Texoma.

Recent drilling has established production from the Viola limestone and the Oil Creek sand. Six deep wells were drilled and completed by the American Quasar Petroleum Co.; these are discussed in the following section.

South Powell Field (Deep Production)

Deep production (Figs. 54–57) was established in the South Powell field in 1977 by the American Quasar Petroleum 1 Groff well (sec. 2, T8S, R4E),

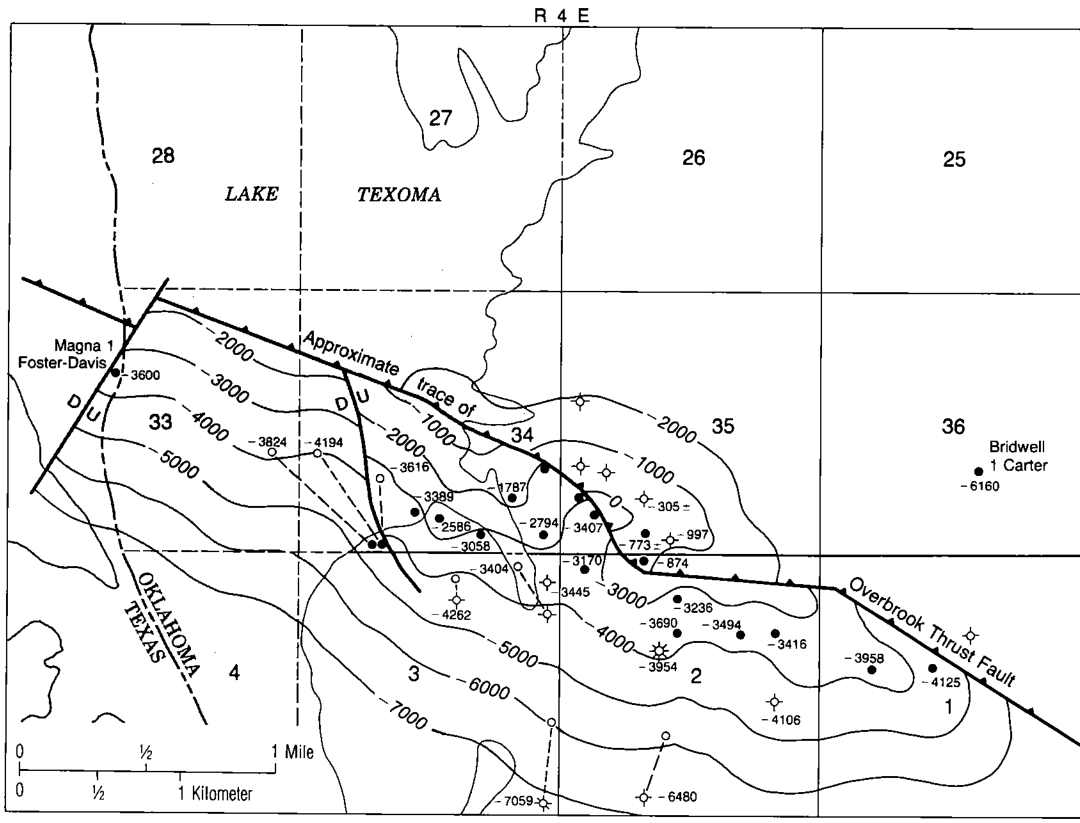

Figure 53. Structure-contour map of the top of the lower "gray Strawn" (Desmoinesian), South Powell field, Marshall County. (Redrawn from unpublished map furnished by Gary E. Henry, Wichita Falls, Texas.)

which was completed for an initial production of 10,700 Mcf/day of gas through perforations at 14,644–15,011 ft in the Viola limestone for a new-zone discovery. The total depth was 17,815 ft. The second deep test, the American Quasar Petroleum 1 Beard (sec. 3, T8S, R4E), was completed in 1979 for an initial production of 4,000 Mcf/day of gas and 50 bbl/day of 54°-gravity condensate from perforations in the Oil Creek sandstone at 16,406–16,460 ft. The well was drilled to a total depth of 16,596 ft. The 1 Beard was reworked in 1980 and completed as a gas well in the Viola limestone through perforations at 13,771–14,553 ft. Initial production from the Viola was 610 Mcf/day of gas and 18 bbl/day of 58°-gravity condensate.

The third deep test was the American Quasar Petroleum 1 Federal (sec. 11, T8S, R4E), which was completed November 13, 1979, for an initial production of 4,500 Mcf/day of gas from the Oil Creek sandstone through perforations at 16,162–16,212 ft; the total depth is 19,000 ft. The American Quasar Petroleum 1 Cowan (sec. 12, T8S, R4E) was completed on December 5, 1980, in the Oil Creek sandstone for 3,000 Mcf/day of gas and 8 bbl/day of 54°-gravity condensate through perforations at 15,881–15,934 ft. The total depth was 16,150 ft. The 1 Cowan well was reworked and completed for a zone discovery in the Bostwick Formation through perforations at 11,765–11,770 ft (5-20-81). Production was 53 bbl/day of oil and 135 Mcf of gas.

The American Quasar Petroleum 1 Cox (sec. 34, T7S, R4E) was completed August 23, 1981, in the Viola limestone through perforations at 14,552–15,400 ft; the total depth was 15,500 ft. Initial production was 2,000 Mcf/day of gas and 240 bbl/day of 63°-gravity condensate. The American Quasar Petroleum 1 Keeton (sec. 10, T8S, R4E) was drilled to a total depth of 17,110 ft. The Viola limestone was topped at 15,020 (−14,556) ft. The Oil Creek sandstone was logged at 16,240 (−15,576) ft. The well was completed in the lower Dornick Hills through perforations at 13,325–13,395 ft and in the Bostwick through perforations at 12,414–13,158 ft. Commingled flow amounted to 100 bbl/day of 47°-gravity oil and 220 Mcf/day of gas. The well was completed September 25, 1981.

Because of proximity to Lake Texoma and the

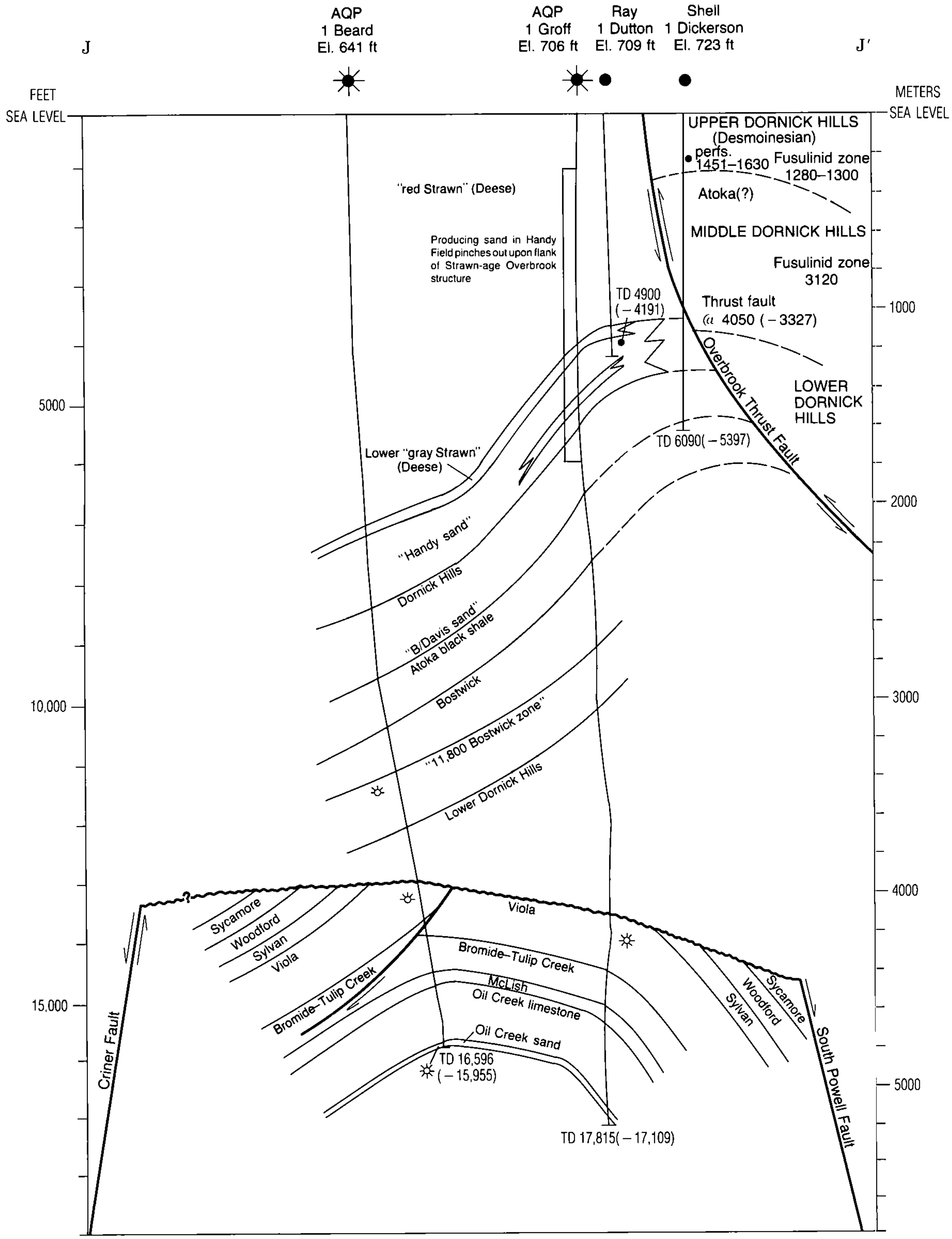

Figure 54. Cross section of the South Powell field, Marshall County. Line of cross section is shown in Figures 56 and 57. (Redrawn from an unpublished section furnished by Herbert E. Ware, Jr., American Quasar Petroleum Co., Midland, Texas.)

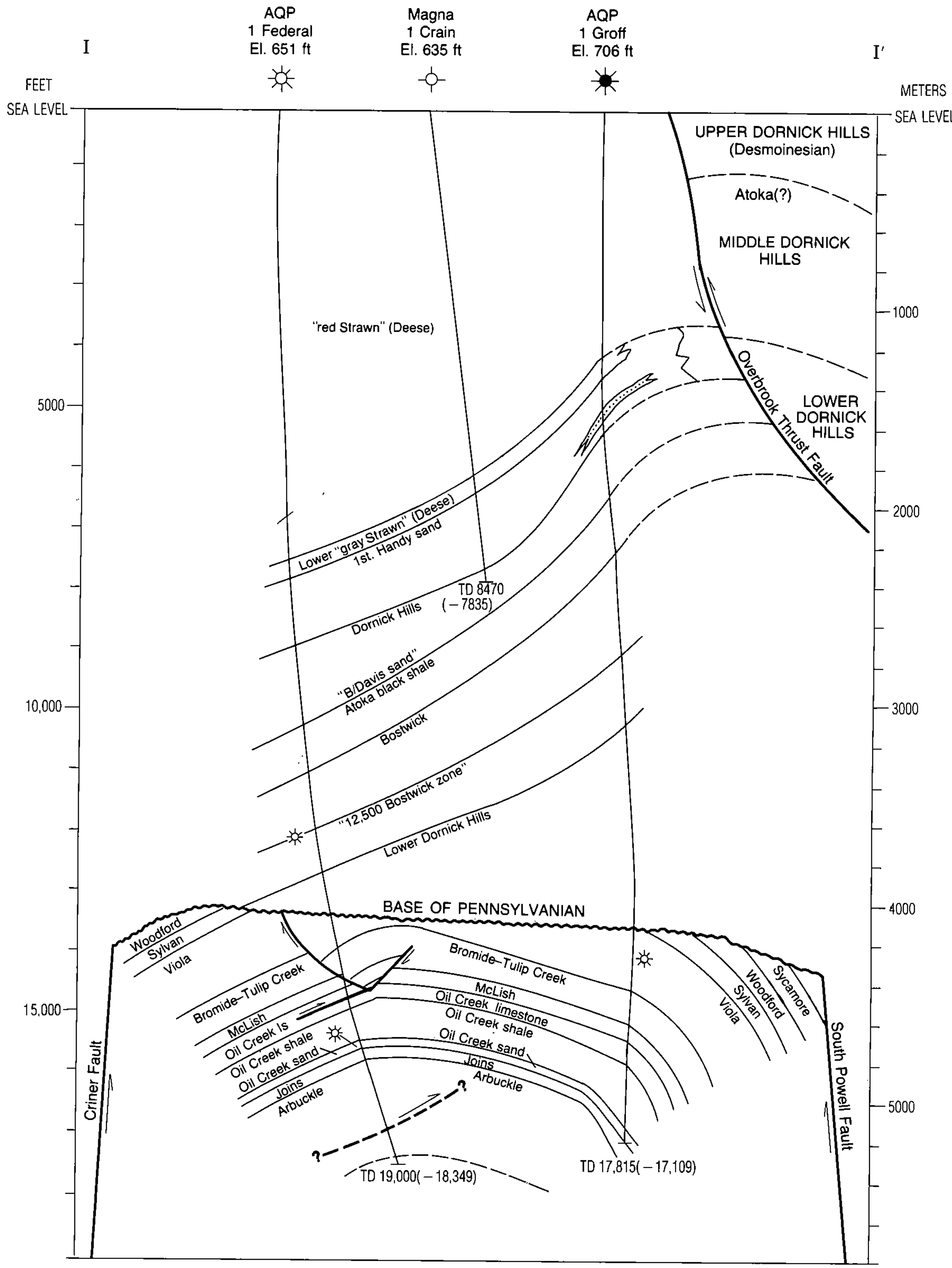

Figure 55. Cross section of the South Powell field, Marshall County. Line of cross section is shown in Figures 56 and 57. (Redrawn from an unpublished section furnished by Herbert E. Ware, Jr., American Quasar Petroleum Co., Midland, Texas.)

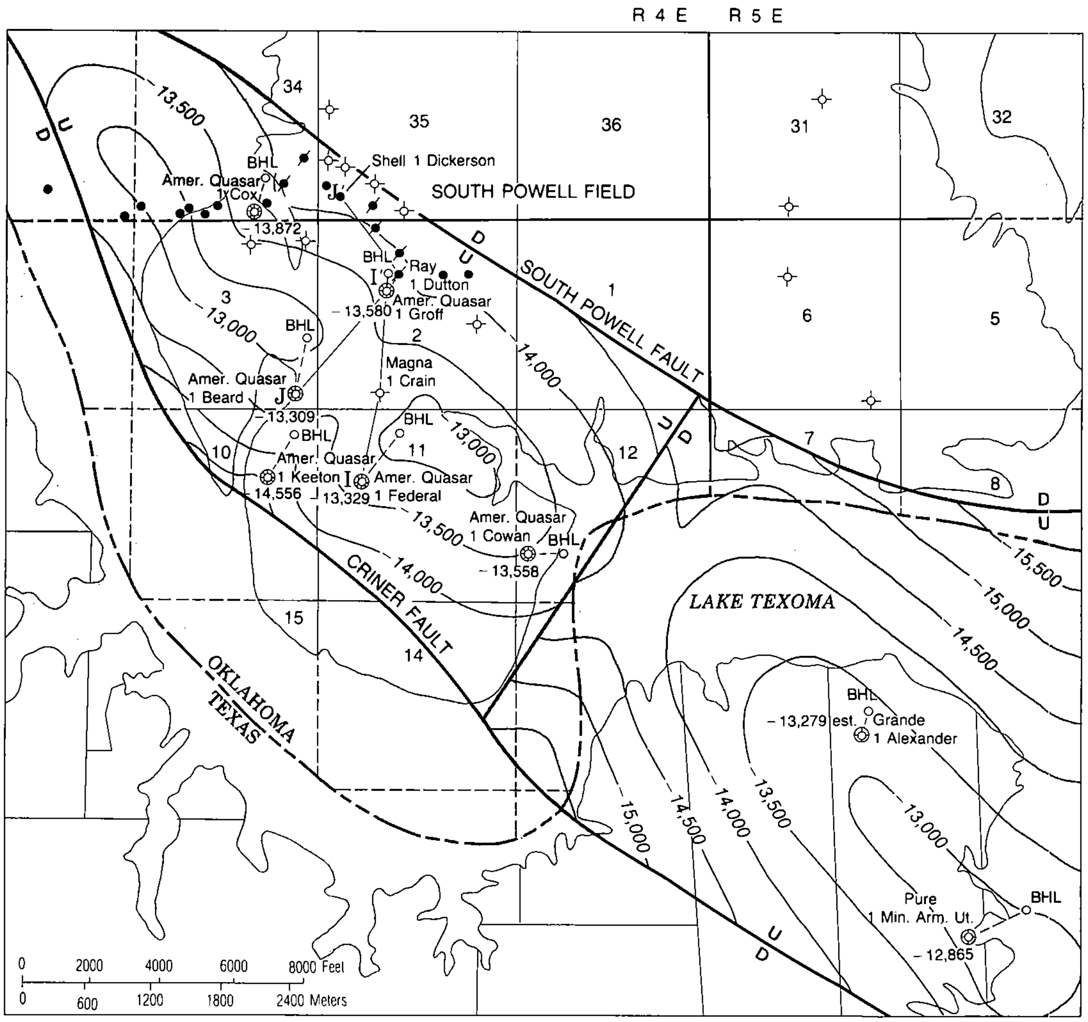

Figure 56. Structure-contour map of the top of the Viola Group, South Powell field, Marshall County. (Redrawn from an unpublished map furnished by Herbert E. Ware, Jr., American Quasar Petroleum Co., Midland, Texas.) Cross sections are shown in Figures 54 and 55.

steep dip encountered, most of the wells were directionally drilled. Both surface location and bottom-hole location are indicated for wells plotted on the Viola and Oil Creek structure-contour maps of the South Powell field (Figs. 56,57).

The structure-contour maps of Figures 56 and 57 and the cross sections of Figures 54 and 55 have been drawn from information furnished by the American Quasar Petroleum Co. Figure 56, contoured on the top of the Viola, shows a NW-trending horst block bounded on the northeast by the South Powell fault (new) and on the southwest by the Criner fault. The horst block shows anticlinal structure with ~1,500 ft of closure in T8S, R4E, Marshall County, Oklahoma. A second anticline just south of the Red River in northern Grayson County, Texas, has >2,000 ft of closure. Two dry holes, the Grande 1 Alexander and the Pure 1 Min. Arm. Ut., appear to condemn the Texas part of the structure. A normal fault, downthrown on the southeast, separates the two anticlines.

Figure 57, contoured on the top of the Oil Creek sandstone, also indicates a horst block bounded on the northeast by the South Powell fault and on the southwest by the Criner fault. Two prominent anticlines, separated by a normal fault downthrown to the southeast, with 500 ft of displacement, are clearly depicted, one in Marshall County, Oklahoma, and a second in Grayson County, Texas. The Oklahoma structure has ~1,500 ft of closure, and the Texas structure has >2,000 ft of closure.

The cross section of Figure 54 shows a buried

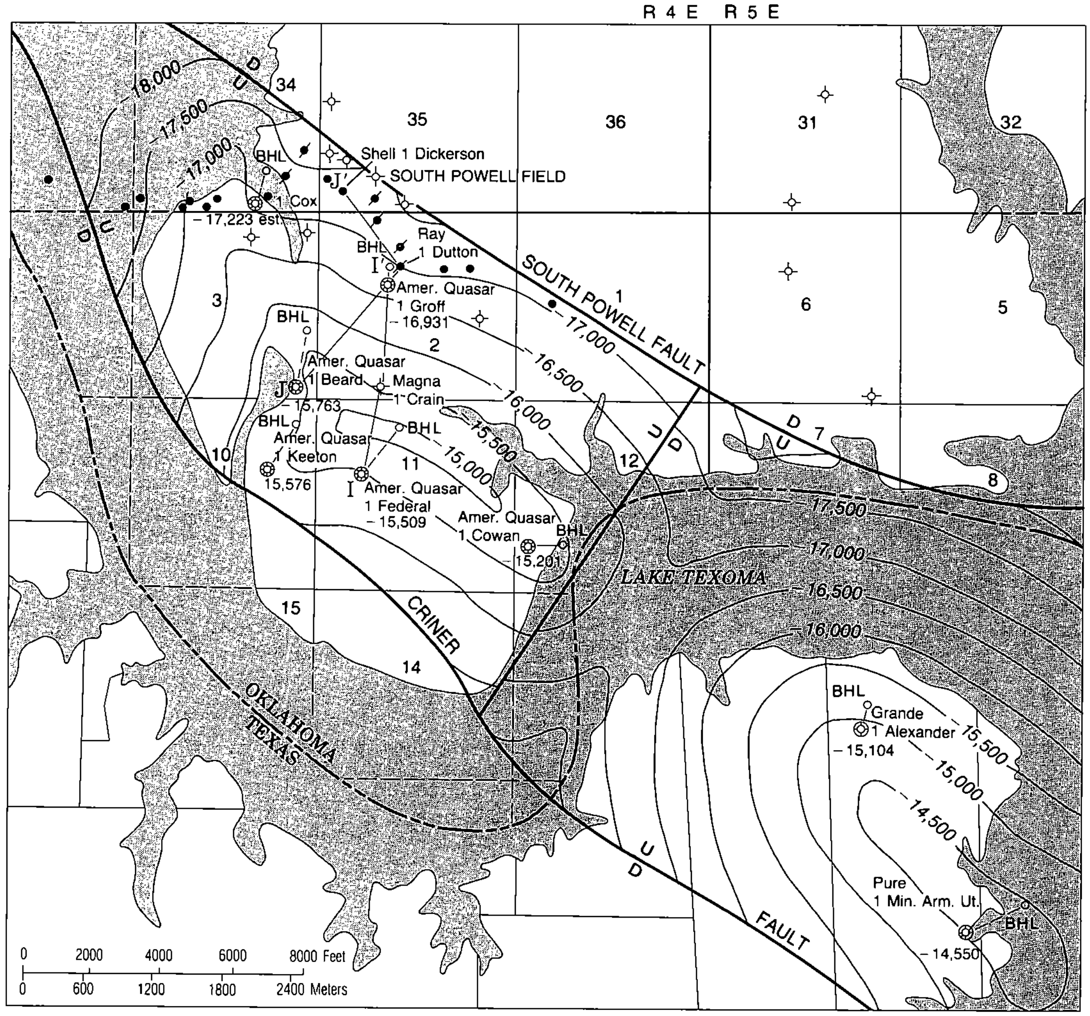

Figure 57. Structure-contour map of the top of the Oil Creek sandstone, South Powell field, Marshall County. (Redrawn from an unpublished map furnished by Herbert E. Ware, Jr., American Quasar Petroleum Co., Midland, Texas.) Cross sections are shown in Figures 54 and 55.

horst block bounded by the South Powell fault and the Criner fault. Basal Pennsylvanian beds rest on eroded Paleozoic rocks of the Arbuckle facies; the lower Dornick Hill Group lies on the Viola limestone on the crest of the structure. The Overbrook thrust passes north of the American Quasar 1 Groff, bringing the Dornick Hills Group to rest against the "red Strawn" (Deese Group).

The cross section of Figure 55 shows the same horst at depth, where the two American Quasar wells found production in the Viola limestone and the Oil Creek sandstone. The Ray 1 Dutton was completed in the shallow "Handy sand" zone, and the Shell 1 Dickerson cut the Overbrook thrust at 4,050 (−3,327) ft and produced from a stray sand in the upper Dornick Hills (Desmoinesian). Northeast of the Overbrook thrust, basal Cretaceous beds rest on the upper Dornick Hills Group; southwest of the fault, the Trinity (Antlers) lies on the "red Strawn" (Deese Group).

Production for the South Powell field in 1984 was 33,753 bbl of oil and 1,102,684 Mcf of gas. Cumulative oil production to January 1, 1985, was 840,360 bbl.

TECTONIC HISTORY AND HYDROCARBON ACCUMULATION

Introduction

Previous studies on the regional tectonics and depositional history of southern Oklahoma include those of Tomlinson and McBee (1959), Huffman (1959), Ham and others (1964), Ham and Wilson (1967), Ham (1969), and Huffman and others (1978). A geologic history of the Mannsville–Madill–Aylesworth area was prepared by Godfrey (1956) and modified by Beckman and Sloss (1966). Most of the material in this section has been taken from Huffman and others (1978).

Paleozoic Geosynclines and Sedimentation

The southern Oklahoma geosyncline formed in late Precambrian or Early Cambrian time as the crust of southern Oklahoma between the Washita Valley fault and the Waurika–Muenster arch separated and subsided to form a broad rift valley known to some geologists as an aulacogen and to others as a taphrogeosyncline. This broad rift valley or pull-apart zone was bordered on the northeast by the Tishomingo–Belton horst block, which formed part of the northeastern craton, and on the southwest by the Waurika–Muenster block, a part of the Texas craton. The geosyncline consisted of a deep, NW-trending basin with en-echelon bordering and intrabasinal uplifts; total structural relief reached a maximum of 40,000 ft on the present basement-rock surface (Ham and Wilson, 1967, p. 396). The western part of this geosyncline is now the Anadarko basin, which is bordered on the southwest by the Wichita uplift. The southeastern part of the old geosyncline is now the Marietta and Ardmore basins, which are separated by the Criner Hills uplift. The Marietta basin is bordered on the south by the Waurika–Muenster arch, and the Ardmore basin is bordered on the north by the Arbuckle anticline, which lies southwest of and adjacent to the Tishomingo–Belton horst block. The Ardmore basin plunges SE into the Bryan basin portion of the Ouachita geosyncline, which was separated from the Atoka basin, also part of the Ouachita geosyncline, by the Tishomingo–Belton segment. Both the southern Oklahoma geosyncline and the Bryan and Atoka basins of the Ouachita geosyncline were deformed by late Paleozoic (Pennsylvanian) orogenic movements.

Ham (1969, p. 7) divided the Paleozoic rocks of the southern Oklahoma geosyncline into four major lithostratigraphic units: (1) Late Cambrian to Early Devonian marine sediments, mainly carbonates; (2) Late Devonian and Mississippian black shales; (3) Pennsylvanian dark shales, sandstones, thin marine limestones, and local conglomerates; and (4) Permian red shales, sandstones, and evaporites. These sediments were deposited on more than 7,000 ft of Middle Cambrian rhyolite flows of the Carlton and Colbert Groups, which have a radiometric age of 525 m.y.

The greatest thickness of Paleozoic rocks lies in the Anadarko basin, where 38,000 ft of Late Cambrian to Late Permian beds are present. A similar section of Paleozoic rocks is present in the Ardmore basin, where 34,000 ft of Late Cambrian through Late Pennsylvanian rocks are preserved. Sedimentary strata thin toward the margin of the geosyncline and are 10,000 ft thick on the adjacent cratonic shelf areas (Ham, 1969, p. 7). Cambrian–Ordovician carbonates are limestone in the geosyncline and dolomite on the craton; the Mississippian is composed of black shales in the geosyncline and carbonates on the craton; the Pennsylvanian is composed of thick shales and sandstones in the geosyncline, and shales, thin limestones, and erratic sand bodies on the craton.

Pennsylvanian sediments of southern Oklahoma are abnormally thick, the southern Oklahoma geosyncline having received 15,000–17,000 ft of clastic sediments. The Ardmore basin received >13,000 ft of post-"Springer" sediments, including 3,000 ft in the Dornick Hills Group, 6,000 ft in the Deese Group, and 4,000 ft in the Hoxbar Group. Virgilian sediments are missing, except for postorogenic conglomerates that encircle the Arbuckle uplift.

The southern Oklahoma geosyncline was relatively stable during the early Paleozoic. Active deposition and essentially continuous subsidence occurred from Late Cambrian through Middle Devonian time, as indicated by the accumulation of thick carbonates. The diastrophic history began with epeirogenic movements in post-Hunton, pre-Woodford time, followed by intermittent orogenic movements during the Late Mississippian and Early Pennsylvanian, reaching a culmination in the Late Pennsylvanian with the folding of the Arbuckle Mountains and the final thrusting of the Ouachita rocks.

Post-Hunton, Pre-Woodford Epeirogeny

The first major Paleozoic crustal movement, after initial rifting in Early Cambrian time and subsequent emplacement of the Middle Cambrian rhyolite porphyry, occurred during the Middle Devonian (post-Hunton, pre-Woodford), when the floor of the southern Oklahoma geosyncline was uplifted and in places eroded. Removal of the Hunton Group from the Mannsville–Madill–Aylesworth anticlinal flexure indicates local warping followed by locally extensive erosion. The Oklahoma Ozarks, Seminole uplift, and other structures were tilted or arched at this time. The pre-Woodford unconformity is one of the major erosion surfaces in the Midcontinent, and the Woodford (and its basal detrital zone, the "Misener" sandstone) lies variably on beds of the Hunton Group, Sylvan Shale, Viola limestone, Simpson Group, and Arbuckle Group (Huffman, 1959, p. 2556–2557). Petroleum accumulation in the Hunton Group along the eastern shelf of the Anadarko basin is due largely to truncation of the Hunton and overlap by the Woodford Shale. The Woodford is succeeded conformably by the Sycamore Limestone and the Delaware Creek ("Caney") Shale.

Late Mississippian–Early Pennsylvanian Movements

Early Mississippian movements in the southern Appalachian Mountains and in "Llanoria," the Paleozoic landmass east of the southern Oklahoma geosyncline, have been documented by the thick sequence of Stanley, Jackfork, and Johns Valley clastics derived from a rising source to the east (Morris, 1977, p. 155–156). The effect of this movement and related movements in the southern Oklahoma geosyncline is difficult to evaluate. The Tishomingo–Belton horst block probably was uplifted in Late Mississippian time to supply the exotic boulders in the "Caney" and Johns Valley formations. A paleogeologic map by Godfrey (1956, pl. 4) suggests that the Goddard rests unconformably upon early Paleozoic beds ranging in age from Ordovician (Simpson Group) to Mississippian (Delaware Creek Shale) along the Mannsville–Madill–Aylesworth flexure. These conditions could also be explained by faulting and change of dip of the fault surfaces. Beckman and Sloss (1966, p. 1348–1359), by means of cross sections and a pre-Goddard paleogeolgic map, attempted to show deep channeling of the pre-Goddard surface, and a thick section of Goddard resting on beds as old as the Arbuckle and Simpson along the crest of the faulted anticline. Other geologists attribute this thick section of Goddard to faulting. Elsewhere in Oklahoma, the Goddard is conformable with the underlying Delaware Creek ("Caney") Shale.

Both Godfrey (1956) and Beckman and Sloss (1966) postulated an unconformity above the Goddard, related to the thinning of the Goddard and absence of "Springer" beds on the crest of the Mannsville–Madill–Aylesworth anticline. Womack (1956) noted that this relationship resulted from post-Goddard folding and faulting followed by pre-Cretaceous erosion. The Golf Course Formation (Dornick Hills Group) appears to be absent on the Aylesworth and Cumberland anticlines, but it has been recognized in the Cumberland and Kingston synclines, where it is represented by thick shales with brown-limestone interbeds.

Early Pennsylvanian Wichita Orogeny

The Early Pennsylvanian Wichita orogeny is well documented in southern Oklahoma by marginal and intrabasinal uplifts (Ham and Wilson, 1967, p. 397). It is also well demonstrated in the Wichita Mountains, where rapid uplift and erosion produced a thick sedimentary section in the Anadarko basin known as "granite wash." The most precise dating of the Wichita orogeny is in the Criner Hills, where the Jolliff Conglomerate (early Morrowan) and the younger Bostwick Conglomerate of early Desmoinesian ("Atoka") age were deposited. This orogeny is recorded over much of Oklahoma by a widespread unconformity. Late Morrowan and early Desmoinesian ("Atoka") rocks are represented in the Kingston and Cumberland synclines by shales and thin sandstones; they appear to be absent along the Cumberland anticline and the Mannsville–Madill–Aylesworth flexure, because of post-Pennsylvanian, pre-Cretaceous erosion. The Criner block was uplifted and faulted during the Wichita orogeny.

Middle Pennsylvanian (Desmoinesian) Movements (Bryan Uplift)

The second episode of Pennsylvanian deformation occurred in Desmoinesian time, when the Wichita Mountains were re-elevated and parts of the Ouachita system, including the Bryan basin, were uplifted to become the source of stream-transported chert pebbles incorporated in the Devils Kitchen and Rocky Point Conglomerates and other units of the Lake Murray region. Careful sample analysis by Saether (1976) suggested that the conglomerate pebbles came from a nearby source, <20 mi away. Pre-Cretaceous erosion stripped most of the Desmoinesian (Deese Group) rocks from the Marshall County uplifts, but left Deese rocks in the Cumberland and Kingston synclines.

Late Pennsylvanian Arbuckle Orogeny

The major deformation in the southern Oklahoma geosyncline occurred in late Missourian to early Virgilian time, when folding of the Arbuckle anticline and deformation in the Ardmore and Marietta basins, Criner Hills, and other major structures occurred. The folding and subsequent faulting that control oil accumulation in Marshall County are believed to have occurred as strong compressional forces from a northeastward-moving plate (Texas plate) acted on the southern Oklahoma geosyncline. Compressional forces from the southwest folded and faulted the rocks in the area of Marshall and Bryan Counties and adjacent parts of northern Texas. Rocks of Marshall and Bryan Counties were forced against the rigid buttress of the Tishomingo–Belton horst block, causing underthrusting of the geosynclinal rocks beneath the Cumberland and Washita Valley faults and creating the Cumberland anticline and the Ravia and Sand Canyon nappes. The Mannsville–Madill–Aylesworth flexure was re-elevated, and the faults were rotated to their present positions. Precise dating of these structures is difficult, but most surface and subsurface evidence indicates that the major oil-producing structures in Marshall County are simply a southeastern extension of the Arbuckle system of folds. The major deformation in the Arbuckle Mountains was dated by Ham (1969, p. 17–18) as post-Hoxbar and pre-early Vanoss (Pontotoc) because the faults that cut the folds in the Arbuckle Mountains also preserve the down-dropped Collings Ranch Conglomerate but pass beneath the Vanoss Conglomerate. The Vanoss Conglomerate has been dated as Late Pennsylvanian, post-Arbuckle folding.

Final Orogenic Movements in the Marathon–Ouachita Tectonic Province

Shortly after (or perhaps partly contemporaneous with) formation of the Arbuckle Mountain structures and the major faults that cut the Arbuckle rocks, strong compressional forces, probably from the southeast (Gulf plate), thrust the rocks of the Atoka and Bryan basins (Ouachita facies) northwestward to their present positions. The unusual shape of the Ouachita front in Marshall, Bryan, and Atoka Counties has been partially explained in at least two ways: (1) erosion of a large sheet of Ouachita-facies rocks from the stable Tishomingo–Belton horst block, or (2) large-scale wrench faulting on both sides of the Tishomingo–Belton block along growth faults and preexisting high-angle faults, the Bryan basin and Atoka basin rocks having been carried to their present positions by lateral movement. Proof of either of these hypotheses is lacking, although the concept of large-scale wrench faulting along preexisting growth faults seems most likely. The parallelism of the major folds and faults in the Marshall County area precludes the possibility that these structures were formed by wrench faulting alone, as postulated by some geologists. Compressional forces from the southwest created by northeastward movement of the Texas plate (late Missourian to early Virgilian Arbuckle orogeny) are believed responsible for the NW-trending folds and faults; Late Pennsylvanian (Ouachita–Marathon) movements involving northwestward movement of the Gulf plate produced the northwestward thrusting and lateral displacements along the faults.

The "Atoka" formation (Lynn Mountain Formation of Pitt and others, 1982) is the youngest rock unit known in the Ouachita facies. Thus, early Desmoinesian movements must have preceded the Virgilian movements in the Ouachita system, as evidenced by the Devils Kitchen and other conglomerates which extend into the Ardmore basin from the southeast. Final thrusting of the Ouachita rocks onto rocks of the Arbuckle facies is believed to have produced the SE-dipping joint system in the Arbuckle Mountains.

Post-Pennsylvanian History

Pre-Cretaceous erosion beveled the Late Pennsylvanian structures to a surface of moderate relief upon which the Cretaceous strata were deposited. Differential compaction and subsequent adjustment along preexisting faults and folds caused gentle folding of Cretaceous rocks. Such structures as the Preston anticline, Kingston syncline, Mannsville–Madill–Aylesworth anticline and fault system, Cumberland syncline—and possibly the Cumberland anticline and related faults (Washita Valley and Cumberland)—are reflected in the outcrop patterns of Cretaceous beds. Microfracturing of Cretaceous and underlying rocks along major faults and folds provided for development of post-Cretaceous hydrocarbon-migration paths.

The Late Cretaceous Laramide orogeny had little effect on the rocks of Marshall County, although Cretaceous seas withdrew from the area. Tertiary time was one of erosion and gentle tilting toward the Gulf of Mexico. In the Quaternary (Pleistocene), several terrace levels developed during the interglacial ages, and renewed downcutting occurred during the pluvial stages in association with ice accumulation west of Oklahoma in the Rocky Mountains.

Time of Hydrocarbon Accumulation

Oil and gas accumulation and entrapment in Marshall County are believed to have taken place largely in Late Pennsylvanian time and to have occurred after the folds and faults of the Arbuckle System had been formed. Final uplift and migration of hydrocarbons in the Cumberland, Aylesworth, Madill, North Madill, and Southeast Mannsville fields are believed to date from this time, inasmuch as the producing structures seem to be closely related to the Arbuckle movements. The overturning of fault surfaces and the northeastward underthrusting of the Cumberland block beneath the Cumberland fault and its associated nappes appear to have been Late Pennsylvanian events.

Oil and gas in nearby fields (East Madill and in part Madill) in "stray" Pennsylvanian sands such as the Primrose and basal Deese are believed to have accumulated during Late Pennsylvanian time, inasmuch as they too are related to Late Pennsylvanian structures. Folding and thrusting characterize the rocks of southern Marshall County where the Criner and Overbrook blocks continue southeastward from Carter and Love Counties. Oil and gas accumulations in Marshall County resulted from a combination of structural and stratigraphic trapping mechanisms and are related to several episodes of orogenic movement.

Accumulations of gas and oil in basal Cretaceous sands—as in the Madill, Kingston, Enos, and Isom Springs fields—apparently resulted from upward leakage along faults and fracture systems that cut pre-Cretaceous beds. Structural adjustments during the Cretaceous may have been partially responsible for these avenues of vertical migration.

Ouachita-facies rocks in southeastern Marshall County produce from fractured cherts of the Bigfork Chert (Ordovician), Missouri Mountain Formation (Silurian), Arkansas Novaculite (Late Devonian–Early Mississippian), and Stanley Group (Mississippian). The rocks in the Ouachita thrust sheet are intensely faulted, fractured, and overturned in some of the thrust slices. The folding and fracturing are believed to date from very Late Pennsylvanian time, inasmuch as rocks of the Ouachita facies have been thrust upon and against Pennsylvanian rocks of the Ardmore basin (Arbuckle facies) in the Kingston syncline, as shown by seismic profiles. Oil and gas in the Ouachita facies are thought to have migrated into these traps near the close of the Pennsylvanian Period. Earlier uplift in the Ouachita province is evidenced by the presence of chert conglomerates in the Devils Kitchen, Rocky Point, and other formations in the Ardmore basin.

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Appendix

Measured Stratigraphic Sections

APPENDIX—Measured Stratigraphic Sections

1

Bluff on west side of Oil Creek, SE$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 35, T4S, R5E (Holtzman, 1978, p. 92).

	Thickness (ft)
GOODLAND LIMESTONE	
Limestone, massive, finely crystalline, nodular, white on fresh surface, light gray to dull yellow on weathered surface; upper part weathers into thin, curved plates	10.5
ANTLERS FORMATION	
Sandstone, brownish yellow, medium- to fine-grained, moderately sorted, soft, some iron staining; scattered thin, light-gray clay lenses in lower 5 ft; contact with overlying formation sharp . .	25.0
Clay, medium gray to bright orange on weathered surface, light gray on fresh surface; sandy, soft; some iron staining	3.2
Base of exposure	
Goodland Limestone, measured total	10.5
Antlers Formation, measured total	28.2

2

Section-line road, 0.6 mi south of Simpson, SE$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 4, T5S, R4E (Holtzman, 1978, p. 87).

	Thickness (ft)
GOODLAND LIMESTONE	
Limestone, finely crystalline, massive, nodular, dull white on fresh surface, medium gray on weathered surface; breaks into thin, curved plates with honeycombed surfaces; fossiliferous; forms resistant cap on underlying sandstone	1.0
ANTLERS FORMATION	
Sandstone, light brown to dull white on weathered surface; white with shades of orange on fresh surface; medium- to fine-grained sand; moderately sorted; friable; clayey; sand and clay layers in alternating sequence (clay, 2-4 in. thick; sand, 5-10 in. thick); upper contact sharp	2.0

	Thickness (ft)
Sandstone, white to dull yellow, fine- to medium-grained, moderately sorted; subrounded to rounded grains; friable; some iron staining; some parts weather into small rounded masses; upper contact sharp	4.3
Base of exposure	
Goodland Limestone, measured total	1.0
Antlers Formation, measured total	6.3

3

Bluff on east bank of Hauani Creek about 25 yd south of State Highway 199, NE¼NW¼NW¼ sec. 27, T5S, R4E (Holtzman, 1978, p. 96-97).

	Thickness (ft)
GOODLAND LIMESTONE	
Limestone, massive, finely crystalline, dense, nodular, fossiliferous; weathered surface is dull white; light gray to white on fresh surface; unit weathers into thin, curved plates that litter the surface	7.2
Limestone as above; coloration on parts of limestone surface weathers brilliant white as compared to characteristic dull white or light gray; forms distinct ledge.	5.0
Limestone as above, some iron staining	3.4
Limestone; weathers to dull white; light gray on fresh surface; silty; scattered calcite veinlets; fossiliferous; weathers into thin plates	1.5
Clay, tan, blocky, calcareous, fossiliferous; unit occurs in thin beds approximately 0.25 ft thick; within the clay are small blocks of marly limestone; clay content decreases upward	1.6
ANTLERS FORMATION	
Sandstone, varicolored (orange, gray, reddish-brown); clay content increases upward; sand grains are rounded to subrounded; clayey; bits of carbonaceous wood scattered throughout	1.1
Sandstone, orange, fine- to medium- to coarse-grained, moderately sorted; rounded to subrounded grains; soft; scattered rounded masses of sandstone surrounded by poorly cemented sand; masses are composed of soft, friable, orange sand that weathers dark . . .	4.5

	Thickness (ft)
Covered interval; sandstone and limestone rubble partially covered by vegetation	16.0
Base of exposure in creek bed	
Goodland Limestone, measured total	18.7
Antlers Formation, measured total	21.6

4

Small hill south of flood plain of Glasses Creek, NW¼SW¼SW¼ sec. 36, T5S, R5E (Holtzman, 1978, p. 95).

	Thickness (ft)
CADDO FORMATION	
Duck Creek Member	
Clay, black; mostly soil on grass-covered slope	7.5
KIAMICHI FORMATION	
Limestone, dark yellowish brown, finely crystalline, hard, abundantly fossiliferous, containing _Texigryphaea_ _navia_ (Hall); commonly referred to as "shell beds".	0.9
Shale, dark gray to black; exposure mostly grass-covered; limestone blocks and fragments from overlying unit litter slope . . .	13.0
Covered interval, largely black alluvium with scattered limestone fragments; forms narrow flood plain along Glasses Creek	5.0
GOODLAND LIMESTONE	
Top of Goodland Limestone floors creek bottom	
Duck Creek Member, measured total	7.5
Kiamichi Formation, measured total	13.9
Covered interval, measured total	5.0

5

Road cut, NW¼NW¼NW¼ sec. 4, T5S, R6E (Ganser, 1968, p. 60).

	Thickness (ft)
GOODLAND LIMESTONE	
Limestone, white, weathers gray, biomicritic; base is slightly irregular (probably from deposition, not erosion)	3.0
Clay, yellow-gray to light gray, silty, calcareous; several thin yellow limestone interbeds; possibly Walnut Clay facies	2.5
ANTLERS FORMATION	
Clay, sand, and silt interbedded; clay gray and sandy; sand yellow and fine-grained; silt brown	5.9
Clay, blue-gray, shaly; selenite crystals weather from top of lenticular unit; limonite concretions weather from base of lenticular unit	5.0
Base of exposure	
Goodland Limestone, measured total	5.5
Antlers Formation, measured total	10.9

6

South bank of creek, SW¼SW¼NE¼, sec. 5, T5S, R6E (Ganser, 1968, p. 59-60).

	Thickness (ft)
KIAMICHI FORMATION (not measured)	
GOODLAND LIMESTONE	
Limestone, yellow-brown; weathers brown; well indurated, sandy; contains fossil fragments; transitional from Goodland to Kiamichi Formation; lower contact sharp	0.1
Limestone, gray-white; weathers light gray; thin, platy, pitted by solution, fossiliferous; lower contact gradational	0.5
Limestone, gray-white; weathers dark gray; compact; six massive beds; solution-pitted; fossiliferous; forms escarpment	16.2
Clay, calcareous, yellowish-white, irregularly bedded, fossiliferous, easily eroded; contains *Enallaster texanus*; probably Walnut Clay facies	2.5
ANTLERS FORMATION (not measured)	
Goodland Limestone, measured total	19.3

7

South bank of north-flowing tributary of Glasses Creek on Smiley Ranch, NW¼NE¼NW¼ sec. 6, T6S, R6E (Holtzman, 1978, p. 88).

	Thickness (ft)
KIAMICHI FORMATION	
Limestone, thin-bedded, yellowish brown, fossiliferous; contains abundant Texigryphaea navia (Hall) ("shell bed")	2.0
Shale, brown on weathered surface, black to yellowish-brown on fresh surface, soft, crumbly	25.0
Limestone, thin-bedded, brownish yellow, finely crystalline, fossiliferous; thin layers of soft, light-gray clay separate thicker limestone layers; Texigryphaea navia (Hall)	0.9
Shale, black on fresh surface; weathers dark gray and whitish gray; fissile, platy; thin silty-clay lenses (3-4 in. thick) scattered throughout	6.2
Base of exposure in creek alluvium	
Kiamichi Formation, measured total	34.1

8

Dry pond approximately 20 yd west of section-line road, SE¼SE¼SE¼ sec. 13, T6S, R4E (Holtzman, 1978, p. 90).

	Thickness (ft)
CADDO FORMATION	
Duck Creek Member	
Clay, tan-white on weathered surface, blue-gray on fresh surface, blocky; no fossils observed	6.0
Limestone, thick-bedded, silty, grayish white on fresh surface, light tan on weathered surface, fossiliferous	0.8
Clay, silty, dull light gray on weathered surface, bluish gray on fresh surface; no fossils observed	5.0
Limestone, thick-bedded, silty, tan to light brown on weathered surface, dull white on fresh surface, fossiliferous	1.1
Base of exposure, light-gray shale (not measured)	
Duck Creek Member, measured total	12.9

9

West bank of Buncombe Creek, 100 yd south of section-line road, NW¼NW¼NE¼ sec. 28, T6S, R5E (Holtzman, 1978, p. 91).

	Thickness (ft)
CADDO FORMATION	
Duck Creek Member	
Clay, gray, shaly; interbedded with thin, white, fossiliferous, silty limestones	4.2
Limestone, light gray on fresh surface, yellowish brown on weathered surface, silty, fossiliferous; contains scattered ammonites	0.8
Clay, gray, shaly; interbedded with thin, silty, fossiliferous limestones averaging 4-5 in. thick; limestones weather to a yellowish tan	5.2
Limestone, silty; weathers dull-gray; light gray on fresh surface; fossiliferous; scattered ammonites and *Texigryphaea*	1.7
Clay, gray, shaly, some iron staining; lower contact sharp	4.3
Base of exposure, top of Kiamichi Formation in creek bed	
Duck Creek Member, measured total	16.2

10

East bank of Briar Creek, NE¼NE¼NW¼ sec. 30, T6S, R5E (Holtzman, 1978, p. 89).

	Thickness (ft)
GOODLAND LIMESTONE	
Limestone, dull gray on weathered surface, white on fresh surface, fossiliferous; weathers into thin, curved sheets	2.0
Limestone, massive, nodular, finely crystalline, dull gray on weathered surface, white on fresh surface, fossiliferous throughout	12.3
Base of exposure, creek alluvium	
Goodland Limestone, measured total	14.3

11

Abandoned quarry (Smith Quarry) 200 yd south of State Highway 32, approximately 3 mi west of Kingston, NW¼NE¼ sec. 33, T6S, R5E (Bridges, 1979, p. 116).

	Thickness (ft)
KIAMICHI FORMATION	
Clay, olive-gray to brown, calcareous, silty; contains 6-in. bed of lenticular buff marlstone; lower contact sharp	6.0
Shale, dark brown to dark gray, platy, calcareous; contacts sharp	6.0
GOODLAND LIMESTONE	
Limestone, white to light gray, very fine-grained and dense, hard; contains 1- to 2-in. partings of light-gray marl at irregular intervals; fossils most common in marly layers	15.0
Base of exposure	
Kiamichi Formation, measured total	12.0
Goodland Limestone, measured total	15.0

12

East bank of north-flowing tributary of Little Glasses Creek, about 150 yd east of north-south section-line road, SW¼SW¼SW¼ sec. 18, T6S, R6E (Holtzman, 1978, p. 93-94).

	Thickness (ft)
CADDO FORMATION	
Fort Worth Limestone Member	
Limestone, dark yellowish brown, well indurated, highly fossiliferous; contains abundant Aetostreon walkeri (White) and Texigryphaea washitaensis (Hill); forms resistant cap	0.6
Clay, blue-gray, shaly, thin-bedded; no fossils	10.2
Limestone, yellowish brown, dense, fossiliferous; abundant Aetostreon walkeri (White) and Texigryphaea washitaensis (Hill)	1.3
Clay, light gray where weathered, blue-gray where fresh; shaly; no fossils observed	2.0
Limestone, yellow-brown, dense, fossiliferous	1.2
Clay, blue-gray to light gray, shaly, thin-bedded	12.3
Limestone, yellowish brown to tan on weathered surface, dull gray where fresh; compact, fossiliferous	0.6

	Thickness (ft)
Clay, blue-gray, shaly, thin-bedded	1.4
Limestone, yellowish brown to tan, silty, fossiliferous	1.0
Clay, blue-gray where fresh; weathers light gray; shaly, fissile; no fossils observed	0.9
Limestone, yellowish tan where weathered; silty, fossiliferous	0.4
Clay as above	1.0
Limestone, light gray on weathered surface, dull gray on fresh surface; silty, fossiliferous	0.3
Clay as above, but with iron staining	0.5
Limestone, weathers yellowish tan; silty; iron staining; fossiliferous . . .	0.9
Clay, blue-gray to light gray, fissile, silty	0.8
Limestone, yellowish tan on weathered surface, silty, iron-stained, fossiliferous	1.2
Clay, blue-gray; weathers light gray; calcareous, silty	1.0
Base of exposure, stream alluvium	
Fort Worth Limestone Member, measured total	37.6

13

North side of road cut through hill at west end of Roosevelt Bridge, U.S. Highway 70, SE¼SW¼SW¼ sec. 25, T6S, R6E (Ganser, 1968, p. 56-57).

	Thickness (ft)
BOKCHITO FORMATION	
Denton Clay Member	
Clay, brown to blue-gray, sandy to very sandy; thin, hard layers of siltstone; limonite concretions; nodular layer of reddish-brown siltstone with limonite stain on surface; clay-ironstone litters surface.	20.0
Limestone, very sandy, blue-gray; weathers to dark-yellow, sandy layers that litter slope	0.2
Clay, blue-gray, scattered thin layers of very fine-grained sandstone and siltstone; selenite crystals on surface	19.1
Base of exposure, top of Caddo Formation (Fort Worth Limestone Member)	
Denton Clay Member, measured total	39.3

14

Cliff along Lake Texoma on point of land jutting into lake, SE¼NE¼NE¼ sec. 26, T6S, R6E (Ganser, 1968, p. 58).

	Thickness (ft)
CADDO FORMATION	
Fort Worth Limestone Member	
Limestone, gray; weathers yellow; biomicritic; beds up to 6 in. thick; top is mostly limestone; a few limestone beds at base; yellow-brown clay abundant at base	34.0
Duck Creek Member	
Clay, brown; gray, biomicritic limestone increases toward base	48.0
Clay, very dark brown, grading upward into gray shale; becomes calcareous toward top, with a few limestone beds	13.0
Base of exposure, water's edge, Lake Texoma	
Fort Worth Limestone Member, measured total	34.0
Duck Creek Member, measured total	61.0

15

Section measured just south of Roosevelt Bridge along shore of Lake Texoma, NW¼ sec. 36, T6S, R6E (Bridges, 1979, p. 118-119).

	Thickness (ft)
CADDO FORMATION	
Fort Worth Limestone Member	
Clay, olive-gray, calcareous; contains thin lenses of light-gray coquinoidal limestone; lower contact sharp	1.5
Limestone, gray, fossiliferous, silty; contacts sharp	1.4
Clay, olive-gray, calcareous; contacts sharp	1.5
Limestone, gray on fresh surface; weathers light brown to gray; fossiliferous; competent, unevenly bedded; contacts sharp	1.0
Clay, gray-green, shaly, calcareous, fossiliferous; contains thin lenses of gray limestone that are either fine-grained, marly, and unfossiliferous or very fossiliferous and marly; contacts sharp	1.8
Limestone, light gray, fine-grained, compact, unfossiliferous, marly; contacts sharp	0.4
Shale, olive-gray, clayey, calcareous; contacts sharp	0.1
Limestone, gray, fine-grained, marly, relatively unfossiliferous, hard, compact; contacts sharp	1.0

	Thickness (ft)
Clay, olive-gray, calcareous, slightly fossiliferous; contains thin, nodular, marly limestone	0.4
Limestone, gray to light gray, fine-grained, marly, relatively unfossiliferous, unevenly bedded	1.4
Cover (mostly talus) to water's edge	
Fort Worth Limestone Member, measured total	10.5

16

Section measured just east of dirt road on west-facing hill, SE¼NW¼ sec. 26, T7S, R4E (Bridges, 1979, p. 112-113).

	Thickness (ft)
GOODLAND LIMESTONE	
Limestone, dull white to light gray, finely crystalline; nodular at base, grading upward into massive unit; lower contact sharp . . .	3.0
Walnut Clay facies	
Clay, brown, calcareous, silty; lower contact gradational	4.0
Shale, gray, noncalcareous; contacts sharp	3.0
Sandstone, brown, fine- to very fine-grained, very calcareous, fossiliferous; contacts sharp	1.5
Clay, gray-brown to brown, calcareous, silty to sandy; fossils numerous; interbedded thin, platy, calcareous, gray-brown to brown sandstone; contacts sharp	3.0
ANTLERS FORMATION	
Sandstone, gray, very fine-grained; contacts sharp	2.0
Clay, gray to dark-gray, thinly laminated; contacts sharp	3.0
Sandstone, gray, very fine-grained; contains sparse ferruginous concretions about 1 in. in diameter	5.3
Covered.	5.3
Sandstone, gray, very fine-grained, clayey; contacts sharp	11.0
Sandstone, brown, fine- to very fine-grained, silty; contacts sharp . . .	1.5
Sandstone, gray, fine-grained, clayey	2.5
Base of exposure	
Goodland Limestone, measured total	3.0
Walnut Clay facies, measured total	11.5
Antlers Formation, measured total	30.6

17

Railroad cut directly north of Woodville near section line in southern part of secs. 2 and 3, T7S, R6E (Bridges, 1979, p. 124).

	Thickness (ft)
BOKCHITO FORMATION	
Pawpaw Sandstone Member	
Sandstone, white to light gray where fresh; weathers brown; fine-grained; exhibits medium-scale cross-bedding; contains gray clay partings and scattered clay-ironstone concretions	9.0
Covered	3.0
Sandstone, brown, fine-grained, evenly bedded; lower contact sharp . . .	2.0
Clay, olive-gray; contacts sharp	0.3
Sandstone, brown, fine-grained, clayey; contacts sharp.	1.9
Clay, gray, thinly laminated; contacts sharp	2.1
McNutt Limestone Member	
Limestone, maroon, fine-grained, arenaceous; contains pebble-sized clasts of clay and sand, and traces of carbonaceous wood; lower contact obscured	1.0
Covered to base of cut	
Pawpaw Sandstone Member, measured total	18.3
McNutt Limestone Member, measured total	1.0

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North-facing cut bank of Rooster Creek, SE¼NE¼ sec. 3, T7S, R6E (Bridges, 1979, p. 122).

	Thickness (ft)
BOKCHITO FORMATION	
Weno Clay Member	
Shale, gray and olive-gray, silty; calcareous at base, becoming less calcareous upward; contains thin (<2 in.) lenses of light-brown, very fine-grained, well-sorted, calcareous sandstone; ironstone concretions up to 2 in. in diameter scattered throughout; lower contact gradational	23.0
Sandstone, brown, very fine-grained, well sorted, micaceous, calcareous; contains laminations and zones of gray clay-ironstone concretions; unevenly bedded; contacts gradational	0.4

	Thickness (ft)
Shale, grayish-brown, silty, calcareous; contains 0.5- to 3-in. lenses of gray-brown, micaceous, calcareous, very fine-grained sandstone	7.0
Base of exposure, top of Soper Limestone Member in creek	
Weno Clay Member, measured total	30.4

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East-facing cut bank of tributary to Caney Creek, SW¼SW¼ sec. 8, T7S, R6E (Bridges, 1979, p. 117).

	Thickness (ft)
CADDO FORMATION	
Duck Creek Member	
Shale, dark gray, calcareous, platy; contains thin lenses of gray, marly limestone; lower contact gradational	5.0
Limestone, blue-gray, marly, fine-grained, unevenly bedded; contacts gradational	0.4
Shale, blue-gray, calcareous, platy; lower contact sharp	0.5
Limestone, blue-gray, marly, very fine-grained, lenticular; scattered fossils of *Inoceramus*; contacts sharp	0.3
Shale, blue-gray, calcareous; lower contact gradational	0.4
Limestone, gray, shaly, very fine-grained, unevenly bedded; contacts gradational	0.6
Shale, gray, calcareous, platy	4.0
Base of exposure, creek bed	
Duck Creek Member, measured total	11.2

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Ditch on west side of paved road, SE¼ sec. 14, T7S, R6E (Bridges, 1979, p. 123).

	Thickness (ft)
BOKCHITO FORMATION	
Pawpaw Sandstone Member	
Shale, brown and gray, silty; contains scattered lenses of tan and brown, very fine- to fine-grained sandstone up to 4 in. thick; lower contact sharp	15.0
Covered	24.0

	Thickness (ft)
McNutt Limestone Member	
Sandstone, gray to brown, fine-grained, very calcareous; contains scattered pebble-sized clay-ironstone concretions; contacts sharp	1.5
Weno Clay Member	
Sandstone, dark brown, fine-grained; contains pebble-sized clay-ironstone concretions; contacts sharp	1.5
Sandstone, light-brown, fine-grained; contains flattened clay-ironstone concretions	2.0
Pawpaw Sandstone Member, measured total	39.0
McNutt Limestone Member, measured total	1.5
Weno Clay Member, measured total	3.5

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Ditch on west side of road, SW¼SW¼ sec. 15, T7S, R6E (Bridges, 1979, p. 120-121).

	Thickness (ft)
BOKCHITO FORMATION	
Soper Limestone Member	
Limestone, brown to yellow-brown, slightly silty, compact, evenly bedded, very fossiliferous; lower contact sharp	1.0
Denton Clay Member	
Clay, brown, calcareous; lower contact gradational	0.5
Limestone, brown to yellow-brown, marly, coquinoidal, unevenly bedded; contacts gradational	1.5
Clay, gray-green to brown, arenaceous, calcareous; contains scattered thin lenses of arenaceous, fossiliferous limestone; contacts gradational	7.0
Sandstone, maroon, very fine- to fine-grained, calcareous, unevenly bedded; contains pelecypod casts; contacts gradational . . .	0.2
Sandstone, reddish brown, very fine- to fine-grained, loosely consolidated, evenly bedded, clayey; lower contact sharp	2.5

	Thickness (ft)
Clay, brown to gray-green, calcareous; contacts sharp.	0.7
Sandstone, brown to light brown, very fine-grained, well indurated, evenly bedded; contacts sharp.	0.1
Clay shale, brown, calcareous, arenaceous	10.0
Base of exposure, talus to base of hill	
Soper Limestone Member, measured total	1.0
Denton Clay Member, measured total	22.5

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South-facing bank along shore of Lake Texoma, southern part of sec. 20, T7S, R6E (Bridges, 1979, p. 114-115).

	Thickness (ft)
GOODLAND LIMESTONE	
Limestone, white to light gray, very fine-grained to dense; scattered 1- to 2-in. partings of light-gray marl containing fossils; limestone beds exfoliate into thin plates; lower contact gradational.	17.5
Limestone, nodular, light gray, chalky; interbedded with olive-gray, silty marl; contacts gradational	2.5
Walnut Clay facies	
Clay, reddish brown to gray, calcareous, silty; contains scattered shell beds up to 3 in. thick that pinch out abruptly; lower contact sharp.	4.0
Sandstone, brown, fine- to very fine-grained, very calcareous, silty; contains small-scale cross-bedding; fossiliferous; contains plant impressions and carbonaceous wood; lower contact gradational	2.0
Clay, reddish brown, silty, calcareous; lower contact sharp	2.0
ANTLERS FORMATION	
Sandstone, white to light gray, very fine-grained.	2.0
Base of exposure, water's edge	
Goodland Limestone, measured total	20.0
Walnut Clay facies, measured total	8.0
Antlers Formation, measured total	2.0

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Railroad cut, north-facing exposure, SW¼SW¼, sec. 5, T7S, R7E (Bridges, 1979, p. 125-126).

	Thickness (ft)
GRAYSON MARLSTONE	
Limestones and shales, interbedded, partially covered; limestones gray to tan, fine-grained, marly, fossiliferous; individual beds 4 in. to 1 ft thick, unevenly bedded; clay beds gray-green to olive-gray, calcareous, fossiliferous; lower contact sharp	8.0
BENNINGTON LIMESTONE	
Limestone, gray to brownish gray, very fine-grained, dense, compact; fossiliferous, with abundant Ilymatogyra arietina; contacts sharp . . .	1.5
BOKCHITO FORMATION	
Pawpaw Sandstone Member	
Sandstone, brownish gray, very fine- to fine-grained, clayey; lower contact gradational	0.8
Sandstone and shale, interbedded; sandstone reddish brown to brown, fine-grained, well-sorted, evenly bedded; poorly consolidated; shale gray, clayey, with beds attaining thickness of 5 in.; lower contact sharp	2.5
Sandstone, reddish brown, fine-grained, silty, well sorted, poorly consolidated; lower contact gradational	2.0
Sandstone, light brown, fine-grained, silty, well sorted, lenticular, loosely consolidated; lower contact obscured	3.3
Covered to base of exposure	10.0
Base of exposure, bottom of railroad cut	
Grayson Marlstone, measured total	8.0
Bennington Limestone, measured total	1.5
Pawpaw Sandstone Member, measured total	18.6

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