OKLAHOMA GEOLOGICAL SURVEY

CARL C. BRANSON, *Director*

CIRCULAR 63

GEOLOGY AND PETROLEUM OF LOVE COUNTY, OKLAHOMA

PART I.—GEOLOGY OF LOVE COUNTY

E. A. FREDERICKSON AND R. H. REDMAN

PART II.—PETROLEUM GEOLOGY OF LOVE COUNTY

JEROME M. WESTHEIMER

The University of Oklahoma
Norman
1965

CONTENTS

ILLUSTRATIONS

PLATES

Figures

Geology and Petroleum of Love County, Oklahoma

ABSTRACT

Part I.—Geology of Love County: Love County occupies a central position in the tier of counties bordering the Red River which forms the southern boundary of Oklahoma. The county is almost wholly within the Gulf Coastal Plain Province and is underlain by gently southward-dipping rocks of Cretaceous age. Exceptions are the extreme northwest corner of the county where horizontal Permian sandstones occur beyond the Cretaceous cover, and the northeastern area where steeply dipping, folded, and faulted strata of Pennsylvanian age are exposed where the Cretaceous sediments have been removed by erosion.

The Cretaceous sequence of sedimentary rocks consists of the formations of the Trinity, Fredericksburg, and Washita Groups. Of special significance is the discovery of a 5- to 6-foot-thick biostrome of limestone in the southwestern limb of the Marietta syncline. This biostrome is interpreted as a tongue of the Walnut Formation extending northward within the upper part of the Antlers Sand.

Pleistocene terrace deposits are well developed along the Red River in Love County. Five terrace levels, the Cooke and Ambrose Alluvial Terraces of Wisconsinan age, the intermediate terrace (Illinoian), the Hardeman Alluvial Terrace (Kansan), and the Nebraskan terrace have been identified.

Geologic structures in Love County range from the complexly folded and faulted strata of Pennsylvanian age, representing the extension of the Ardmore Basin Province into northeastern Love County to the gently warped, nearly horizontal Cretaceous sequence. The dominant structure in Cretaceous rocks is the Marietta syncline. A review of the structural development of the area leads to the conclusion that present structures in Cretaceous rocks have resulted from subsidence.

Part II.—Petroleum Geology of Love County: Love County lies in a geosynclinal area between the cratons of the eastern Arbuckle Mountains and the Muenster-Nocona arch. This geosyncline is characterized by a thick section of Cambrian and Ordovician rocks. A significant uplift after early Caney time in eastern Love County caused the deposition of conglomerates containing Sycamore and Woodford pebbles in late Caney time. From middle Meramecian time until the end of Morrowan or early Atokan time (Wichita orogeny) the area of the present Marietta basin remained at or slightly above sea level. In middle Atokan time the downwarping of the Marietta basin began with the seas encroaching from the southeast. Erosion had cut as deep as lower Simpson in the present area of the Marietta basin, and some of the earliest Pennsylvanian sediments are readily recognizable as being reworked Simpson material. The Micaceous

(Davis) sand is correlated with the Hartshorne Sandstone of east-central Oklahoma, and considerably constricts the sediments in southern Oklahoma assignable to Atokan age.

The major oil fields of Love County are the three retrograde gas-distillate fields of eastern Love County—West Enville, Southwest Enville, and Southeast Marietta. The main producing horizon of these fields is the basal Oil Creek (Simpson) sandstone, and the fields are near the western edge of deposition of this sandstone member. The fields along the Wichita Mountains-Criner Hills trend were folded and faulted mainly at the time of the Wichita orogeny. The West Enville field, which lies on the Overbrook anticline structural trend, was affected by the early orogeny, but the major folding occurred during the later Arbuckle orogeny. Tilting first to the northeast and later to the southwest can be clearly seen in the area of these fields, as well as in many other areas of southern Oklahoma. Other fields in the Marietta basin and on its flanks produce mainly from lenticular Deese sandstones. Most of these fields exhibit some structure but stratigraphic elements are perhaps the more important factor in the localization of oil and gas accumulation. Higher Deese and Hoxbar sediments, which are characterized by more uniform conditions of deposition and by having sandstones of greater areal extent, have yielded no gas or oil from the deeper parts of the Marietta basin. The tilting and countertilting of the area probably allowed the petroleum to escape from the gentle anticlines and migrate to the structures of the major uplifts on either side of the basin.

Part I.—Geology of Love County

E. A. Frederickson* and R. H. Redman†

INTRODUCTION

This study was initiated by the Oklahoma Geological Survey as the result of a cooperative effort with the Texas Bureau of Economic Geology to complete the geological quadrangle-map coverage along the northern border of Texas. These quadrangles, at a scale of 1/250,000, overlap into Oklahoma, and in Love County reach the 34th parallel, encompassing the southern two-thirds of the county.

This report includes a detailed map of the geology of Love County (pl. I), descriptions of representative Cretaceous formations, and a discussion of exposures of Pennsylvanian, Permian, Cretaceous, and Cenozoic age in Love County.

Detailed mapping and measuring of sections of Cretaceous rocks were accomplished by Redman as partial fulfillment of the requirements for the Master of Science degree in geology. Frederickson directed Redman's thesis, field checked his mapping, made a reconnaissance survey of the terrace deposits and levels, completed the Paleozoic section of the map, and wrote the report, utilizing much of Redman's thesis material.

Love County is one of the tier of counties that adjoin the southern border of Oklahoma (fig. 1). Red River, which is the boundary between Texas and Oklahoma, flows eastward along the southern border of the county. Carter County forms the northern border, Marshall County the eastern, and Jefferson County the western. Love County contains nine townships and parts of ten others, encompassing an area of approximately 523 square miles.

Love County lies almost entirely within the Gulf Coastal Plain Province (Curtis and Ham, 1957) and is underlain by gently southward-dipping sedimentary rocks of Cretaceous age. The western edge of the Coastal Plain Province in Oklahoma is in the

* Kent State University, Kent, Ohio.
† Atlantic Refining Company, Dallas, Texas.

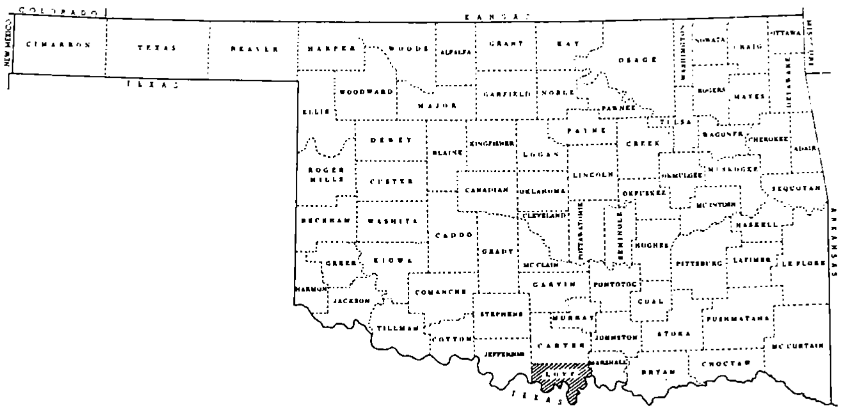


Figure 1. Index map of Oklahoma showing location of Love County.

extreme northwest corner of Love County, where Lower Cretaceous sandstones have been removed by erosion and the underlying horizontal Permian sandstones of the Central Redbed Plains are exposed. Steeply dipping, folded, and faulted Paleozoic sedimentary rocks of the Ardmore Basin Province (Curtis and Ham, 1957), representing southernmost exposures of the Criner Hills anticlinorium and the Overbrook anticline, extend a short distance into northeastern Love County.

Red River is the master stream of the area, all other streams being tributary to it. The Red River tributaries flow southward or southeastward. The major tributaries are Mud Creek in the west, Walnut Bayou in the center, and Hickory Creek in the east.

The highest point in the county, 1,026 feet above sea level, is on the divide between Walnut Bayou and Hickory Creek at the northernmost extension of the Goodland Limestone escarpment. The lowest point is along the Red River at the Love-Marshall county line on the shore of Lake Texoma, which has a normal controlled elevation of 617 feet.

The topography differs with the character of the underlying rock. The Antlers Sand, in the northern and western areas of Love County, forms rolling, dissected timbered uplands. However, in areas where the Goodland Limestone has recently been eroded away, level prairielike expanses are found. The Goodland Limestone forms a steep escarpment wherever the contact with the underlying Antlers Formation is exposed (fig. 2). The surfaces of both the Goodland and Caddo Limestones form broad, level areas covered with rich,

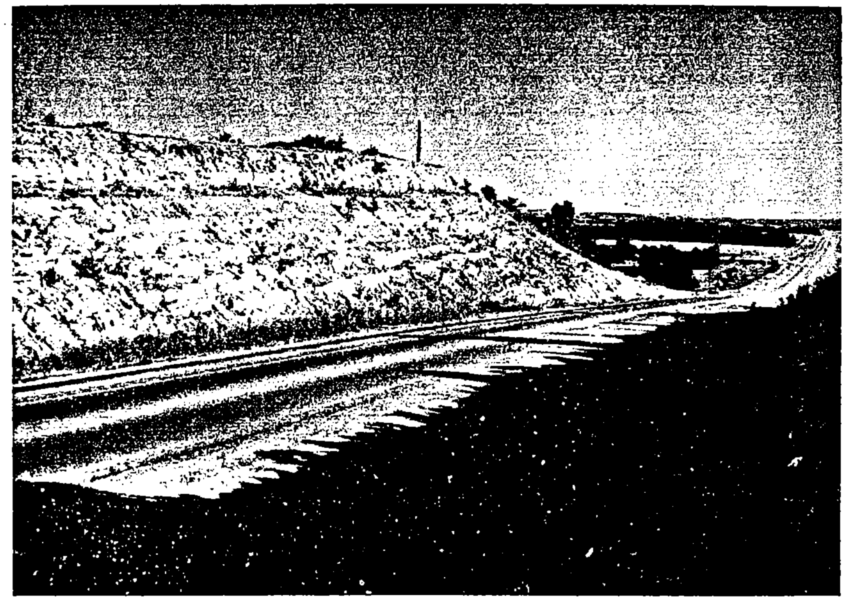


Figure 2. Goodland escarpment looking north. Antlers-Goodland contact at break of slope. Antlers Sand terrain visible in background.

black soil. Younger Cretaceous formations are commonly deeply eroded and form moderately steep hills and valleys.

Along the Red River, wide, flat terrace deposits of Pleistocene age form a succession of levels (Frye and Leonard, 1963). Among these the best developed is the early Wisconsinan Ambrose Alluvial Terrace, occurring on the broad point bars of the meandering Red River at an elevation of 30 to 40 feet above the channel. High-terrace deposits of Nebraskan age occur at an elevation of 180 to 230 feet above the channel in the vicinity of Thackerville and Bomar. The Hardeman Alluvial Terrace of Kansan age is well developed in many areas bordering the Red River above the Ambrose Terrace at an elevation of 90 to 120 feet.

U. S. Highway 77 is the major north-south highway through Love County, connecting the cities of Ardmore and Marietta with Gainesville, Texas. It is the only road in Love County which crosses Red River into Texas. State Highway 76 runs north from the town of Leon in the western part of the county, and State Highway 32 traverses the county from east to west. Section-line and private roads provide access to most local points.

The Gulf Colorado and Santa Fe Railway traverses the county from north to south, generally paralleling U. S. Highway 77. The service road which parallels the track provides an excellent means of reaching otherwise isolated areas.

The earliest work on the Cretaceous rocks of southern Oklahoma was done by Roemer (1852). Other early geologists who published upon this region were G. G. Shumard (1854), Marcou (1856), and B. F. Shumard (1860).

Hill (1887) published the first accurate description of the Cretaceous strata in this region. In 1901 he published the monograph which has long been the standard reference on the Cretaceous of northern Texas and southern Oklahoma.

Taff (1902, 1903) proposed a different nomenclature for his subdivisions of the Cretaceous rocks in southern Oklahoma, although his subdivisions were similar to those of Hill (fig. 3). Larkin (1909) summarized previous information. Stephenson (1918) mapped and described the Cretaceous rocks of southern Oklahoma and northern Texas, and modified Hill's terminology (fig. 3).

Bullard (1925) authored Bulletin 33 of the Oklahoma Geological Survey, *Geology of Love County, Oklahoma,* which also included a geologic map. In this bulletin, Taff's terminology was used, although Bullard attempted correlation with the Cretaceous nomenclature of Stephenson used in northern Texas.

Redfield (1929) suggested modifications concerned mainly with rank of the Cretaceous units, and Perkins (1960) made a biostratigraphic study of the Comanche Series in northern Texas.

Various writers have suggested changes in the concept of the Cretaceous stratigraphy. Among these are Bradfield (1959), Forgotson (1957, 1963), Hazzard (1939), Lozo (1944, 1949, 1959), and Winton and Adkins (1919).

We are indebted to the Oklahoma Geological Survey and its Director, C. C. Branson, for defrayment of field expenses and for financing the preparation of this paper. A. J. Myers and C. C. Branson offered many valuable suggestions during the course of this work. A. J. Maxwell of the Ardmore district office of the Soil Conservation Service, U. S. Department of Agriculture, furnished copies of the preliminary *General Soil Map of Love County,* which was helpful in determining the areal extent of the redbeds and terrace deposits. Logan L. Urban and Andrew J. Robinson assisted in mapping of the biostromes of the Walnut Formation.

STRATIGRAPHY

General Statement

More than ninety percent of the surface rocks of Love County consists of Lower Cretaceous (Comanchean) sedimentary rocks dipping gently to the southeast. The remaining ten percent is about equally divided between the horizontal Permian redbeds, which are in the northwest corner of the county, and pre-Permian Paleozoic rocks, which are exposed in a narrow southeastward-trending band in the northeastern part of the county. The latter represent once-buried structural features of the Ardmore Basin Province which have been exhumed by the stripping away of the Cretaceous rocks. These outcropping strata consist of the southeast extension of the Criner Hills anticlinorium and the adjacent Overbrook anticline. Details of these structures and the age of the strata are discussed under the section on structure.

Permian System

Essentially horizontal redbeds of Permian age are exposed in the northwest corner of Love County in T. 6 S., R. 3 W. The surface exposures consist of red sandy and loamy and clayey soil. No exposures that showed the sequence of the strata were found. Bunn (1930) mapped Permian redbeds along the Love-Jefferson county line, adjacent to the Love County exposures, as the Addington Formation. From Jefferson County exposures, he described the Addington as follows:

> It is characterized by the brilliant red and vermillion hues of its shale members . . . . The sandstones are characterized by their black red color and slabby appearance on weathering. The weathered slabs are extremely hard and resistant. When freshly broken, they resemble a fine-grained reddish quartzite.

The location of the Addington Formation and its stratigraphic position above known basal Garber correlatives (Branson, Burwell, and Chase, 1955, p. 7) allows tentative correlation of the geographically adjacent redbeds of Love County with the upper Garber Sandstone of the Leonardian Series.

Determination of the Permian-Cretaceous contact in western

Love County presents a difficult problem because, as Bullard (1925, p. 15, 16) stated, "the basal member of the Trinity Sand contains beds of red shale and sandstone, very similar to the Permian red-beds." Both Bullard (1925, p. 16) and Shannon (1917, p. 308) believed that the Permian-Comanchean contact was to the west and that no Permian surface exposures were present in Love County.

The Addington-Antlers contact shown on the geologic map (pl. I) was ultimately determined upon the basis of the preliminary *General Soil Map of Love County.*

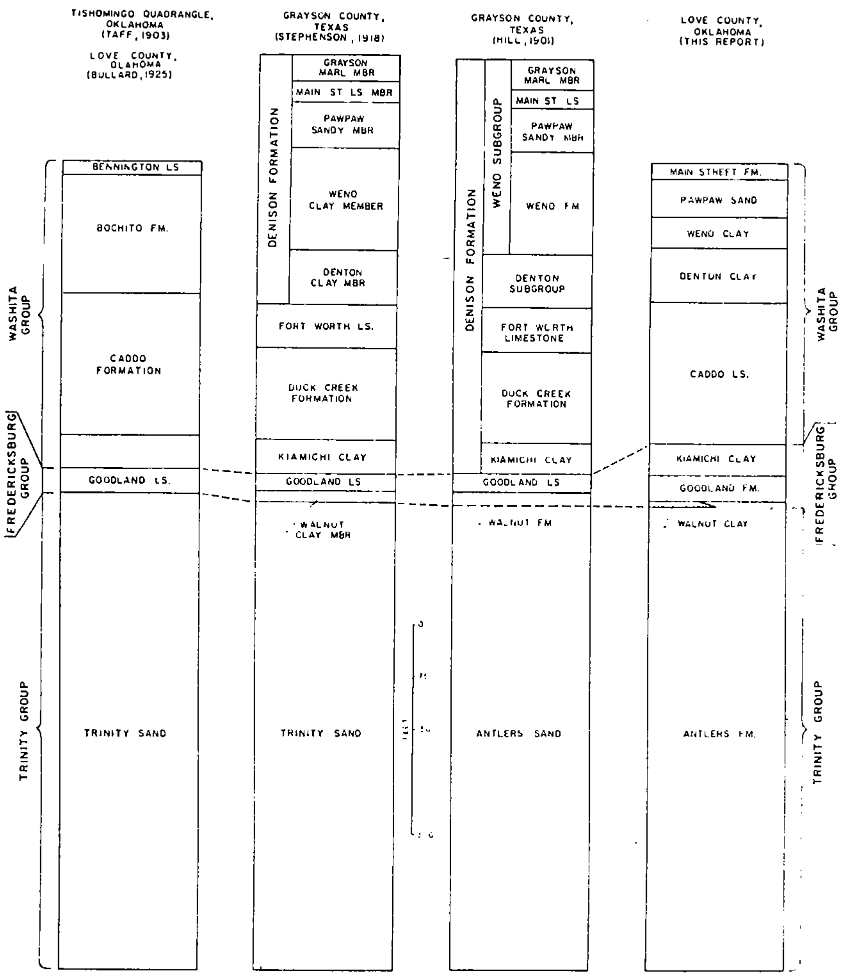


Figure 3. Cretaceous correlation chart.

Cretaceous System

GENERAL STATEMENT

Hill (1893, p. 337) consolidated previous published work upon the Lower Cretaceous of the Texas-Oklahoma region, and proposed three divisions (groups) of the Comanche Series from oldest to youngest: the Trinity, the Fredericksburg, and the Washita. These divisions grouped together previous named formations and members. Later Hill (1901) published his monumental work upon the Cretaceous of that region. Subsequently, Hill's members were raised to formational standing (fig. 3).

All three groups of the Lower Cretaceous are recognized in Love County. The Fredericksburg and Washita Groups are nearly constant in thickness, but the Trinity Group exhibits a wide range in thickness over the county. Total thickness of the Comanchean section in the county ranges from 600 to 1,000 feet.

According to Stephenson (1918, p. 159) and Bullard (1925, p. 43), the Cretaceous rocks in southern Oklahoma and northeastern Texas dip gulfward at 30 to 80 feet per mile. In Love County the regional dip is interrupted by the Marietta syncline and associated minor local features.

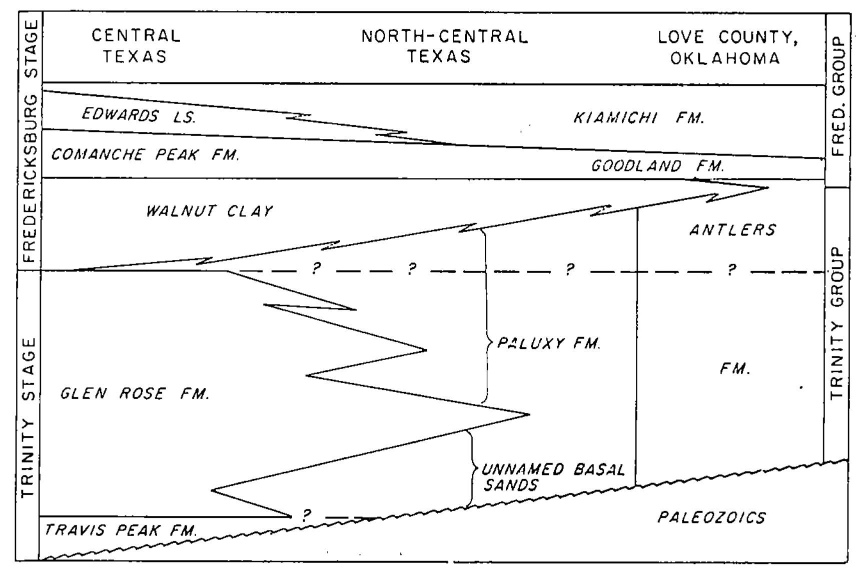


Figure 4. Trinity and Fredericksburg correlation chart.

The following section of Cretaceous rocks is recognized in Love County:

Comanchean Series
Washita Group
Main Street Formation
Pawpaw Sand
Weno Clay
Denton Clay
Caddo Limestone (Equivalent to the Fort Worth and Duck Creek Formations of northern Texas.)

Fredericksburg Group
Kiamichi Clay
Goodland Formation
upper part of Antlers Formation
Walnut Formation

Trinity Group
Antlers Formation

TRINITY GROUP

The sequence of sands, sandy shales, and conglomerates at the base of the Cretaceous section in southern Oklahoma is assigned to the Trinity Group, although it is recognized that the upper part is in all probability of Fredericksburg age. Hill (1893) described the Trinity division as consisting of the basement beds or Trinity sands proper and the overlying calcareous Glen Rose Beds. But, in the following year, Hill (1894, p. 303) placed the Paluxy sands at the top of the Trinity division above the Glen Rose Beds. In that publication, discussing the southern Oklahoma section he stated: "to distinguish this Indian Territory phase of these basement sands from their differentiated character. . . in Texas, I shall use the provisional name . . . Antlers sands." In 1901, Hill formalized the name Antlers sands for this sequence.

In southern Oklahoma, the names Trinity Sand (Bullard, 1925, 1926, 1928) and Paluxy Sand (Miser, 1954) have frequently been used for this basal sequence. Forgotson (1957, chart, p. 2332) used the term Antlers Sand undifferentiated for the southeastern Oklahoma outcrop. We propose to revive the term Antlers in Hill's original sense and raise it to formational standing to represent those sands and shales between the base of the Comanchean and the lowest formation of the Fredericksburg Group in southern Oklahoma and northern Texas, where the intervening Glen Rose Limestone is absent. In Love County the entire Trinity Group is represented by the Antlers Formation.

Antlers Formation.—The sediments of the Antlers Formation represent materials derived from the nearby shoreline of a slowly advancing sea. Locally at the base of the group, exposed conglomerates or calcareous cemented sandstones rest upon the eroded surface of Paleozoic rocks. The pebbles in the conglomerates are composed mainly of chert and quartz up to three inches in diameter. Limestone pebbles, which can be related to the underlying Paleozoic strata, are concentrated locally.

The conglomerates are not confined to the basal part of the Antlers but may occur as elongate lenslike bodies throughout the lower part of the formation. Many of the conglomerates are cemented with an opaque, white, opaline cement forming a hard, glassy orthoquartzite, which is a distinctive identifying character of these clastics. Carbonized wood, in many places associated with marcasite concretions, is found locally in the lower part.

The upper part of the Antlers Formation (fig. 5) consists of a

Figure 5. Upper part of Antlers Sand at measured section LA-1, 3.2 miles north of Marietta on U. S. Highway 77, 49.5 feet of section shown, contact with Goodland Limestone near top.

series of poorly cemented sandstones, pack sands, and sandy shales. They range in color from white to maroon, with reds and yellows predominating. At several horizons the sandstones are well indurated by a ferruginous cement resulting in a hard, dark-red, resistant bed. Locally, these indurated sandstones exhibit excellent cross-bedding. On surface exposures, many of the sandy shales near the top of the formation are covered with a fine, yellow, powdered sulphur coating, which is interpreted as a weathering product.

The Antlers Formation has considerable lateral and vertical variations in thickness and composition. It generally is heavily covered with vegetation and outcrops are highly weathered. A complete exposed section was not found, and, because rapid lateral facies changes make correlation impossible, a composite section is not available. Two incomplete sections of the upper part exposed in road cuts are described in measured sections LA-1 and LA-2.

A thickness of 200 feet was approximated for the Antlers Formation in northern Love County by measuring the difference in elevation between underlying Paleozoic rocks, where exposed in stream channels underneath the Antlers Sand, and the base of the Goodland Limestone. The formation thickens to the south, reaching a thickness of 600 feet on the Texas side of the Red River opposite sec. 13, T. 8 S., R. 1 W. (Bullard, 1925, p. 21). Prewit (1961, p. 53) reported a thickness of 818 feet from a well in sec. 21, T. 8 S., R. 2 E., near the axis of the Marietta syncline.

The correlation of the undifferentiated sands and conglomerates of the Antlers Sand with the formations in the Trinity Group south and east of Oklahoma has long been of concern to geologists working in the Cretaceous of the Gulf region.

Hill (1894, p. 303) admitted to confusion as to whether the Oklahoma clastics represented the Trinity (Basement sands), the Paluxy sands, or both, and as a result, named them the Antlers Sand. Later, Hill (1901, p. 133) concluded that the main body of the Antlers Sand was Paluxy time equivalent but that the top was of Fredericksburg age, thus representing late nearshore deposits of the northward-advancing Comanchean sea.

Stephenson (1918, p. 134, pl. 17) used the term Trinity sand for the Oklahoma clastics and in his correlation table questionably correlated it with the Basement sands, Glen Rose Formation, and the Paluxy sands of the Trinity Group of central Texas.

Miser (1927, p. 445) noted that the Trinity of Oklahoma was younger than the Trinity of Arkansas "owing to a westward overlap of the upper part . . . over the lower part." Vanderpool (1928, p. 1089) stated that "on the basis of paleontological evidence, it would be possible to include the upper part of the Paluxy [Antlers] sand in the Fredericksburg group."

Lozo (1959, p. 5) considered the Antlers to be in part Paluxy equivalent, and stated further that "a line . . . northeast from Lampasas toward Waco, marks the passage of the Paluxy into the . . . Walnut."

Forgotson (1963, p. 76) presented the general consensus of recent workers when he concluded:

> The exact limit of the Trinity time-stratigraphic unit cannot be defined within the predominantly sand section . . . . . Sandstones in the lower part of the Fredericksburg time-stratigraphic unit overlap the Trinity sandstones near their updip margin. These sandstones cannot be differentiated . . . . The Trinity time-stratigraphic unit probably did not extend much farther west or northwest than the present-day erosional edge of the Trinity Group in northeastern Texas.

Available evidence indicates that the Antlers Sand was deposited contemporaneously with the Walnut Formation, the Paluxy Sand of Fredericksburg and Trinity age, and the Glen Rose (in part) of Trinity age (fig. 4).

FREDERICKSBURG GROUP

Hill (1894, p. 303) considered the Fredericksburg division of the Red River area to be composed of the Walnut Clay and the Goodland Limestone. Taff (1902, 1903) and Bullard (1925, 1926) followed Hill's division with the exception of the Walnut, which they did not recognize in southern Oklahoma. Stephenson and others (1942) in the Cretaceous correlation chart also considered the Walnut and the Goodland as composing the Fredericksburg Group. However, Lozo (1949) upon the basis of surface and subsurface investigations, showed that the Paluxy of north-central Texas was of Fredericksburg age and in part equivalent of the Walnut Formation. The proper classification of the Kiamichi Formation has also been controversial. For many years the Kiamichi was assigned to the base of the Washita Group. It is now considered the top of the Fredericksburg Group by the U. S. Geological Survey (Imlay, 1944). For an excellent discussion of the history of nomenclature of the Kiamichi Formation see Shelburne (1959, p. 108).

In Love County, only the Goodland Limestone and the Kiamichi Formation of the Fredericksburg Group are present as mappable lithic units. Beds at the base of the Goodland and at the top of the Antlers have been assigned to the Walnut by some previous investigators (Hill, 1894, 1901; Stephenson, 1918; Bullard, 1925) and are discussed in the following paragraphs.

Walnut Formation.—Hill (1894, p. 303) stated that "north of Marietta the typical Walnut clays (*Exogyra texana* beds) have a slight development below the Goodland limestone . . . ." In 1901 (p. 208) he stated further:

> Through Indian Territory no well-marked lithologic representative of the Walnut clays is found, the Goodland limestone resting directly upon the Basement sands.
>
> From Red River to the Clear Fork of the Trinity the Walnut formation rapidly thickens along the line of outcrop through Cooke, Wise and Parker counties.
>
> At Preston and Little Mineral Creek in northern Grayson County, and a few miles northwest of Marietta, Indian Territory, the Walnut formation is represented by a few clay layers bearing *Exogyra texana* in the Basement sands beneath the Goodland limestone.

Stephenson (1918, p. 135) applied the name "Walnut Shaly member" to the basal 3 to 6 feet of the Goodland Limestone, which he described as "layers of persistent hard thin-bedded coquina-like limestone with interbedded thin layers of dark marly shale." This sequence was not recognized as a discrete unit by Bullard (1925) nor by subsequent authors.

In 1925, Bullard (p. 21) described a measured section of Trinity (Antlers) Sand on the Texas side of the Red River across from Love County. He noted that a 4-foot interval of fossiliferous marly clay 16 feet below the basal Goodland could be traced southward into Cooke County, Texas, where it thickened at the expense of the overlying Antlers Sand until the fossiliferous unit occupied a position directly beneath the Goodland Limestone. Bullard (1925, p. 23) wrote: "It is probable that these beds are the equivalent of the Walnut Clay of Central Texas, rather than the beds immediately underlying the Goodland, as used by Stephenson and other authors."

Bullard's measured section included 11.9 feet of laminated brown clay immediately beneath the base of the Goodland Limestone. The clay in turn was underlain by shell beds containing *Exogyra texana,* a characteristic fossil of Fredericksburg age found in the Walnut Formation and the lower part of the Goodland Limestone.

Layers of brown, sandy or silty clay, such as described by Hill (1901, p. 208), are present directly beneath the Goodland Limestone extending from SW¼ sec. 18, T. 7 S., R. 3 E., northeast of Marietta around the exposed northwest end of the Marietta syncline to the southernmost exposure found in Love County in SW¼ sec. 27, T. 7 S., R. 1 E. The greatest thickness of these brown clay layers is along the northern edge of the Goodland escarpment in SW¼ sec. 22, T. 6 S., R. 1 E., where it is approximately 3 feet thick. From this point, the clay thins eastward to less than 1 foot, and southward to 1 inch. In all areas of exposure, these brown clay beds are interbedded with or underlain by typical Antlers Sand.

Frederickson, with two graduate students, Logan L. Urban and Andrew J. Robinson, while tracing these brown clay exposures, found an outcrop of resistant limestone shell beds in an unnamed creek, south of State Highway 32 in NW¼ sec. 19, T. 7 S., R. 1 W. At this locality the shell beds were approximately 16 feet below the base of the Goodland. Further investigation revealed numerous exposures of this limestone facies in sec. 36, T. 6 S., R. 1 W., and in secs. 11, 14, 24, T. 7 S., R. 1 W., and sec. 19, T. 7 S., R. 1 E. (figs. 6, 7).

Where complete exposures from the base of the Goodland to the top of the shelly limestone facies occur (measured sections LW-1 and LW-2), a typical upper Antlers Sand section occupies the interval between. This sand section, including the thin brown clay at the top, ranges from 16 to 22 feet.

The limestone facies consists of marly shell beds containing abundant *Ostrea* sp. and *Exogyra texana,* ledge-forming, fossiliferous, crystalline limestone, and interbedded shale and marly shale.

Along the western edge of the Marietta syncline the resistant limestones form a conspicuous bench beneath the escarpment-forming Goodland Limestone, and are separated from it by the gentle slope formed by the overlying Antlers Sand facies.

The limestones are interpreted as a local biostromal facies of the Walnut Formation which extends northward from Texas as a tongue underlain and overlain by the Antlers Sand. The marly clay

Figure 6. Bench formed by biostrome in tongue of Walnut Formation within Antlers Sand. Hill is capped by Goodland Limestone in left background. View toward the north from State Highway 32, SE¼ SE¼ sec. 14, T. 7 S., R. 1 W.

Figure 7. Biostrome outlier of Walnut Formation similar to that shown in figure 6, about 100 yards to the west.

horizon, described by Bullard (1925, p. 23) as "the equivalent of the Walnut Clay," occupies the same stratigraphic position as the limestone tongue and undoubtedly constitutes a lateral, more shaly facies.

The complete area of exposure of the limestones of the Walnut Formation is less than 5 miles in length along the western part of the southwest limb of the Marietta syncline. Apparently the biostromal development was confined to the area of the southwest limb as only thick exposures of Antlers Sand are found beneath the Goodland escarpment along the northeast limb. Undoubtedly the upper part of the Antlers Sand in Love County is of Fredericksburg age and the equivalent of the Walnut Formation.

Goodland Limestone.—The Goodland Formation in Love County is a compact, white, biomicritic limestone approximately 24 feet thick. It is a relatively pure limestone at the top and becomes increasingly argillaceous and marly toward the base. The entire formation is fossiliferous with the greatest amount of fossil material occurring near the base.

Characteristically, the Goodland has a 3- to 4-foot-thick lower nodular limestone containing thin beds of marly shale. Above this

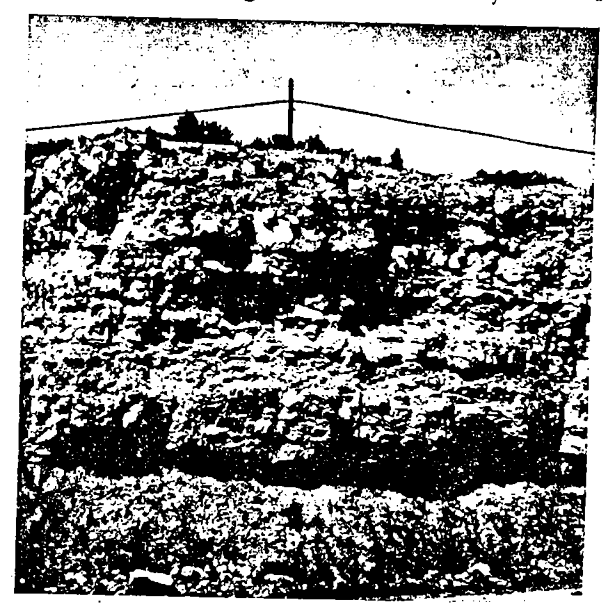


Figure 8. Goodland Limestone at measured section LG-3. Thickness 22.9 feet, contact with Antlers Sand at break in profile. Note limestone units.

Figure 9. Clay zone (Walnut?), top of Antlers Sand at contact with Goodland Limestone, NW¼ sec. 27, T. 6 S., R. 1 E., along county road.

basal unit, the sequence of beds differs in eastern and western Love County. In the western exposures, the upper 20 feet can be divided into three distinctive limestone units (measured section LG-3), separated by thin beds of shale (fig. 8). In eastern Love County, the upper 20 feet consists of massive white limestone, and the three upper divisions cannot be readily distinguished.

The lower contact of the Goodland Formation is placed at the base of the lower nodular limestone. In areas where the thin brown clays are present, the contact appears to be gradational, but where they are absent, the abrupt change from the Antlers Sand to the lower limestone is markedly abrupt. In regions where the Goodland crops out in contact with the underlying Antlers, a pronounced escarpment occurs, rising 75 to 100 feet above the adjacent eroded expanse of the Trinity Group.

The upper contact was mapped at the first appearance of the clays and yellow limestones of the Kiamichi Formation (fig. 10). This contact is considered to be regionally unconformable in northern and central Texas (Shelburne, 1959, p. 115). Evidence of unconformable relationship was not observed in Love County.

The Goodland thickens southward into Cooke County, Texas

Figure 10. Goodland-Kiamichi contact, SW¼ sec. 5, T. 7 S., R. 2 E.

(Stephenson, 1918, p. 137), and reaches a thickness of 125 feet west of Fort Worth (Lozo, 1959, p. 4).

The Goodland Formation of southern Oklahoma and northern Texas is considered by Lozo (1959, p. 4) to be laterally equivalent to the Edwards, Comanche Peak, and upper part of the Walnut of the central Texas section. However, in Love County, where the presence of the Walnut Formation is now established, only the Comanche Peak and Edwards Limestones are considered equivalents in this report.

Kiamichi Formation.—The uppermost formation of the Fredericksburg Group in southern Oklahoma, the Kiamichi, has an average thickness of 30 feet. Dark-brown to blue-gray, marly clays and shales, interbedded with thin, yellow limestone beds, compose most of this sequence. At the base, thin, platy, sandy limestone beds totalling 1 to 3 inches in thickness overlie the Goodland. Commonly these beds are obscured by weathering and slump. The top of the formation is well marked. A gray to buff limestone shell bed, packed with the pelecypod *Gryphaea navia* Hall, and averaging 8 inches thick, prominently marks the top of the Kiamichi and locally forms a narrow bench adjacent to the base of the Caddo Formation.

Generally, the surface of the Kiamichi exposure contains numerous large slabs of this shell bed, tilted at various angles and locally known as "edge rocks." Weathering and slump of the soft clay marls beneath the shell bed have caused the limestone to break, and further slumping and creep have moved the shell beds downslope into the various tilted positions (fig. 11).

The Kiamichi is of nearly constant thickness in Love County and as far south as the vicinity of Fort Worth, Texas. From that area southward, the Kiamichi Formation thins at a rate of 0.5 to 1 foot per mile (Shelburne, 1959, p. 112) and is completely absent by onlap south of the Coryell-Bell county line in central Texas (Lozo, 1959, p. 4).

The lower contact of the Kiamichi with the underlying Goodland Formation appears to be conformable, although locally irregular. The Kiamichi marly clays are easily eroded, and the formation is at few places more than a few feet thick at the contact. The irregularity is interpreted as solution of the limestone underlying the clay.

Various workers (Scott and Armstrong, 1932, p. 59; Adkins and

Figure 11. "Edge rocks" of the Kiamichi Formation. Typical example of slumped oyster-shell beds. SW¼ sec. 5, T. 7 S., R. 3 E.

Arick, 1930, p. 40; Thompson, 1935, p. 1529) have noted an unconformity at the top of the Kiamichi in central and north-central Texas. However, Shelburne (1959, p. 115) and Perkins (1960, p. 24) reported it to have a conformable contact with the overlying Duck Creek Limestone. Love County exposures of the contact between the Kiamichi and the Duck Creek (Caddo) are uncommon and are obscured by erosion. Where found, no evidence of unconformable relationship was observed.

The Kiamichi Formation is exposed as grassy slopes in a narrow band, commonly between 0.25 and 0.5 mile wide, paralleling the outcrops of the Goodland Formation.

WASHITA GROUP

The U. S. Geological Survey and the Oklahoma Geological Survey (Miser, 1954) recognize the following formations in the Washita Group in southern Oklahoma:

Grayson Formation
Main Street Formation
Pawpaw Sand
Weno Clay
Denton Clay
Fort Worth Limestone } Caddo Limestone of this report
Duck Creek Formation }

The Grayson Formation occurs in Marshall County to the east, but is not present in Love County and is not included in this report. Only the lower part of the Main Street Formation is present as outliers capping hills in the center of the Marietta syncline.

Caddo Limestone.—Taff (1902, p. 6) used the term Caddo Formation for 150 feet of clay, calcareous marls, and limestones overlying the Kiamichi Formation which Hill (1891, p. 504, 516) had earlier divided into the Duck Creek Chalk and the Fort Worth Limestone in northern Texas.

Bullard (1925, p. 33-35) followed Taff's usage of Caddo Formation for the similar calcareous sequence in Love County, although he stated: "At the top of the Caddo formation is a limestone member 19 feet thick with numerous shale partings. This bed is equivalent, in part at least, to the Fort Worth limestone of the Texas section."

Although the dominantly limestone sequence near the top of the Fort Worth can be distinguished from the marly, fucoidal limestones and interbedded gray shales of the underlying Duck

Creek, the determination of the contact between the two upon the basis of lithology is difficult. Attempting to divide the Caddo Formation and the Fort Worth Limestone, ultimately results in an arbitrary decision as to where the contact should be placed. The upper part of the middle sequence consists mainly of shaly marls with a few interbedded limestones. Thicker, more abundant limestones are found at the base of the upper unit, but upward, these, too, grade into shale before the appearance of the massive limestones of the top of the formation. Upon the basis of lithology, the contact could be placed at the base of the upper unit or at the base of the massive limestones. The contact could have been determined paleontologically, but time did not permit. In either case, both possible contacts are poorly exposed in the area except upon the bluffs along Red River. The formations cannot be distinguished on aerial photographs, and therefore we combined them into the Caddo Formation.

The Caddo is approximately 140 feet thick in Love County and is composed of yellow to white, chalky, argillaceous limestone, interbedded with bluish-gray shales and marly clays. Shales and clays comprise approximately 80 percent of the section.

The Caddo Limestone in this area can be divided generally into three units. The basal sequence consists of limestones (2 inches to 2 feet thick), alternating with equal thicknesses of marly shale and reaching a total thickness of 30 to 40 feet. About 20 feet above the base is a grayish-white to buff limestone with interbedded shales from 6 to 8 feet thick and with abundant ammonites assigned to *Eopachydiscus brazoensis* and *Pervinquieria* sp. This is the limestone exposed at the base of measured section LC-1.

Above this lower unit is a thick (60 to 70 feet) section consisting predominantly of gray marly shale with interbedded limestones which are numerous at the base but less so near the top. These two lower units may be considered essentially Duck Creek equivalents.

The uppermost unit of the Caddo (Fort Worth equivalent?) is mainly limestone and ranges between 30 and 40 feet in thickness. The lower 20 to 25 feet consists of interbedded limestones and shales, with the limestones more abundant at the base. The top is a massive limestone unit 10 to 15 feet thick with numerous shale partings.

Throughout the Caddo Formation occur large fossil "fucoids."

These have been interpreted as crab-burrow fillings by Perkins (1960, p. 26).

The Caddo is considered conformable with the underlying Kiamichi Formation in Love County. The upper contact of the Caddo is placed at the top of the sequence of massive white limestones. Where the overlying Denton Clay has not been eroded, the contact is also marked by the basal sands and sandy shales of that formation. This contact is also considered conformable.

The Caddo is exposed in an oval pattern surrounding Marietta in east-central Love County and occupies the major portion of the center of the Marietta syncline where it forms broad prairies. Steep bluffs at Horseshoe Bend along the Red River expose the upper three-fourths of the section (measured section LC-1).

Denton Clay.—In Love County, the Denton Clay (see Winton and Adkins, 1919, for usage) is about 70 feet thick and is composed of calcareous shales, marly clays, interbedded sandstones, and poorly consolidated shell beds at the top.

The base of the formation consists of 2.5 feet of gray calcareous shale resting conformably upon the limestones at the top of the Caddo Formation. Thin sandstones appear interbedded with the

Figure 12. Denton-Weno contact, SW¼ sec. 13, T. 8 S., R. 2 E. Topmost *Gryphaea* beds of Denton in contact (note hammer head) with thin basal sandstone of Weno.

Figure 13. Slab of ripple-marked sandstone from Denton Formation.

shales, and near the middle of the section is a well-indurated, ripple-marked, buff, ferruginous sandstone bed up to 2 feet thick. This sandstone forms an excellent marker bed because of a circular weathering feature (fig. 13). Large circular sandstone slabs are abundant, covering the slope below the inconspicuous escarpment which this bed normally forms. The top of the formation is marked by 4 feet of fossiliferous marl capped by a thin, dense, fossiliferous limestone bed which Hill (1901, p. 267) called the *Ostrea carinata* [*Lopha colubrina*] horizon. In this area, specimens of *Gryphaea washitaensis* are the dominant fossils at this horizon. This bed marks the sharply defined conformable contact of the Denton with the overlying basal red sandstone sequence of the Weno Clay (fig. 12).

The Denton is exposed in the center of the Marietta syncline southeast of Marietta. It forms gentle, grass-covered slopes between the underlying Caddo Limestone and the somewhat more resistant overlying Weno Formation. The Denton Clay thins southward to about 35 feet in Tarrant County, Texas, near Fort Worth (Perkins, 1960, p. 30).

Weno Clay.—Overlying the Denton Clay is a series of similar beds composing the Weno Clay. The latter differs in containing

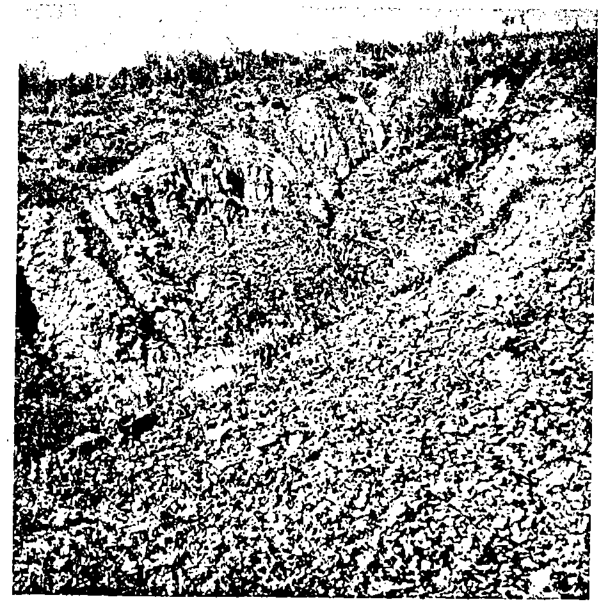


Figure 14. Weno slope, showing litter of ferruginous slabs and concretions.

more sandstone layers. A marked feature of the Weno is the litter of slabby ferruginous concretions that accumulate on the eroded slopes of the outcrop (fig. 14). Locally, small marcasite concretions are common.

The Weno Clay consists of interbedded, gray, marly shales and red, ferruginous, fossiliferous, concretionary sandstones. The poorly cemented sandstones are easily weathered, allowing the more indurated hard "ironstone" concretions to separate out and form a rubble over most of the outcrops. A few of the sandstones are well cemented with a red iron oxide cement and contain an abundance of *Turritella ventrivoluta.* Slabs of this indurated fossiliferous sandstone commonly occur with the concretions.

In SE¼ sec. 36, T. 7 S., R. 2 E., and NW¼ sec. 6, T. 8 S., R. 3 E., small outliers of the Weno have been protected from erosion by these hard beds of sandstone.

Some of these sandstones are locally cross-bedded. About 20 feet above the base of the Weno are several thin gypsum beds, which appear laterally continuous. In bright sun, the light reflects from the crystal faces, and the glistening beds are visible from a distance of several hundred feet.

At the top of the sequence of shales and sandstones is a 2-foot bed of brown, fossiliferous, sandy limestone. Hill (1901, p. 274) called this bed the Quarry limestone and included it in the Weno, stating that "it [Weno] includes all the beds between the top of the *G. washitaensis* agglomerate [Denton], and the top of the Quarry limestone." Stephenson (1918, p. 142), upon the basis of scattered pebbles in the base of the Quarry limestone and limestone-filled worm borings in the underlying clay of the Weno, placed the Quarry limestone at the base of the Pawpaw Formation. Perkins (1960, p. 32), misinterpreting Hill, followed Stephenson's example in excluding the Quarry beds from the Weno Clay. In this paper, the original usage of Hill is followed.

The Weno is approximately 43 feet thick in Love County, and Bullard (1928, p. 33) reported it to be 135 feet thick in Marshall County to the east. Southward the Weno becomes more calcareous and is 50 feet thick at Fort Worth, Texas (Perkins, 1960, p. 33).

According to Lozo (1959, p. 4), the Georgetown Limestone south of the Brazos River is "the thinned correlative of numerous limestone and shale formations (Kiamichi to Main Street inclusive) occurring to the north." The Weno of southern Oklahoma and northern Texas, being within that sequence, is correlated with part of the Georgetown Limestone, as are the other formations in the Washita Group of Love County.

Pawpaw Sand.—A 53-foot-thick section of the Pawpaw Formation was measured in the center of the Marietta syncline southeast of Marietta. The sequence consists of a 16-foot-thick basal unit which rests upon the Quarry limestone and consists of gray to red shales interbedded with thin, red sandstone and brown clay lenses. A 1-foot-thick, sandy, fossiliferous limestone bed similar to the Quarry limestone separates this underlying unit from about 36 feet of buff to red sandstone beds, up to 1.5 feet thick, interbedded with thinner yellow shales. These sandstones are well cemented with iron oxide and contain numerous fossil molds and casts, mainly pelecypods, which have been replaced with the ferruginous material. Many of the shales in the upper part contain limonite lenses and ferruginous concretions.

The Pawpaw crops out in a few limited exposures almost exclusively in T. 7 S., R. 2 E., in the center of the Marietta syncline. Two of these outcrops are on slopes of hills capped by the Main

Street Limestone, and the few other exposures are on adjacent divides between the upper tributaries of Corcoran Creek.

Slopes of these exposures are littered with ferruginous slabs and concretions weathered from the Pawpaw Formation, similar to the material derived from the underlying Weno Clay.

The Pawpaw thickens eastward, reaching 60 feet in Marshall County (Bullard, 1928, p. 35). Southward it thins rapidly. Perkins (1960, p. 33) reported a thickness of 17 feet near Fort Worth, Texas, and a few miles south on the Tarrant-Johnson county line only 12 feet is present (Winton and Adkins, 1919, p. 67).

Main Street Formation.—Hill (1901, p. 280) used the name Main Street for a hard limestone formation overlying the Pawpaw Sand in Indian Territory (southern Oklahoma) and across the Red River in northern Texas. Taff (1902, 1903) applied the name Bennington to this limestone sequence in southern Oklahoma. Bullard (1925, p. 37) followed Taff in the use of the term Bennington, although recognizing its equivalence to the Main Street, and in 1928 (p. 37) used the term Main Street for the unit in southern Oklahoma.

The Main Street Formation in Love County consists of about 13 feet of buff to yellow, fossiliferous, sandy limestone. It is present

Figure 15. Caddo upland in foreground. Peaked hill in right background is capped with the Main Street Limestone; other hill capped with Pawpaw Sand.

only as two small outliers capping hills in secs. 27, 34, T. 7 S., R. 2 E., southeast of Marietta (fig. 15).

Although the contact of the Main Street with the underlying Pawpaw Sand is sharply defined, no evidence of an unconformity could be observed. Stephenson (1918, p. 143) suggested the possibility of an unconformity near Denison, Texas, where he noted the presence of "clay marl with scattered white clay pebbles and ferruginous clay nodules along the base, some of which suggest having been mechanically included."

The Main Street thickens southward from the Red River. Hill (1901, p. 282) reported a thickness of 10 to 15 feet in the northeast corner of Cook County, Texas. Perkins (1960, p. 35) stated: "In Tarrant County [Texas] the Main Street Limestone thickens southward from about 20 feet at the northern border to more than 40 feet at the southern."

Tertiary and Quaternary Systems

GENERAL STATEMENT

No recognizable deposits of Tertiary age have been found in Love County. Bullard (1925, p. 37) noted the occurrence of a thin mantle of gravel containing fragments "up to several inches in diameter . . . questionably referred to as 'Tertiary Gravels' " covering many hills, but preferred to consider them earlier deposits of the Red River. During the course of this investigation, scattered pebbles and cobbles up to 3 inches in length were observed on Cretaceous rocks more than 220 feet above the adjacent Red River at Horseshoe Bend. These are believed to be the eroded remnants of a former widespread terrace of Nebraskan age.

Frye and Leonard (1963, p. 23) found "remnants of terrace gravels, resembling the lenticular channel gravels of the Ogallala Formation," in Montague County, 20 miles southwest of the western extremity of Love County at the Red River. This was the only reported occurrence of the Ogallala in northern Texas east of the High Plains escarpment. Frye and Leonard (1963, p. 23) also stated:

> . . . though these late Tertiary gravels in Montague County are at an elevation 300 feet higher than the Red River channel . . . and 150 feet higher than the comparable Nebraskan terrace in the region, they are distinctly lower than adjacent Cretaceous bedrock divides. This relationship suggests that the Neogene Ogallala sediments ceased to be a blanket deposit a relatively short distance east of the High Plains but continued an unknown distance eastward as channel fillings.

The highest terrace levels and accumulation of surface gravels in Love County were at elevations of approximately 280 feet above the channel of the Red River. Although further investigation might prove these to be of Pliocene age, we are including them with terraces of Nebraskan age.

QUATERNARY TERRACES

Frye and Leonard (1963) reported upon the Pleistocene terraces and terrace deposits along the Texas side of the Red River. They were able to differentiate five Pleistocene terrace levels ranging in age from Wisconsinan to Nebraskan.

Three of the Pleistocene terrace levels were formally named and elevations were determined for all levels above the Red River from the Texas Panhandle to the Arkansas border. Elevations were determined by use of 1:250,000 topographic maps of the Army Map Service with 50-foot contour interval (Frye and Leonard, 1963, p. 7).

The terrace levels and their approximated elevations above the Red River channel in counties in northern Texas adjacent to Love County are as follows (Frye and Leonard, 1963, p. 26):

Name	*Elevation (ft)*
Nebraskan terraces	150-160
Hardeman Terrace (Kansan)	90-110
Intermediate terrace (Illinoian)	70
Ambrose Terrace (early Wisconsinan)	30- 45
Cooke Terrace (late Wisconsinan)	18- 20

Names used by us for the Pleistocene terrace levels in Love County are those used by Frye and Leonard for their counterparts on the Texas side of the Red River. Correlation of these terraces was based upon elevation above the Red River channel level, soil type, and relation of the terraces to one another. Elevations of the Cooke, Ambrose, intermediate (Illinoian), and Hardeman (Kansan) Alluvial Terraces in Love County were in excellent agreement with those in northern Texas. The highest terraces, tentatively assigned a Nebraskan age in this report, are from 30 to 120 feet higher than the level found in northern Texas.

Terrace levels at an elevation of more than 280 feet above the Red River channel are present in the western part of Love County along State Highway 32. The terrace material examined in stream gullies consists of silty sand containing numerous pebbles and cobbles. No well-defined lenses of gravel were observed. These deposits are similar to those near Thackerville at an elevation of 185 to 220 feet above the channel at the west. Both terraces are believed to be of Nebraskan age because of the thickness of the deposits, wide expanse of the level terraces, and their development above the Hardeman Terrace.

The greatest development of the Nebraskan terrace deposits is in Tps. 7, 8 S., Rs. 2, 3 W., in western Love County. In this area the Nebraskan deposits rest unconformably upon the underlying Antlers Sand. Where the major drainage systems, such as Mud Creek and Walnut Bayou, have cut through the terraces, the Cretaceous Antlers Sand is exposed on the valley slopes. Deep gullies, exposing thick sections of terrace deposits, occur at the heads of small tributaries cutting into the broad flat terrace (fig. 16).

Nebraskan terraces are also well developed along U. S. Highway 77 near Thackerville. In this area the Red River flows straight southward for more than 12 miles before swinging northward again to form a thumb-shaped southward extension of Love County, known as Thackerville Bend.

Deposits of Nebraskan age in this area are found as far north as Bomar and extend nearly the width of the peninsulalike feature to 3 miles south of Thackerville, covering an area about 7 miles long and 5 miles wide. An abandoned gravel pit in sec. 17, T. 8 S., R. 2 E. (fig. 17) and a sand pit in sec. 18, T. 8 S., R. 2 E., are both within the terrace area. These are at elevations of about 185 feet above the Red River channel level. Cobbles up to 5 inches in diameter were found in the gravel pit.

The majority of the pebbles and cobbles are composed of quartz and chert. The chert types range from black, brown, yellow-brown banded to white. A few cobbles of quartzite and opal-cemented Antlers Sand were found, and in a few places small slabs of ferruginous sandstones, possibly derived from the Weno or Pawpaw

Formations, were observed. The sand pit, about 1 mile south and slightly lower in elevation, contains clean, medium-grained quartz sand with scattered pebbles lithologically similar to those found in the gravel pit.

Figure 16. Gullying in Nebraskan terrace west of Burneyville.

Figure 17. Sand and gravel pit in Nebraskan terrace deposits.

The Hardeman Alluvial Terrace (Kansan) is nearly continuous along the southern margin of Love County except in the southern one-half of the Thackerville Bend area. In this region, dissection of the margin of the higher Nebraskan terrace and the accumulation of dune deposits from the adjacent Red River have obscured evidence of terrace development.

The most extensive development of the Hardeman Terrace is in eastern Love County north of State Highway 32, where it has been dissected into two parts by Boggy Creek. The eastern part extends in a north-south strip between Boggy and Wilson Creeks. The western part also extends in a north-south direction encompassing the village of Enville. Elevation of the terrace is approximately 90 feet above the normal elevation of Lake Texoma and about 30 feet above the adjacent intermediate terrace.

Elsewhere the Hardeman Terrace, ranging from 0.5 to 2 miles in width, forms elongate, flat farmlands paralleling the course of the Red River. Extending westward from Sivells Bend in T. 7 S., R. 1 E., to the Jefferson County border, the intermediate terrace borders the Hardeman Terrace on the river side and the Nebraskan terrace rises above it to the north. Height of the Hardeman Terrace level above the Red River in Love County ranges from 90 to 120 feet.

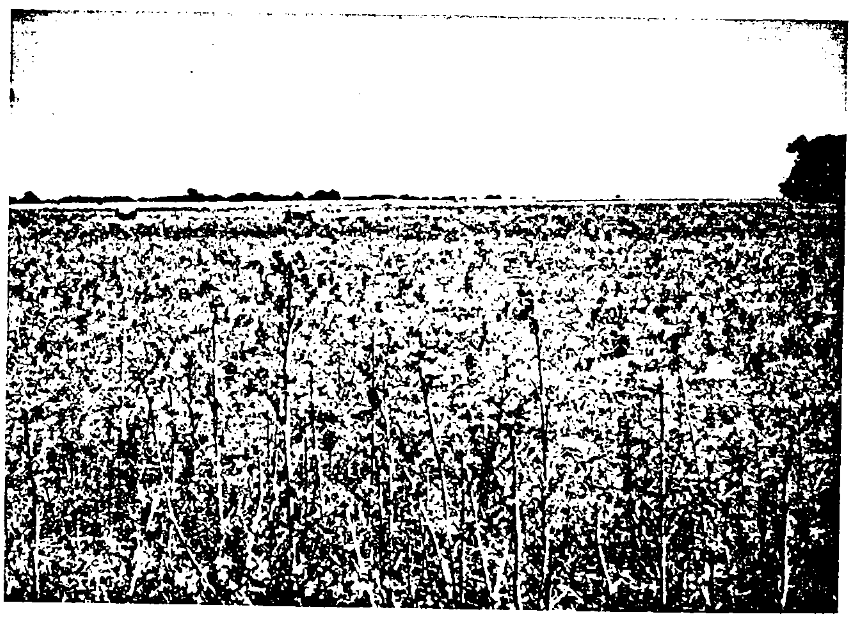


Figure 18. Hardeman Terrace level looking north, 1 mile west of Wilson Creek.

The intermediate alluvial terrace (Illinoian) has distinctive form in Love County in comparison with the lack of development in the northern Texas counties (Montague and Cooke) south of Love County (Frye and Leonard, 1963). Characteristically, the terrace level is between 60 and 70 feet above the channel level of the Red River. The intermediate terrace is well exhibited in eastern Love County just west of Wilson Creek, where it forms a flat plain margined lakeward by the Ambrose Terrace and northward by the broad Hardeman Terrace. Along the west side of Illinois Bend, the intermediate terrace borders the Red River channel 60 feet below. Here, the Cooke and Ambrose terrace deposits have been removed as the result of northward erosion by the meandering river. At the southern end of Thackerville Bend, in the Leeper Lake area, isolated remnants of the intermediate terrace can be distinguished where they have not been buried by vast numbers of sand dunes.

The Wisconsinan Cooke and Ambrose Alluvial Terraces reach their maximum development on the large point bars along the Red River. The early Wisconsinan Ambrose Terrace (fig. 19), particularly, serves as the platform for many fertile farmlands,

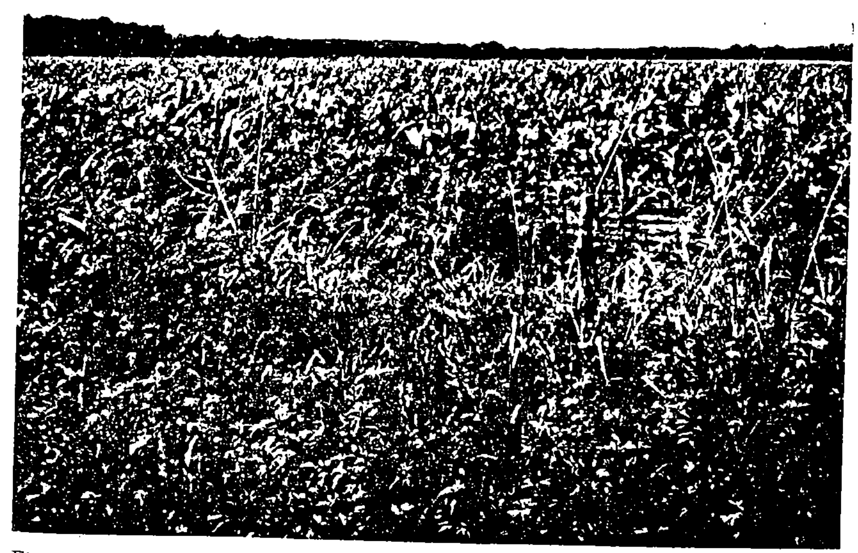


Figure 19. Ambrose Terrace level, east of Horseshoe Bend, T. 8 S., R. 2 W., Hardeman Terrace in background.

Figure 20. Cooke Terrace level, looking southeast towards Red River. East of Horseshoe Bend.

Figure 21. Dunes accumulated at edge of Ambrose Terrace. Cooke Terrace at right. Horseshoe Bend area.

especially at Decherds Bend and in the locality just east of Horseshoe Bend in T. 8 S., R. 3 E. Elongate expanses of the Ambrose Terrace are also developed at Saddler Bend, south of Leon and Jimtown in T. 8 S., R. 2 W., and also between Warrens Bend and Sivells Bend. In all areas of development, the Ambrose Terrace is between 30 to 45 feet above the Red River channel level.

The Cooke Terrace (fig. 20) adjoins the alluvial plain of the Red River. In many areas it consists of a level, brush-covered strip ranging from 0.25 to 0.5 mile wide paralleling the river. At places patches of cultivated land are encountered, and, where the brush has been cleared, the terrace may serve as pasture land. The terrace is consistently about 15 feet above the alluvial plain. At many places, where a considerable expanse of the alluvial plain is developed, the adjoining Cooke Terrace has been invaded by sand dunes. The area of maximum development of the Cooke Terrace is in sec. 24 T. 8 S., R. 2 E., and sec. 19, T. 8 S., R. 3 E., where it is about 2 miles long and 1 mile wide.

STRUCTURE

General Statement

The dominant structural feature in Love County is the Marietta syncline, which is developed in Cretaceous rocks in the east-central area. Despite the synclinal feature, dips in the Cretaceous strata are low and nearly horizontal. However, along the northern border of the county in T. 6 S., Rs. 1, 2 E., pre-Permian Paleozoic rocks are steeply tilted, and upon these the Cretaceous strata rest unconformably. Upon the basis of these features, structures in Love County may be divided into two types: Paleozoic structure and Cretaceous structure.

Paleozoic Structure

Sounthern Oklahoma was the site of two great orogenic pulses during the Late Paleozoic. The first of these was the Wichita orogeny which began during the Late Mississippian and culminated by early Atokan time (Tomlinson and McBee, 1959, p. 25). The second was the Arbuckle orogeny which began during early Desmoinesian time with slight uplift of parts of the Arbuckle area and culminated during early Virgilian time with tremendous crustal shortening and major faulting (Tomlinson and McBee, 1959, p. 38, 46).

SYSTEM	SERIES	GROUP	FORMATION
Mississippian	Chesterian	Springer	Lake Ardmore Fm. Springer Fm.
			Goddard Fm.
	Meramecian		Caney Sh.
	Osagean		Sycamore Ls.
Devonian	Chattanoogan		Woodford Fm.
		Hunton	Bois d'Arc Ls. Haragan Fm.
Silurian			Henryhouse Fm. Chimneyhill Ls.
Ordovician	Cincinnatian		Sylvan Sh.
		Viola	"Fernvale" ls.
	Champlainian		"Trenton" ls.
		Simpson	Bromide Ls.

Figure 22. Sequence of pre-Pennsylvanian strata exposed in northern Love County in core of Criner Hills area.

The section of Paleozoic rocks in the Ardmore Basin Province involved in these orogenies is well known (Tomlinson, 1929; Tomlinson and McBee, 1959; Westheimer, 1936, 1948; Frederickson, 1957; Hicks and others, 1956) and will not be discussed in this report. For reference to formational names and ages see figures 22 and 23.

The Wichita orogeny served to initiate a series of southeastward-trending structural features, consisting of an alternation of uplifts and basins. The Muenster arch, south of Love County in northern Texas (fig. 24), and the Marietta syncline, Criner Hills uplift, and Ardmore basin of Oklahoma were formed during this time. Faulting, as well as folding, played a major part in this development (Tomlinson and McBee, 1959, p. 16-17, fig. 5). Erosion from the uplifted anticlinal structures, the Muenster arch and the Criner Hills

SERIES	GROUP	FORMATION	MEMBER
Virgilian	Pontotoc	Vanoss Fm.	
Missourian	Hoxbar	"Hoxbar"	Zuckermann Ls. Daube Ls. Anadarche Ls. Crinerville Ls. Confederate Ls.
Desmoinesian	Deese	West Arm Fm.	Natsy Ls. Williams Ls.
			Rocky Point Cgl. Arnold Ls. Devils Kitchen Ss.
	Dornick Hills	Big Branch Fm.	Pumpkin Creek Ls.
		Lake Murray Fm.	Frensley Ls. Lester Ls. Bostwick Cgl.
Atokan			
Morrowan		Golf Course Fm.	Otterville Ls. Jolliff Ls. Primrose Ss.

Figure 23. Sequence of Pennsylvanian strata exposed in the Ardmore Basin Province. Beds of Dornick Hills, Deese, and Hoxbar age extend into northern Love County.

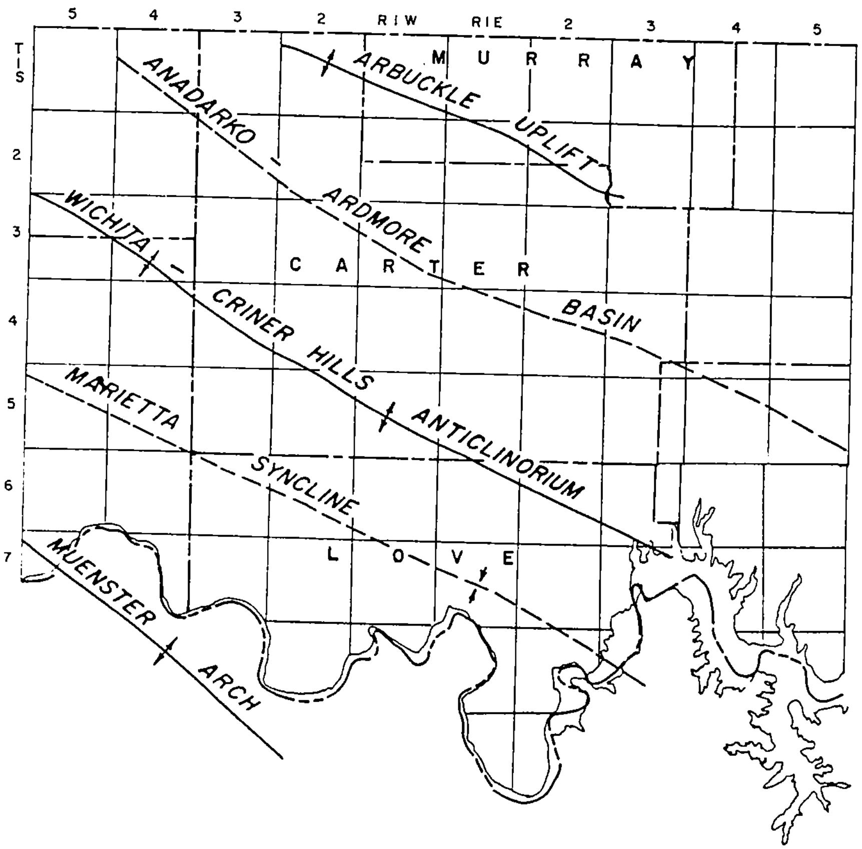


Figure 24. Generalized structural trends of Love and Carter Counties, Oklahoma.

uplift, as well as adjacent highlands, contributed enormous quantities of sediment to the adjoining, slowly subsiding Ardmore basin.

The Marietta basin, although faulted and synclinal in form, did not subside nor receive the vast quantities of sediments being poured into the Ardmore basin. Apparently, it remained as a positive lowland area between the Muenster arch and the Criner Hills uplift. During Late Mississippian (Springeran) time, these areas, Muenster arch, Marietta syncline, and Criner Hills uplift, were also emergent and did not receive the thick deposits of Springer sediments as did the Ardmore basin and adjacent areas to the north (McBee and Vaughn, 1956, p. 360; Reed, 1959, p. 131).

By the end of Atokan time, erosion had stripped thick sequences of sedimentary rocks from the Muenster arch and the Criner Hills uplift and exposed the underlying Ordovician Arbuckle limestone.

During the Desmoinesian Epoch, sediments of the Deese Group were deposited in the Marietta syncline. The entire region was covered ultimately by marine sediments of Missourian (Hoxbar) age.

The Arbuckle orogeny near the end of Pennsylvanian time unleashed tremendous southwesterly directed compressional forces which resulted in extreme crustal shortening and faulting. The Arbuckle Mountains range was formed at this time, and the rising Arbuckles, subject to rapid erosion, immediately began contributing coarse sediments to adjacent areas. The Pennsylvanian sediments which had accumulated in the Ardmore basin were compressed further, and southwesterly directed forces pushed them against the bulwark of the Criner Hills uplift, forming the large thrust-faulted Overbrook anticline. These same forces deformed the Pennsylvanian sediments around the Criner Hills uplift and intensified the structures formed during the Wichita orogeny in the pre-Pennsylvanian rocks. Other structures formed in the Criner Hills area at this time were the Brock anticline, the Royal anticline, the Pleasant Hill syncline, the Hickory Creek syncline (new term) and the Criner fault.

The rigidity of the Criner Hills uplift tended to absorb the tremendous southwesterly directed forces and, except for moderate increases in dips and slight movement along the faults, the Muenster arch and the Marietta syncline were little affected (Reed, 1959, p. 141).

By the end of Pennsylvanian time the entire region, including the Arbuckle Mountains at the north, was peneplaned. Redbed sediments of Virgilian and Permian age were deposited over the upturned eroded structures resulting from the Pennsylvanian orogenies. According to Tomlinson and McBee (1959, p. 49), "much of this redbed cover was stripped off the buried ranges in Triassic or Jurassic time, permitting Comanchean sands to be deposited directly on pre-Pennsylvanian rocks in the Criner Hills."

The Criner Hills area (Frederickson, 1957), as exposed today, includes not only the eroded Criner Hills anticlinorium, first formed in Early Pennsylvanian time, but also the Late Pennsylvanian structures such as the Brock anticline at the west and the Pleasant Hill syncline at the east. Resistant sedimentary strata of these structures extend into Love County in the northeastern part of T. 6 S., R. 1 E., and the northwestern part of T. 6 S., R. 2 E. Paleozoic strata from Middle Ordovician to Mississippian are exposed in the southward extension of the eroded core of the anticline. Pennsylvanian strata of Deese and Hoxbar age represent the southward extension of the Brock anticline in sec. 2, T. 6 S., R. 1 E.

The Hickory Creek syncline, named for exposures along Hickory Creek, has a southeast plunge. The axis of this syncline is in line with the northwestward-plunging axis of the Pleasant Hill syncline, and, although erosion has removed any evidence, it is possible that a small transverse flexure once separated the two. The limbs of this syncline cannot be traced southeastward owing to rapid facies changes, cross faulting, and the presence of the overlying Antlers Sand. Fusulinid studies by the Paleontological Laboratory Inc., Midland, Texas, indicate that the limestones and conglomerates forming the oldest beds in this structure are of early Deese age, probably post-Pumpkin Creek pre-Devils Kitchen. This is in accord with the findings of Ramay (1957) for the basal conglomerate beds (Bostwick? of Tomlinson and McBee, 1959, p. 26) in the Pleasant Hill syncline.

Resistant limestones, sandstones, and conglomerates trending southeastward through the north one-half of T. 6 S., R. 2 E., represent the extension of the Overbrook anticline. These strata, with northeasterly directed dips ranging from 45° to 90°, represent the northeast flank of the Overbrook anticline. Strata of Springer, Dornick Hills, Deese, and Hoxbar age are represented.

Cretaceous Structure

Although widely separated in time of deposition, the structure of the Permian Addington Formation is intimately associated with the Cretaceous structure. Bunn (1930, p. 16, 17) described three southeastward-trending structures exhibited in Permian sediments in Jefferson County. The northernmost structure, the Healdton uplift, he considered an extension of the Criner Hills. The southernmost structure, which he called the Nocona uplift, has since been included in the Muenster-Waurika arch (Tomlinson and McBee, 1959, p. 28). For the feature between these two structural uplifts, he used the term Ringling basin and stated:

> This geosyncline parallels and separates the adjoining major structural highs. The general axis extends in a northwest-southeast direction across the north half of the county. It is shown on the surface by general dips off the paralleling uplifts and by the outcrop of the Addington formation.

The Addington Formation is the youngest Permian strata exposed in Jefferson County, and it marks the center of the southeastward-plunging syncline which Bunn (1930) called the Ringling basin. The axis of this structure when continued through the Addington redbed deposits in western Love County essentially corresponds to the axis of the southeastward-plunging Marietta syncline as developed in Cretaceous strata. The pre-Atokan paleogeologic map complied by Reed (1959, pl. 1) showed the two to be one continuous structure.

The Marietta syncline is outlined on the surface in east-central Love County by the outcrop pattern of the Goodland Limestone. As exposed in the Cretaceous rocks, it forms an asymmetrical syncline plunging southeastward. Dips average 60 to 70 feet per mile toward the southwest on the steeper northeastern flank, and the more gently dipping southwestern limb dips 20 to 30 feet per mile in the opposite direction. Southeastward the syncline is shallower and rapidly flattens. As with most Cretaceous structures in southern Oklahoma, the topographic highs are the structural lows, and on the axis of the syncline southeast of Marietta, the youngest Cretaceous rocks in the county are exposed on several prominent hills (fig. 15).

Bullard (1925, pl. 19) constructed structural contours of the top of the Goodland Limestone. These excellently define the syncline and show the southwest limb changing its southeasterly direction at the town of Bomar and trending slightly southwestward. Bullard (1925, p. 12) postulated that the course of the Red River, outlining the southward extension of Love County known as Thackerville Bend, was structurally controlled by the resistant Goodland Limestone.

Bullard (1925, p. 46, 47) also suggested that minor associated folds in the Cretaceous sediments were responsible for the meander pattern at Horseshoe Bend, T. 8 S., R. 2 E., and at Walnut Bend, T. 9 S., R. 2 E. Bullard's evidence for the Walnut Bend flexure was meagre and unsatisfactory. However, for the Horseshoe Bend anticline he cited buckling of the Kiamichi oyster beds in exposures at the edge of the Red River at Horseshoe Bend and reversal of dip in the lower part of the Caddo Formation near the edge of the water level. Unfortunately, alluvium now covers these beds. The exposure of the Caddo Formation through younger formations along the axis of the sharp change in trend of the structural contours of the Goodland Limestone, however, tends to substantiate Bullard's explanation. Reed (1959, pl. 1), upon the basis of subsurface evidence, postulated the presence of a westward-plunging anticlinal nose in buried pre-Pennsylvanian strata between Horseshoe Bend and Walnut Bend.

Subsurface evidence indicates the development of the Marietta syncline during the Wichita orogeny in Late Mississippian and Early Pennsylvanian time (McBee and Vaughn, 1956, p. 358-363; Tomlinson and McBee, 1959, p. 16-17, fig. 5). Subsidence of the basin during Middle and Late Pennsylvanian time is also evidenced by the thickening basinward of sediments of Desmoinesian, Missourian, and Virgilian age.

Bunn's cross sections of the Ringling basin in adjacent Jefferson County (1930, pl. 2) show evidence of further subsidence after deposition of the Permian strata. Inasmuch as the Ringling basin is continuous with the Marietta syncline, it is logical to conclude that the Marietta syncline also continued to subside in post-Permian time.

Prewit (1961, pls. 1-4) presented a series of isopach maps of the Trinity, Fredericksburg, and Washita Groups, and a contour map of the base of the Cretaceous in southern Oklahoma. He stated that "the isopach maps of the rock groups in the Comanchean series reveal a pronounced thickening in synclinal areas and thinning over anticlines," and concluded: "thus, these structures present in the Cretaceous rocks of southern Oklahoma would be the result of a draping of the Comanchean sediments over pre-existing topographic features."

Prewit's map of the base of the Cretaceous (paleotopographic? map) plainly shows a depressed basinal area, deepening to the southeast in the region of the present-day Marietta syncline. Also, on the isopach map of the Trinity Group he showed a thickness of 818 feet near the axis of the syncline in sec. 21, T. 8 S., R. 2 E., as con-

trasted to a thickness of 100 feet about 5 miles north of Marietta. These two features, in part, were the basis for his conclusion of the draping of Cretaceous rocks over pre-existing structures.

We disagree with this conclusion. Prewit's evidence does not prove the existence of the buried topographic features at the beginning of Cretaceous time; it merely shows their presence now. The depressed basin shown on the contour map of the base of the Cretaceous could have been formed by continued subsidence during or after the deposition of the Comanchean sediments. Furthermore, according to Prewit's map, the basin had a maximum relief of 800 feet which would be nearly filled by the first phase of deposition by the Comanchean sea, the Antlers Sand. Thinning over the highs and thickening in the basin of the Fredericksburg and Washita Groups, therefore, can only be accounted for by continued subsidence.

We conclude that present structural features observable in Cretaceous rocks in Love County, and probably elsewhere in southern Oklahoma, are a result of continued structural adjustment and not a result of draping over pre-existing topographic features.

Part II.—Petroleum Geology of Love County

Jerome M. Westheimer*

INTRODUCTION

Love County is approximately midway between the east and west lines of the State of Oklahoma, and is bounded on the south by the Red River, the south bank of which is the boundary between Oklahoma and Texas. Geologically, most of the county lies in the Marietta basin or syncline, to the south of which lies the Muenster-Nocona arch. To the north of the syncline is the Wichita Mountains-Criner Hills complex with its buried extensions.

Oil was discovered, both to the north and south, decades before Love County had its first commercial production in 1936. This fact is readily explained because to the north in Carter County the early production was shallow and was discovered by either surface geology or random drilling. This is equally true to the south in Cooke, Montague, and Clay Counties, Texas, where oil was first discovered at Petrolia in Clay County in 1898, seven years earlier than the first field (Wheeler) in Carter County, Oklahoma. There was sporadic wildcatting in Love County, but, because most of the production is rather deep (especially compared to the average well depth before 1936) and most of the county is covered with Cretaceous sediments, no commercial production was found.

* Consulting geologist, Ardmore, Oklahoma.

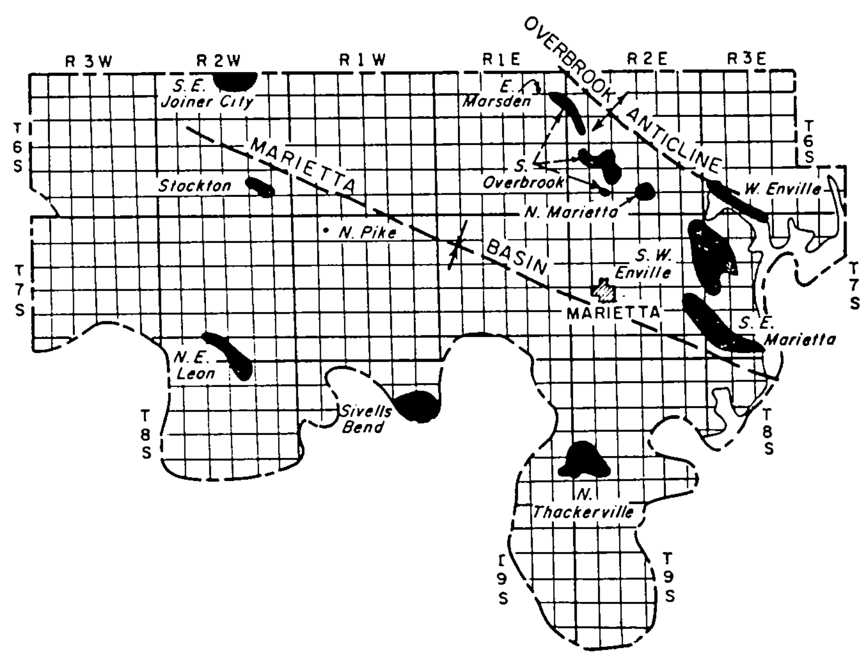


Figure 25. Map of Love County, showing some major structural features and locations of oil and gas fields.

In October 1935, the Carter Oil Company completed its 1 Ruth Williams well, sec. 27, T. 2 S., R. 3 W., a prolific deep Simpson producer in the Fox field of Carter County. This well stirred intensive geological and geophysical exploration throughout southern Oklahoma. Sinclair-Prairie Oil Company, after geophysical surveys in the Marietta-Sherman syncline, completed its 1 Stockton well, sec. 26, T. 6 S., R. 2 W., in December 1936, as the first commercial producer in Love County. Subsequently, in 1938, it opened the important Walnut Bend field in the Sherman (Texas) syncline and approximately 5 miles east of Thackerville, Oklahoma.

The author is deeply grateful to the many geologists, working in southern Oklahoma, who have been generous with their time and information, and without whose assistance this report would not have been possible. The author also thanks the members of the staff of the Oklahoma Geological Survey, who assisted with drafting, helpful criticism, and editing.

STRATIGRAPHY

Numerous papers on southern Oklahoma and northern Texas have adequately described the general stratigraphy of the area. Consequently, as a detailed description herein would be largely redundant, the discussion is brief.

The stratigraphic nomenclature used herein (fig. 26) is that which has been long established and is generally employed by petroleum geologists in the southern Oklahoma area. It differs in a few particulars from that which is widely accepted by others and by the Oklahoma Geological Survey as the result of more recent work. The older nomenclature is adhered to in the belief that it is more convenient for those currently engaged in petroleum exploration and development in the Love County area.

The principal modifications of the nomenclature presented in figure 26 involve the Viola group, Woodford Formation, and Springer Formation. Surface rocks corresponding to the Viola group of the subsurface are the Viola Formation and "Fernvale" Limestone, the former being referred to as the Trenton limestone in the subsurface; the units are not assigned to a named group at the surface. The nomenclature of this part of the stratigraphic section is in need of drastic revision, particularly because the terms "Fernvale" and "Trenton" are considered inappropriate for these rocks, and it is hoped that work now in progress will result in such revision. The Woodford Formation is classified herein as Mississippian (Kinderhookian), but it is now known to be Devonian ("Chattanoogan"). The age of the Springer Formation is in doubt. Earlier views favored a Pennsylvanian age for the Springer and Goodard. The Goodard has since been proved to be Chesterian and the current consensus is predominantly in favor of a Mississippian age for the Springer as well.

Arbuckle Group

Few wells in Love County have drilled deeply into the rocks of the Arbuckle Group, and these have drilled only the West Spring Creek Formation, stopping in the uppermost Kindblade. The West Spring Creek Formation is approximately 1,500 feet thick, although the Union Texas Petroleum Company 1 Daube well, in sec. 27, T. 6 S., R. 2 E., drilled almost twice this thickness of steeply dipping West Spring Creek sediments.

The top of the Arbuckle is picked on the top of the cream to light-tan, semidense, slightly dolomitic limestones, immediately underlying the basal sucrosic dolomite of the Joins Formation. From 150 to 200 feet below the top of the Arbuckle is a zone, 50 to 100 feet thick, consisting of sucrosic dolomites, some arenaceous, and in places thin beds of loosely bonded, medium-grained, rounded sandstone. The underlying 600 to 700 feet of sediments is composed predominantly of semidense, light-tan to gray, dolomitic limestones with minor amounts of dolomite. Below this lies a zone of predominantly fine-grained to sucrosic dolomites. This zone is correlated with the prolific "Brown zone" of the Healdton field of Carter County. This zone ranges in thickness from 500 to 600 feet, and the base of this zone is considered to be the base of the West Spring Creek Formation.

Simpson Group

Joins Formation.—The Joins Formation in Love County has been divided into two units—the lower, commonly called the Joins dolomite, and the upper, the Joins limestone. The lower or dolomite member is from 100 to 150 feet thick. It is composed of upper and lower members of sucrosic dolomite with an intervening member of rather dense, slightly dolomitic limestone. The dolomite members can be readily picked on electric logs by their relative high self-potentials and low resistivities. The dolomite is producing in several wells in the North Thackerville field.

The Joins limestone is also from 100 to 150 feet thick and is composed mainly of brown to gray, microcrystalline limestone.

Oil Creek Formation.—The basal sandstone of the Oil Creek Formation is by far the most important producing horizon in Love County, being the main producing zone of the West Enville, Southwest Enville, and Southeast Marietta fields. It ranges in thickness from 0 to slightly more than 100 feet. It was probably deposited as beach sands by a westward transgressive sea, and its presence is confined to a small part of Love County (pl. II, fig. B). The sandstone is medium-fine grained. Its grains are uniform, rounded to subrounded, and partly frosted.

SYSTEM	SERIES	GROUP	FORMATION	MEMBERS AND LOCAL NAMES
CRETACEOUS	Comanchean			
PENNSYLVANIAN	Virgilian	Cisco	Pontotoc terrane	Shale, sandstone, and arkosic conglomerate
				Shale, sandstone, and nonarkosic conglomerate
	Missourian	Hoxbar		Zuckermann Ls. Daube Ls. Anadarche Ls. Crinerville Ls. Confederate Ls. Home Creek Ls. Ranger Ls. Twin lime Hoosier lime
	Desmoinesian	Deese	West Arm Fm.	Natsy Ls. Williams Ls. Chubbee sand Cox sand Lone Grove zone Bruhlmeyer zone
			?	
			Millsap Lake Fm.	Rocky Point Cgl. Arnold Ls. lower "Fusulina" sand Devils Kitchen Cgl. Ryan sand Rasure sand Peabody sand Hudspeth zone Snuggs sand Ramsey sand Best sand Beasley sand Morris sand Dillard sand Stockton sand Winger sand
		Dornick Hills	Big Branch Fm.	Pumpkin Creek Ls.
	Atokan		Lake Murray Fm.	Frensley Ls. Lester Ls. Davis sand Micaceous sand Hartshorne Ss. ? Hefner sand
				Shale above Bostwick Member Bostwick Cgl.
	Morrowan		Golf Course Fm.	Otterville Ls. Wapanucka Ls. Jolliff Ls. Primrose Ss. Union Valley Ls.

SYSTEM	SERIES	GROUP	FORMATION	MEMBERS AND LOCAL NAMES
			Springer Fm.	Lake Ardmore Ss. Overbrook Ss. Rod Club Ss. Markham sand Aldridge sand
MISSISSIPPIAN	Chesterian		Goddard Fm.	Redoak Hollow Ss.
	Meramecian		Caney Sh. (conglomeratic) Caney Sh.	
	Osagean		Sycamore Ls.	
	Kinderhookian		Woodford Fm.	
DEVONIAN	Helderbergian	Hunton	Bois d'Arc Ls. Haragan Fm.	
SILURIAN	Niagaran		Henryhouse Fm.	
	Alexandrian		Chimneyhill Ls.	
ORDOVICIAN	Cincinnatian		Sylvan Sh.	
	Mohawkian	"Viola"	Fernvale ls. Trenton ls.	
	Chazyan	Simpson	Bromide Fm. McLish Fm. Oil Creek Fm. Joins Fm.	Joins dolomite "Wade zone"
	Canadian	Arbuckle	West Spring Creek Fm. Kindblade Fm.	"Bray zone" "Brown zone"

Figure 26. Stratigraphic units of Love County and some correlations with those of adjoining areas.

Above the basal sandstone is a section of approximately 800 feet of sediments, composed mainly of dull green-gray shales with thin, soft, gray- and white-splotched, chalky, pyritic limestones, with the limestones increasing in the lowermost 200 feet. The distinctive ostracode, *Aparchites perforatus,* is common in this part of the Oil Creek Formation. The dense, birdseye-type limestone, and the underlying oölitic member comprise the upper 150 feet of the Oil Creek Formation.

McLish Formation.—This formation has an average thickness of 400 to 500 feet. Normally at the base is a 10- to 15-foot, tightly cemented, arenaceous limestone or calcareous sandstone, composed of large, rounded, frosted quartz grains. The overlying sediments are interbedded, platy, rather bright emerald-green shales and medium- to coarse-crystalline limestones.

Bromide Formation.—The thickness of Bromide sediments in Love County is about 700 feet. The lower two-thirds is very fine-grained, calcareous sandstones, in many places glauconitic, bright emerald-green and brown, platy shales, and arenaceous ostracodal limestones. The upper part is less arenaceous and the uppermost member is composed of cream to light-gray, dense limestone.

Viola Group

As used by petroleum geologists working in the subsurface of southern Oklahoma, the Viola group contains the Trenton (Viola Formation of the surface) and the overlying Fernvale limestone, which have an aggregate thickness of 950 to 1,000 feet. The Trenton limestone consists of three members in ascending order: a basal, chocolate-brown, siliceous limestone; an ash-gray, noncherty member with abundant graptolite fragments; and buff to tan microcrystalline limestones with thin beds of gray, spicular chert and tan chert. The Fernvale is normally less than 25 feet thick and is composed of medium- to coarse-crystalline, noncherty limestone.

Sylvan Formation

The Sylvan Formation is approximately 300 feet thick in Love County. The basal part consists of brown, argillaceous, sucrosic dolomite, overlain by silvery gray to pale apple-green shales with a satiny sheen.

Hunton Group

Owing to the widespread pre-Chattanooga unconformity, the Hunton Group exhibits a much greater range in thickness than do the underlying sediments.

The lowermost Chimneyhill Formation of the Hunton Group consists of three members. The basal member is a fine-crystalline limestone containing poorly formed, tan, coarse oölites. The middle member is composed of dense to crystalline, white limestone with sparse to abundant, coarse glauconite grains. The top Chimneyhill member is a crystalline limestone with some pink crinoid fragments.

Overlying the Chimneyhill Formation are the Henryhouse and Haragan marls. There is no clear-cut distinction between the two, but the Henryhouse is normally buff-colored and less marly, especially in the lower part. It grades into typical Haragan, which is sucrosic, gray-greenish, marly limestone.

The Bois d'Arc Formation overlies the Haragan and consists of fine- to coarse-crystalline limestone, with chert being more prominent in the upper part of the formation.

In the Southeast Joiner City field in T. 6 S., R. 2 W., where the Hunton is productive, it has a maximum thickness of about 400 feet, and beds from Chimneyhill through Bois d'Arc are all present. In eastern Love County, the Hunton Group has been eroded considerably. Some wells in sec. 27, T. 6 S., R. 2 E., have no Hunton at all, the stratigraphic interval being represented by a few feet of conglomeratic dolomite. Throughout Tps. 6, 7 S., Rs. 2, 3 E., the Hunton is less than half as thick as it is in western Love County, the upper part of the group having been eroded away.

Woodford Formation

The Woodford Formation, 200 to 300 feet thick, is composed of shale, cherty shale, and chert. Pale-green and emerald-green shale is commonly prominent in the lower part of the formation, and the top part generally contains more chert. Algae are abundant throughout.

Sycamore Formation

The Sycamore Formation is generally between 200 and 300 feet thick. The lowest member is gray, dolomitic shale, overlain by cherty limestone, some of which may be slightly arenaceous. The upper approximate two-thirds of the formation consists of interbedded Mayes-type shale and finely arenaceous limestones.

Caney Shale

The Caney Shale ranges in thickness from 500 to at least 1,000 feet. The lower half is the typical Caney Shale section of southern Oklahoma. However, the upper part in Tps. 6, 7 S., Rs. 2, 3 E., is of a character heretofore unknown. Although this section has many of the characteristics of the typical Caney—the brown-black, resistant shales—it also contains numerous conglomeratic beds, composed of Sycamore and Woodford chert pebbles. The earliest occurrence of these conglomerates previously reported is in the Jolliff Limestone of Morrowan age and leads to the conclusion that earlier movement occurred in the area of the Southeast Marietta field and adjacent areas. The typical Caney and the conglomeratic Caney can usually be distinguished on electric logs. The typical Caney shows a low self-potential which is practically a straight line, whereas the upper conglomeratic part shows more variation.

Goddard? Formation

This group of rocks is perhaps the most difficult to measure and classify. Its occurrence is limited to the northeastern part of the county. The top is marked by a pronounced unconformity (pre-Morrowan), and, as the rocks are predominantly plastic-type shale in a highly deformed area, the thickness is extremely variable. The shales are medium gray, generally thinly laminated, slightly micaceous, and contain thin, brownish, ironstone beds. The few sandstones in this section are thin and discontinuous. Some wells have encountered as much as 3,500 feet of these sediments, but it is doubtful if the true thickness is 50 percent of this figure.

It is thought that these beds are of Goddard age and that Springer sediments have not been found to date in Love County. Whether they were not deposited because of the early movement discussed above or were deposited and subsequently eroded cannot be proved at this time, although the first assumption seems more logical. This view is further strengthened by the fact that the Primrose Sandstone, of early Morrowan age, has not been found in Love County.

Dornick Hills Group

Like the Goddard, Dornick Hills sediments are confined to the northeastern part of the county. The type section for northeastern Love County was taken from the Humble Oil & Refining Company 1 Resources Unit, NE¼ SW¼ SW¼ sec. 14, T. 6 S., R. 2 E. In this well approximately 6,000 feet of Dornick Hills sediments was drilled, but correction by dipmeter readings shows the actual thickness to be between 3,200 and 3,300 feet.

The Primrose Sandstone is not present in this well and the lowest member of the Dornick Hills is the Jolliff Limestone, the base of which is at 6,877 feet. The Jolliff Member is a sandy, fine-grained limestone with gray chert pebbles (Sycamore?). The overlying 1,100 feet (corrected) of sediments consists of thin, sandy limestones, some cherty, typical Wapanucka-type shale, and, in the upper part, sandy, glauconitic, oölitic limestones. This part of the section represents the Jolliff-Otterville or Wapanucka section of Morrowan age.

No distinct break occurs between the Morrowan sediments and the overlying Bostwick beds of Atokan age. The limestones are still sandy, cherty, and conglomeratic, and the shales grade almost imperceptibly from the evenly micaceous, satiny Wapanucka type to the less evenly micaceous, rougher textured shales of the Bostwick. This conglomerate and shale section is 800 feet thick in the Humble well and is overlain by 325 feet of gray shale.

Superjacent to this shale is a zone of thin sandstones and intercalated shales about 110 feet thick. The sandstone is very fine-grained, quite micaceous, and contains minute carbonaceous flecks. The intercalated shales are also very micaceous. This member, locally called the Micaceous sand, is widespread in southern Oklahoma and northern Texas. Eastward it can be carried through Marshall and Bryan Counties and probably is correlative with the Hartshorne Sandstone of the Arkoma basin. Southeastward it can be carried into Grayson and Cooke Counties, Texas, and into the Southeast Marietta field, where it is called locally the Davis sand. With less certainty it can be correlated with the Hefner sand of northwest Carter County and Stephens County.

Approxiamtely 200 feet above the Micaceous sand is an arenaceous, fossiliferous, glauconitic, brown oölitic limestone that is correlated with the Lester Member of the surface section.

The 700 feet of Dornick Hills sediments above the Lester Limestone consists of fine-grained sandstones, gray and maroon shales, and two limestone members—Frensley and Pumpkin Creek.

Deese Group

Deese Group sediments are composed almost entirely of shales and sandstones, with a few conglomerates and fewer thin limestones. Sandstones of the Deese Group are, next to the Oil Creek (Simpson), by far the most important oil- and gas-bearing zones in the geologic column.

The base of the Deese Group is an extremely difficult point to pick. The main part of the Marietta basin was a positive area throughout Early Pennsylvanian time. In Lake Murray time seas encroached from the southeast into parts of Tps. 7, 8 S., R. 3 E., and progressively continued their transgression to the northwest. Later, as the entire basin foundered, the seas spread out in other directions. The earliest sediments in the Marietta basin were derived from nearby sources, which to a large extent were eroded down to Simpson or Arbuckle sediments. As a consequence, the Early Pennsylvanian shales, in texture, resemble Simpson shales, although their difference in color makes confusion unlikely. The limestones, too, are similar in lithology to West Spring Creek limestones and some to dense Simpson limestones. In the Stockton field, T. 6 S., R. 2 W., this type of sedimentary material usually aggregates about 1,000 feet, and nearly reaches a thickness of 1,800 feet.

That part of this section is of late Dornick Hills age can be proved by fusulinids, but much of this section is probably of earliest Deese age, and the time equivalent of the lower Deese sandstone and shale section in the area of the Southeast Marietta field, where these sediments were from a different (southeastern) source.

Above this section lies the Millsap Lake Formation or "maroon Deese," composed of maroon and greenish clay and shale, gray shale, and numerous sandstones, some of which are locally conglomeratic. In the lower part of the Millsap Lake are numerous erratic sandstones that are the productive oil and gas zones in the fields of the Marietta basin. These individual members are also generally of limited areal extent, mostly not continuous for more

than 2 to 3 miles. The Hudspeth zone, although its individual beds vary, can be traced on electric logs throughout most of Love County, where it is present. Within the Hudspeth zone occurs a medium-grained sandstone, generally cherty, which was first called Rocky Point Conglomerate in the subsurface in the Sivells Bend field of Cooke County, Texas. It is believed that this member is probably the equivalent of the surface member of the same name. Some 200 feet above the Hudspeth zone lies another persistent zone of sandstones and shales, the Bruhlmeyer zone, in which maroon shales first make a conspicuous appearance. The Bruhlmeyer is considered to be the time equivalent of the middle part of the Lone Grove sand sequence.

Above the Millsap Lake Formation lies 600 to 900 feet of sediments, composed of gray shales, sandstones and conglomerates, thin limestones, and arenaceous, oölitic limestone. This part of the section has been correlated with the West Arm Formation. Generally speaking, maroon shales are practically nonexistent in this formation. On the outcrop section maroon shales appear a few feet below the Williams Limestone, which by Harlton's definition marks the base of the West Arm Formation. Nevertheless, the first appearance of maroon shales must be used with caution. In the Walnut Bend field of Cooke County, Texas, they occur several hundred feet higher stratigraphically, possibly near the Natsy Limestone. In western Love County in the Stockton field, they are first found in the Hudspeth zone, but only become prominent some 700 feet below this point.

On electric logs the shale characteristics start changing generally in the Bruhlmeyer zone and become pronounced in the Hudspeth zone. Above this point the shale lines are relatively straight and featureless; below they become progressively more irregular, particularly on the resistivity side of the log.

The Chubbee sand is considered to be the uppermost member of the Deese Group. It consists of a zone of sandstones having a wide range in amount of sandstone and in thickness. In places the Chubbee consists of almost 400 feet of practically pure sandstone, whereas in other places it is represented by a zone of thin sandstones less than 100 feet thick. The Chubbee sand consists of medium-coarse rounded grains, loosely bonded in the upper part.

Hoxbar Group

Sediments of Deese time exhibit a tremendous range in thickness and lithologic character. By Hoxbar time conditions in the Marietta basin were much more stable, and consequently the sediments are much more uniform. The Hoxbar sediments range from approximately 1,600 to 2,000 feet in thickness and consist of gray to greenish-gray shales with four to five individual limestone zones and usually thin sandstones and few conglomerates. Throughout western Love County the limestone zones are remarkably consistent and can be traced from Carter County through western Love County into Montague County, Texas, to the south.

The top of the Hoxbar has been subjected to pre-Cisco erosion, and in places the upper portion has been eroded to a considerable depth with Cisco chert conglomerates lying upon upper Hoxbar beds.

Cisco (Pontotoc) Group

Sediments assigned to the Cisco Group attain a thickness of 2,600 feet in the deeper parts of the Marietta basin. Even the lower part of the Cisco sediments is predominantly nonmarine, being composed of gray, greenish-gray, and maroon shales and cherty, conglomeratic sandstones. Upward the shales become predominantly maroon, and the conglomeratic sandstones more massive. The conglomerates in the upper part also contain arkosic pebbles, which increase in abundance northward. The Cisco Group is overlain by Early Cretaceous Comanchean strata in most of the county, pre-Cretaceous post-Cisco rocks being absent.

STRUCTURAL HISTORY

Although no wells in Love County have penetrated Cambrian rocks, it is assumed that Upper Cambrian sediments overlie Lower and possibly Middle Cambrian igneous extrusives (Carlton rhyolite). As shown on the geologic map of basement rocks in southern Oklahoma by Ham, Denison, and Merritt (1964, pl. I), Love County lies in an early down-warped geosynclinal area between the cratonic areas of the eastern Arbuckle Mountains and the Muenster-Nocona arch. Throughout Late Cambrian and Ordovician time this geosyncline continued to subside. The thickest sections of the Arbuckle, Simpson, and Viola Groups are in this area.

In Simpson time transgressing seas deposited clastics in southern Oklahoma. The seas depositing the basal Oil Creek sandstone encroached from the east, whereas those that deposited the Bromide sandstones came from an entirely different direction.

After deposition of the Hunton limestone the area was subjected to a period of uplift and erosion—the well-described pre-Chattanooga unconformity. In western Love County is a normal Hunton section, whereas in eastern Love County the upper portion is eroded and in a few wells in T. 6 S., R. 2 E., the entire Hunton has been stripped off.

It is in Meramecian time, however, that a significant uplift occurred in parts of Love County that, heretofore, had not been known in other parts of southern Oklahoma. It is probable that the entire area of the Marietta basin was uplifted to near sea level after the deposition of the Caney Shale, and, locally, areas were subjected to greater uplift which furnished the source of these Caney conglomerates. These conglomeratic beds are limited to Tps. 6, 7 S., Rs. 2, 3 E., and apparently thin toward the Ardmore basin. As in the case of the later Bostwick conglomerate the source of these conglomerates was nearby and may have been the uplifted areas shown in figure c of plate II.

There followed in Chester time a period of quiescence in the Marietta basin, although in the northeastern part of the county (and in Carter County) the area on the northeast limb of the Overbrook anticline was more or less continuously sinking. This situation continued throughout Springer time with the sea regressing northeastward. Some renewed uplift occurred in parts of the Marietta basin at or near the end of Springer time, and erosion from this orogeny furnished the Mississippian conglomeratic material found in the Jolliff and Otterville Limestones. In Morrow time the seas encroached southwestward. The basal Morrow (Primrose Sandstone) has not been found in Love County, the Jolliff Limestone being the oldest Morrowan bed. Minor pulsations occurred throughout the Morrowan as indicated by the conglomeratic character of the Otterville limestones. At the end of Morrowan time occurred the culmination of the first major Pennsylvanian orogeny (the Wichita orogeny).

The Criner Hills were folded and faulted and eroded practically to their present state at this time, as was the Muenster arch to the south. Some of the structures in the Marietta basin—for example, the Southeast Marietta field (pl. II, fig. c)—received their present configuration at that time. These uplifts furnished the coarse conglomerates in the Bostwick beds and in the Dornick Hills conglomerates on the southwest side of the Muenster arch.

Although sedimentation had been relatively continuous in the Ardmore basin and the Gordonville trough (southeast of the Marietta basin), the present Marietta basin had remained at or slightly above sea level since middle Meramecian time. Shortly after the Wichita orogeny the Marietta basin started to subside, with the seas trangressing westward from the deeper Sherman basin. In the southern part of Tps. 7, 8 S., R. 3 E., are found beds of Atokan age. These seas progressively transgressed northwestward in the deeper part of the basin throughout late Dornick Hills time, and later began spreading over the higher elevations as the Criner Hills and the peaks of the Muenster arch. However, tilting and almost continuous minor movements occurred in the basin in Deese time. The Ouachita orogeny probably contributed to this instability as it probably did as a source of the sediments.

By the end of Deese time relative quiescence had returned and continued throughout Hoxbar time. At the close of the Missourian occurred the second major orogeny—the Arbuckle uplift. The Overbrook anticline had its main orogenic movement at this time as did the West Enville field. However, some areas to the south (Southeast Marietta field) showed little effect from this diastrophism, except possibly tilting. Other areas such as the Stockton field

T. 6 S., R. 2 W., which was affected in the pre-Pennsylvanian by the Wichita orogeny, were also folded into their present anticlinal configuration in the Pennsylvanian by the Arbuckle movement. In Cisco time the Marietta basin again began sinking and received conglomerates from the uplifted Arbuckle Mountains.

An interesting feature of Love County (and southern Oklahoma) geology is the surprising amount of tilting that has occurred. On the cross section (pl. II, fig. D) the horizontal distance between the Pasotex 6 R. Brannan, Jr., Unit 1 well in sec. 25, T. 7 S., R. 2 E., and the Sinclair 1 Sanger Unit well in sec. 4, T. 7 S., R. 3 E., is approximately 26,000 feet. In addition, at least 11,000 feet of crustal shortening makes an original distance of around 37,000 feet. By the time of the Wichita orogeny the area of the Pasotex well in sec. 25, T. 7 S., R. 2 E., had been uplifted and shortly thereafter eroded down to the McLish Formation of the Simpson Group.

At that time the area of the Pasotex well was more than 6,000 feet higher structurally than the Sinclair well. However, following the Arbuckle orogeny and possibly later southwestward tilting, the strata at the Sinclair well are now structurally 1,500 feet higher than at the Pasotex well, or a counter-rotation of about 7,500 feet.

The mountainous areas of southern Oklahoma and northern Texas were rather well peneplained by Early Permian time. No sediments from Middle Permian to Cretaceous are found in Love County, and by Cretaceous time the tilt of the area had been reversed from a west-northwest direction to a south-southeast direction. Comanchean sediments were laid down over most, if not all, of Love County. After Cretaceous time the Comanchean sediments were warped into a gentle syncline, roughly conforming to the underlying Pennsylvanian syncline of the Marietta basin.

OIL AND GAS FIELDS

Introduction

The following is a list of the oil and gas fields of Love County, as shown on figure 25. Also included are the number of wells and the cumulative oil or condensate production to January 1, 1965.

Field	Number of Wells	Average Daily Production Per Well	Cumulative Production (bbls)
Enville, Southwest	30	82	2,622,033
Enville, West	6	28	479,229
Joiner City, Southeast	8	27	139,125
Leon, Northeast	9	94	305,375
Marietta, North	4	8	145,774
Marietta, Southeast	8	246	3,596,032
Marsden, East	1	6	19,257
Overbrook, South	107	4	2,873,740
Pike, North	1	8	78,263
Sivells Bend	20	9	1,433,951
Stockton	6	11	518,486
Thackerville, North	32	60	659,254
		Total	12,870,519

The South Overbrook and Stockton fields have been previously described (Hager, 1957; Reeves and Brazelton, 1961). Two of the fields are one-well fields and at present of little economic importance.

The North Marietta pool, in secs. 27, 28, 34, T. 6 S., R. 2 E., was discovered by Amerada Petroleum Corporation in 1937. Production is from fractured Viola limestone on an anticline, which is bounded on its southwest side by the major thrust zone (pl. II, fig. B). Proximity to this intense faulting was indubitably responsible for the fracturing of the Viola limestone, which in the discovery well started out flowing 220 barrels per day. Production declined rapidly and development was sporadic.

The Northeast Leon field is in secs. 28, 33, 34, T. 7 S., R. 2 W., and sec. 3, T. 8 S., R. 2 W. The structure is a gentle anticline, and production is mainly from the Taylor sand, a lower Deese

sandstone that is near the stratigraphic position of the Rasure sand of the Sivells Bend field. Because the sandstone is generally thin (less than 20 feet) and erratic, development has been rather desultory.

The Southeast Joiner City field consists of nine producing wells in Love County, in secs. 2, 3, 4, T. 6 S., R. 2 W. These wells are on the southeast end of an anticline in T. 5 S., R. 2 W., Carter County, where the major part of the field lies. Production is from fractured Woodford chert, and from the Bois d'Arc and Chimneyhill Formations of the Hunton Group.

The Southwest Enville, West Enville, and Southeast Marietta, from a productive standpoint, are by far the more important fields in Love County. They all produce the greater part of their hydrocarbons from the Oil Creek sandstone, and all can be classified as retrograde gas fields.

Southwest Enville Field

The discovery Oil Creek sandstone well was drilled by the Texas Company in NW¼ SW¼ NW¼ sec. 17, T. 7 S., R. 3 E. This discovery well was completed March 13, 1957, for a gauge of 2,530,000 cubic feet of gas and 174 barrels of condensate per day through an 11/64-tubing choke. Subsequent development quickly disclosed a complicated faulted anticline. The Texas Company 1 Rose well in NW¼ NW¼ SW¼ sec. 17, T. 7 S., R. 3 E., 0.25 mile south of the discovery well, drilled a normal section to the Oil Creek Formation, and then encountered at least three reverse faults. At a total depth of 10,017 feet subsea this well had not reached the Oil Creek sandstone, being at this point more than 2,100 feet lower structurally than the discovery well. As can be seen from the cross section (pl. II, fig. D), this faulting occurred before the deposition of the upper part of the Dornick Hills and the Deese sediments, which are tilted but not affected by this intense faulting. Repeated uplifts in this area beginning in Mississippian time resulted in an early high, eroded at least as deeply as the Hunton limestone (pl. II, fig. C).

The Southwest Enville field is actually two pools separated by the zone of thrust faulting. The portion of the field northeast of the thrust zone will be referred to as Southwest Enville shallow pool and that to the southwest as Southwest Enville deep pool.

The shallow Southwest Enville pool has ten Oil Creek sandstone retrograde gas wells and seven oil wells. The over-all thickness of the Oil Creek sandstone zone ranges from 66 to more than 150 feet and normally is thicker toward the northeast. The gas column extends over a structural height of approximately 1,200 feet, and the oil column between 600 and 700 feet, making a productive column of about 1,900 feet. Several normal faults show displacements up to about 600 feet. These faults were probably formed shortly after the main uplift and concomitant thrusting. The normal faults of greatest importance appear to be the north-south fault in sec. 1, T. 7 S., R. 2 E., and sec. 36, T. 6 S., R. 2 E., and the one in secs. 26, 34, 35, T. 6 S., R. 2 E. (pl. II, fig. B).

It is obvious that this segment between the two above-described faults is the structurally highest in the shallow Southwest Enville field. However, this sector has been practically nonproductive. The Sun Oil Company 1 Brahma well in NE¼ SW¼ SE¼ sec. 35, T. 6 S., R. 2 E., being near the west pinch-out line, had a thin section of Oil Creek sandstone which did yield a small amount of oil before the well was abandoned. The Texaco 1 Daube Trust Unit well (SE¼ SW¼ NW¼ sec. 1, T. 7 S., R. 2 E.)found the Oil Creek sandstone less than 100 feet lower (corrected depth) than the Sun well but had salt water in the same sandstone. Rather extensive asphalt deposits are in the Trinity sandstone in secs. 27 and 35, T. 6 S., R. 2 E. Is it possible that during later tilting movements, faults bounding this structural segment were rejuvenated to allow most of the entrapped hydrocarbons to escape?

In addition to the Oil Creek producers in shallow Southwest Enville, one well in SE¼ SE¼ SW¼ sec. 7, T. 7 S., R. 3 E., produces from Bromide sandstone, and five wells in secs. 17, 18, T. 7 S., R. 3 E., produce from the Sycamore limestone.

The deep Southwest Enville field consists of six Oil Creek sandstone retrograde gas producers and one oil well. Structurally, it is a relatively simple southeastward-trending anticline, which is approximately 2,800 feet lower than the shallow Southwest Enville structure. The one oil well in sec. 12, T. 7 S., R. 2 E., is doubtless separated from the gas wells by a normal fault because there is a marked difference in bottom-hole pressures. On the northeast side of the structure, wells encounter extremely thick sections as a result

of the thrust zone. The Texaco 1 Sadler Unit well, NE¼ SE¼ NE¼ sec. 13, T. 7 S., R. 2 E., had 1,955 feet of Sycamore limestone; the well in NE¼ SW¼ SE¼ sec. 12, T. 7 S., R. 2 E., had 3,820 feet of Viola, whereas the Texaco 1 Little-Green Unit well in NE¼ SW¼ NW¼ sec. 18, T. 7 S., R. 3 E., and along strike had 2,732 feet. A proven productive column of approximately 1,000 feet is in this field. The Oil Creek sandstone zone averages between 60 and 65 feet in thickness.

In addition to the Oil Creek producers, there is one Deese sand producer, the Gant 1 Liddell well, NE¼ SW¼ NE¼ sec. 13, T. 7 S., R. 2 E., which predated the Oil Creek production.

West Enville Field

The West Enville field was discovered in May 1958 by Sinclair Oil and Gas Company in its 1 Tucker well, NE¼ NW¼ SW¼ sec. 32, T. 6 S., R. 3 E.

Included in this field are parts of secs. 30, 31, 32, 33, T. 6 S., R. 3 E., and sec. 4, T. 7 S., R. 3 E. Originally there were seven Oil Creek sandstone gas-condensate wells. However, the three wells in secs. 30, 31, T. 6 S., R. 3 E., quickly went to water and were abandoned, having produced less than 2 billion cubic feet of gas. One of these wells, Pan American 1 Merrick, SE¼ NW¼ NE¼ sec. 31, T. 6 S., R. 3 E., was plugged back to the Viola limestone, where it was recompleted as an oil well.

Whereas the Southwest Enville structure is closely associated with the Criner Hills uplift, being a buried southeast extension, the West Enville structure is closely associated with the Overbrook anticline, the axis of which is fairly close to the subsurface West Enville axis.

Two prominent faults cutting Pennsylvanian beds can be found in the West Enville field (pl. II, fig. A). The northwest-southeast fault is a rather large normal fault with a displacement of from 3,000 to 3,500 feet. The north-south fault in secs. 30, 31, T. 6 S., R. 3 E., is of less magnitude but is important from a productive standpoint. To the west of it lies the segment containing the three wells that rapidly went from gas to water. Is there a relationship between this segment and the one discussed in the Southwest Enville field?

The Sinclair 1 Tucker well, NE¼ NW¼ SW¼ sec. 32, T. 6 S.,

R. 3 E., is separated from the three producing wells to the east by a strike-slip fault. This fault was interpreted from dipmeter readings in the Tucker well, which are incompatible with the structure to the east.

The West Enville anticline is more steeply folded than are the structures to the southwest, which were greatly affected by the Late Mississippian and pre-Bostwick tectonics. It is not possible to prove any appreciable early movement in the West Enville field, and it is believed its main diastrophism occurred during the Arbuckle orogenic epoch. This may account for the fact that this field has a smaller producing area and a shorter producing column than has the shallow Southwest Enville field.

Proven productive closure is about 1,100 feet in the West Enville field. No oil has been found on the edge of this field, wells going directly from gas-condensate to salt water.

Southeast Marietta Field

The Southeast Marietta field was discovered by Pasotex Petroleum, Inc. in its 1 J. C. Brannan 3 well, NW¼ NE¼ SE¼ sec. 30, T. 7 S., R. 3 E., which was completed as a basal Oil Creek sandstone well on February 13, 1958. The field consists of eleven gas-condensate wells and one oil well, which produces from a limestone in the McLish Formation. Ten of the gas-condensate wells are producing from the Oil Creek sandstone, with one, Pasotex 8 R. Brannan, Jr., Unit 1 in W½ NE¼ sec. 31, T. 7 S., R. 3 E., dually completed from both fault blocks. The other gas-condensate well, Pasotex 1 J. C. Brannan 3, Unit 2, in NE¼ sec. 25, T. 7 S., R. 2 E., found the Oil Creek sandstone nonpermeable and is producing from open hole with both the Joins and more than 1,500 feet of the Arbuckle exposed.

The Southeast Marietta field is separated from the Southwest Enville field by a normal fault with more than 1,000 feet of displacement, the Southeast Marietta field being on the downthrown side. The Southeast Marietta field was an early structural feature, having been uplifted in Late Mississippian and Early Pennsylvanian time, and eroded as deeply as the Oil Creek shale in the southern part of the pool. The structure was subsequently folded and faulted during the Wichita Mountains-Criner Hills orogeny and folded and faulted to practically its present configuration. Later movements

(pl. II, fig. D) resulted mainly in steep southwestward tilting (3,500 feet in 1.25 miles).

The field is divided into two main fault blocks separated by the north thrust fault which extends from C sec. 25, T. 7 S., R. 2 E., to approximately the center of the east line of NE¼ sec. 4, T. 8 S., R. 3 E. The sector north of this fault has been called Fault Block 1. It had a lower initial bottom-hole pressure (about 8,100 pounds) and a lower yield of condensate (from 75 to 85 barrels per million cubic feet of gas). The south block (Fault Block 2) had a considerably higher bottom-hole pressure (9,400 pounds) and a richer condensate yield (more than 100 barrels per million).

The north block consists of an anticline with transverse normal faults on its southeast end. Its south limb is developed into a complexly folded structure with a recumbent syncline (pl. II, fig. B) underneath the small thrust and intersected by the larger south thrust. This anticline shows no plunge to the west-northwest, but production is limited by the western limit of the Oil Creek sandstone deposition. The wells in NW¼ sec. 24 and NE¼ sec. 25, T. 7 S., R. 2 E., showed some westward thinning of the over-all Oil Creek sandstone section, and found the permeability too low for commercial production. One other Oil Creek sandstone producer is east of sec. 33, T. 7 S., R. 3 E., in Cooke County, Texas, and should be considered part of this field.

Because the Southeast Marietta field covers a larger area than do the other fields, the operators initiated plans for unitization and recycling early in the development of the field. Also the dew point in Fault Block 1 was approximately 6,500 pounds, whereas the initial bottom-hole pressure was appreciably higher—8,100 pounds. In the other fields of this area the dew point was close to the original bottom-hole pressure.

The Southeast Marietta field, developed on 320-acre spacing, was unitized, and recycling was started early in 1961. All the gas (except that used in plant operation) was returned to the reservoir until October 1964, when the commercial sale of gas was commenced.

Development Problems in Oil Creek Fields

Development is comparatively costly in the Love County Oil Creek fields, reaching a cost of $500,000 for a completed well in the deepest areas. Hard drilling, steep dips with the attendant difficulty of drilling straight holes, and high pressures in the Oil Creek sandstones, all contribute to making completions expensive. Casing programs also add to the expense. In most cases a short string of 20-inch or 13⅜-inch casing is run, followed by from 1,000 to 2,000 feet of 9⅝-inch or 10¾-inch casing; 7-inch casing is then usually cemented either in the Viola limestone or in or through the Oil Creek birdseye limestone; 5-inch liners are then cemented through the Oil Creek sandstone.

The Oil Creek sandstone has an average porosity of from 10.4 to 11.4 percent and a permeability of 40 to 50 millidarcys. However, the sandstone drills very hard and was often cored with diamond core heads. Initial bottom-hole pressures were all abnormally high: West Enville 6,500 pounds; Southeast Enville shallow 5,500 pounds; Southwest Enville deep 6,800 pounds; and Southeast Marietta 8,100 and 9,400 pounds.

The gas is gathered by the Cimarron Transmission Company and delivered to the Natural Gas Pipeline Company of America in western Love County for interstate shipment. Cumulative gas production from the West Enville and Southwest Enville fields through June 1964 was 24,675,000,000 cubic feet.

Sivells Bend Field

The other two oil fields of Love County, Sivells Bend and North Thackerville, are closely related to fields across the Red River in Cooke County, Texas. Consequently figure 27 is a structural map covering the area of these fields on both sides of the river. It is contoured on the base of the Rocky Point Conglomerate, because this is the lowermost datum that can be consistently correlated over the entire map area. Also it closely resembles maps made on horizons lower in the Deese Group.

The Oklahoma part of the Sivells Bend field was discovered several years after the Texas part. The California Company opened the Oklahoma pool with its 1 Wright well, NE¼ NW¼ sec. 13, T. 8 S., R. 1 W., in 1946. The field has been developed on a 40-acre spacing pattern and has 22 producing oil wells in secs. 10, 11, 12, 13, T. 8 S., R. 1 W. The main producing horizon is the Beasley sand which is also the most prolific production zone in the Texas Sivells Bend field. The Beasley sand is found between −5,830 feet and −5,937 feet subsea, and has a thickness generally between 20 and 50 feet. The Ryan sands 300 to 400 feet above the Beasley are productive in a few wells high on structure, but are water-bearing downdip. No wells have penetrated the Arbuckle limestone in the Oklahoma Sivells Bend field, but the Standard Oil Company of Texas 1 Evans-Baum Unit well in the Evans Bend field, about 0.5 mile west of the Oklahoma state line, went from Pennsylvanian sediments into the McLish Formation and drilled about 400 feet of Arbuckle. Total depth of this well was 9,300 feet.

The Sivells Bend and Evans Bend fields are on the south flank of the Marietta basin and the north flank of the Muenster-Nocona arch. They can be described as a relatively simple, gentle, sprawling anticline, bounded by faults on the south and north sides (fault zones A and B on fig. 27). The zone on the south side, fault zone A, consists of two more or less parallel normal faults, the southernmost one downthrown to the north, and the northern one downthrown to the south, forming a narrow but extremely complex graben. On the south side of the Texas Sivells Bend field the north fault has a displacement of 900 feet but to the east the throw is less than 100 feet in some places. The normal fault zone on the north side of these fields, fault zone B, is downthrown to the north, toward the axis of the Marietta basin. Displacement of this fault zone is from 500 to 600 feet on the base of the Rocky Point Conglomerate and from 700 to 800 feet on the Beasley sand.

This area was uplifted in Late Mississippian-Early Pennsylvanian time, probably contemporaneously with the Southwest Enville-Southeast Marietta field area, and eroded down to rocks of the Simpson Group before the deposition of Pennsylvanian sediments. Uppermost Dornick Hills or lower Deese sediments covered this eroded surface, followed by transgressing and regressing early Deese seas on a gently oscillating mobile area. In late Deese and Hoxbar time the area was more stable and deposition more regular. After the end of Missourian time, the area was folded and faulted during the Arbuckle orogeny.

North Thackerville Field

The discovery of the North Thackerville field was due largely to the persistent efforts of T. I. Sanders. He was instrumental in promoting and participating in many wildcat failures in the

Thackerville area. However, a successful venture in which he had an interest, the Britton 1 Smith-McGeehee well in SE¼ NE¼ sec. 25, T. 8 S., R. 1 E., opened the North Thackerville field. This well was completed January 26, 1961, from the Dillard sand from 7,310 to 7,350 feet, flowing 120 barrels of oil in 6 hours through a 20/64-inch tubing choke.

This field lies on a structural terrace, where the relatively steep dip from the North Walnut Bend field flattens. Early Deese seas spread sands, some as irregularly shaped bars, in this area. The gentle dip continues westward and this area could also be considered a flat, basinlike area between the anticlines to the west and east. The two graben-forming faults discussed previously at Sivells Bend are present on the south side of the field. The south fault (fig. 27), at least on the Rocky Point datum, has the larger throw, being downthrown some 1,000 feet to the north. The north fault shows on this datum some 100 feet of throw. Figure 28 shows the structure of the field contoured on the Daube Limestone. The north fault increases in throw with depth and the fault bifurcates. The upper branch of this fault at the Rocky Point Conglomerate is the one shown on figure 27. The west extension is different in the two maps. The west end of the fault on the Rocky Point datum is where the upper branch of the fault joins another fault that dies out before reaching the Daube horizon. The lower branch of the fault may cut the pre-Pennsylvanian in the Texaco 1 Wilson well, SW¼ SW¼ sec. 30, and the Stephenson 1 Haralson well, NE¼ SW¼ SE¼ sec. 30, T. 8 S., R. 2 E. Figure 28 also shows the pre-Pennsylvanian paleogeology. One surprising facet of this map shows the present downthrown side of the south fault with the much more deeply eroded pre-Pennsylvanian sediments. Obviously, the present downthrown side was the upthrown side in pre-Bostwick time. The opposite movements on the same fault plane is comparable to the tilting in opposite directions in the Enville area.

The faults bordering the graben were active in early Deese time. The area of the three producing wells in S½ sec. 25, T. 8 S., R. 1 E., was involved in this early movement. On the base of the Pennsylvanian these wells are about 700 feet lower than wells to the north, and more than 2,000 feet lower than the well in NE¼

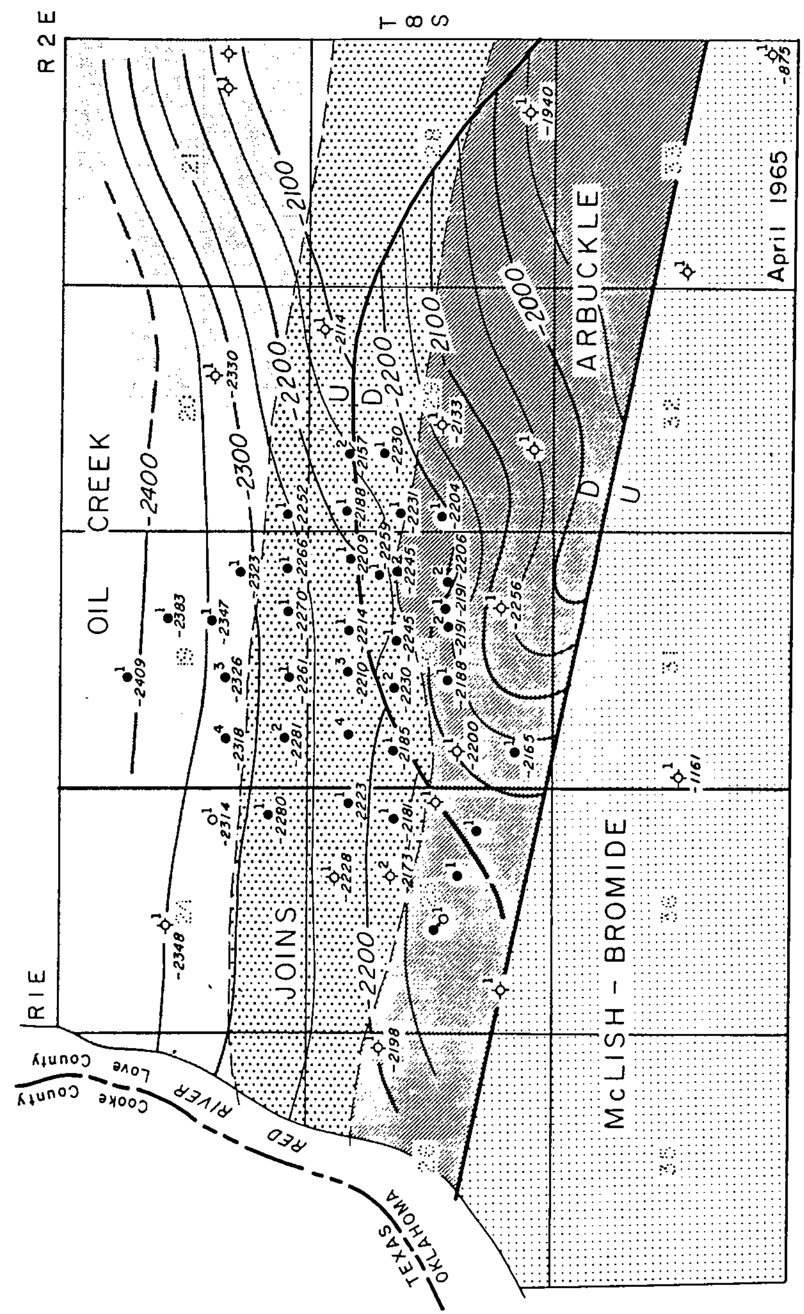


Figure 28. Structure and paleogeologic map of North Thackerville field, contoured on top of Daube Limestone. Contour interval, 50 feet.

SW¼ SW¼ sec. 25, T. 8 S., R. 1 E. Deposition in early Deese time in this narrow depression was at a greater rate than in the high areas, and by Rocky Point time it appeared as only a small depression (fig. 27). Before the discussion of peculiar faulting in this area is concluded, one more fault must be mentioned. The Huber 1 Welch well, SW¼ NW¼ NE¼ sec. 30, T. 8 S., R. 2 E., found the base of the Pennsylvanian and top of the Joins dolomite at 7,805 feet, and the top of the Arbuckle limestone at 7,890 feet. At 7,940 feet this well drilled through a reverse fault, going into Simpson (probably Oil Creek) shale which it drilled to the total depth of 8,287 feet. This fault with at least several hundred feet of throw is not in itself unique. But it is odd that none of the nearby wells, all of which were drilled into Ordovician sediments, encountered this fault and that no evidence of it shows on the paleogeologic map. The Joins dolomite production is at present in the N½ N½ sec. 30, the extreme northeast corner of sec. 25, the southeast corner of sec. 24, and the southwest corner of sec. 19. This fault may be responsible for the development of better porosity and permeability. On the other hand, all of these wells had Joins exposed beneath the Pennsylvanian cover.

Development has been on a 40-acre spacing pattern with many wells dually completed and with some triple completions. At this time the field has 36 producing oil wells. Figure 29 shows an electric log with the main producing zones represented. As of this time two wells produce from or have tested the Arbuckle limestone, seven wells produce from the Joins dolomite, twenty from the basal Pennsylvanian conglomerate, eight from the Foster sand, seven from the Welch sand, and thirteen from the Dillard sand. Two of the wells in the graben area in S½ sec. 25 are producing from the Sanders sand, a sandstone limited to this area. The Texaco 1 Wilson well, SW¼ SW¼ sec. 30, T. 8 S., R. 2 E., made a small producer from a sandstone tentatively identified as equivalent to the Snuggs sand of Walnut Bend.

It should be noted that the main pays of this field are lower stratigraphically than those of Sivells Bend with the exception of the Dillard sand, which occurs only around the east edge of Sivells Bend. These lower sandstones are off-lapped updip to the east and grade into limestone to the west, so it is evident that the North Thackerville field is largely a stratigraphic-type oil pool.

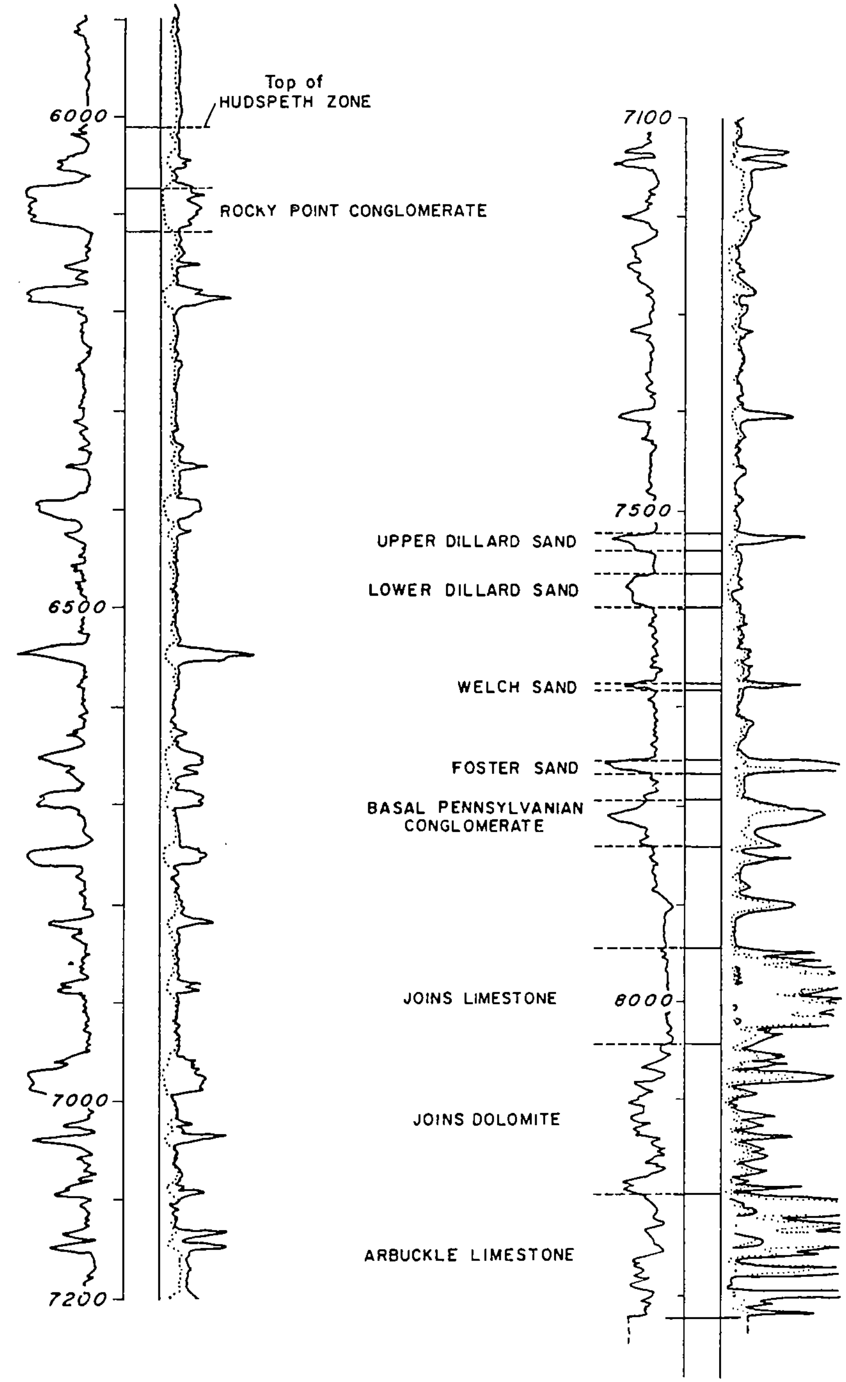


Figure 29. Electric log showing producing sections in the North Thackerville field. Log is of the J. M. Huber Corp. 1 Foster well, SE¼ SW¼ SE¼ sec. 19, T. 8 S., R. 2 E. GL elevation, 884 feet; TD, 8,329 feet.

East Sivells Bend Field

Less than 2 miles west of the North Thackerville pool, but in Cooke County, Texas, J. M. Huber in 1964 opened the East Sivells Bend field. At present five wells are producing and one is dry. One of the wells is producing from the Dillard sand and the other four from the Arbuckle limestone. Production in the Arbuckle is from 150 to 250 feet below the top of the West Spring Creek Formation and comes primarily from thin sandstones or arenaceous limestones. All the logs from this field are not available at this time, so the structure is not discussed.

PENNSYLVANIAN OIL ACCUMULATION

Before the conclusion of this paper, a few comments relative to the accumulation of oil in the Marietta basin and its borderlands are apropos. The Stockton pool, near the axis of the Marietta basin, produces from lower Deese sandstones well below the Rocky Point Conglomerate. The same condition is true on the line of fields, from Sivells Bend to North Walnut Bend, but south of the fault bounding these fields on the south, in the Bob K and Walnut Bend fields, production is found not only in the lower Deese but also in sandstones correlated with the Chubbee sand or top of the Deese Group. Likewise, in other fields on the flanks of the basin, production is found in upper Deese sandstones. For example, the Illinois Bend field of Montague County, Texas, on the south limb and the West Brock and Southwest Lone Grove fields in T. 5 S., R. 1 W., Carter County, on the north flank. Toward the axis of both the Muenster-Nocona arch and the Wichita Mountains-Criner Hills trend production is found from Hoxbar sediments and even from Cisco sediments on the highest structures.

As has been noted previously, the lower Deese sandstones are relatively lenticular, having a limited areal extent. By the time of Rocky Point (Hudspeth zone) deposition, conditions of sedimentation were more stable and the main sandstone zones, although locally variable, can be traced throughout the basin. Consequently, oil that was entrapped in the lower Deese sandstones could not migrate far and would be localized in structural or stratigraphic traps. But oil in upper Deese and younger porous sediments would have been free to migrate out of the deeper parts of the geosyncline, later to be confined to local structures. Had there been some localization of petroleum in upper Deese or younger beds, later tilting would probably have allowed it to migrate updip. The hydrocarbons in the younger Pennsylvanian sediments would have migrated into the highest areas because by Hoxbar time most of the anticlinal areas had been inundated by the advancing seas.

REFERENCES

ADKINS, W. S., and ARICK, M. B., 1930, Geology of Bell County, Texas: Texas, Univ., Bull. 3016, 92 p.

BRADFIELD, H. H., 1957a, The petroleum geology of Grayson County, Texas, *in* The geology and geophysics of Cooke and Grayson Counties, Texas: Dallas Geol. Soc. and Dallas Geophys. Soc., p. 15-49.

————1957b, Subsurface of Cooke County, Texas, *in* The geology and geophysics of Cooke and Grayson Counties, Texas: Dallas Geol. Soc. and Dallas Geophys. Soc., p. 75-98.

————1959, Petroleum geology of Grayson County, Texas, *in* Petroleum geology of southern Oklahoma, vol. II: Tulsa, Amer. Assoc. Petroleum Geologists, p. 53-100.

BRADFIELD, H. H., SEALE, R. I., and PATTERSON, A. B., 1957, Selected oil fields, Cooke County, Texas, *in* The geology and geophysics of Cooke and Grayson Counties, Texas: Dallas Geol. Soc. and Dallas Geophys. Soc., p. 100-129.

BRANSON, C. C., BURWELL, A. L., and CHASE, G. C., 1955, Uranium in Oklahoma, 1955: Okla. Geol. Survey, Mineral Rept. 27.

BULLARD, F. M., 1925, Geology of Love County, Oklahoma: Okla. Geol. Survey, Bull. 33, 76 p.

————1926, Geology of Marshall County, Oklahoma: Okla. Geol. Survey, Bull. 39, 101 p.

————1928, Lower Cretaceous of western Oklahoma: Okla. Geol. Survey, Bull. 47, 116 p.

BUNN, J. R., 1930, Jefferson County, *in* Oil and gas in Oklahoma: Okla. Geol. Survey, Bull. 40-PP., 43 p., *also in* Bull. 40, vol. 2, p. 341-381 (1930).

CURTIS, N. M., JR., and HAM, W. E., 1957, Physiographic map of Oklahoma: Okla. Geol. Survey, Educ. Ser. Map 4.

ELIAS, M. K., 1956, Upper Mississippian and Lower Pennsylvanian formations of south-central Oklahoma, *in* Petroleum geology of southern Oklahoma, vol. I: Tulsa, Amer. Assoc. Petroleum Geologists, p. 56-134.

FORGOTSON, J. M., JR., 1957, Stratigraphy of the Comanchean Cretaceous Trinity group: Amer. Assoc. Petroleum Geologists, Bull., vol. 41, p. 2328-2363.

————1963, Depositional history and paleotectonic framework of Comanchean Cretaceous Trinity Stage, Gulf Coast area: Amer. Assoc. Petroleum Geologists, Bull., vol. 47, p. 69-103.

FREDERICKSON, E. A., 1957, Geologic map of the Criner Hills area, Oklahoma: Okla. Geol. Survey, Map GM-4.

FRYE, J. C., and LEONARD, A. B., 1963, Pleistocene geology of Red River basin in Texas: Texas, Univ., Bur. Econ. Geology, Rept. Inv. 49, 48 p.

HAGER, G. G., 1957, South Overbrook field, *in* Criner Hills field conference: Ardmore Geol. Soc., Guidebook, p. 30-31.

HAM, W. E., 1963, Basement rocks and structural evolution of southern Oklahoma: Ardmore Geol. Soc., Field Conf. Guidebook, 51 p.

HAM, W. E., DENISON, R. E., and MERRITT, C. A., 1964, Basement rocks and structural evolution of southern Oklahoma: Okla. Geol. Survey, Bull. 95, 302 p. (plates I-V also appear in Ham, 1963, above).

HARLTON, B. H., 1960, Stratigraphy of Cement pool and adjacent area, Caddo and Grady Counties, Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 44, p. 210-226.

HAZZARD, R. T., 1939, Notes on the Comanche and pre-Comanche? Mesozoic formations for the Ark-La-Tex area, and a suggested correlation with northern Mexico, *in* Upper and Lower Cretaceous of southwest Arkansas: Shreveport Geol. Soc., Guidebook, 14th Ann. Field Trip, p. 155-165.

HICKS, I. C., and others, 1956, Petroleum geology of southern Oklahoma, vol. I: Tulsa, Amer. Assoc. Petroleum Geologists, 402 p.

HILL, R. T., 1887, The Texas section of the American Cretaceous: Amer. Jour. Science, vol. 134, p. 287-309.

————1891, The Comanche series of the Texas-Arkansas region (with discussion by C. A. White and others): Geol. Soc. America, Bull., vol. 2, p. 503-528.

————1893, The paleontology of the Cretaceous formations of Texas; the invertebrate paleontology of the Trinity division: Biol. Soc. Washington, D. C., Proc., vol. 8, p. 9-40.

————1894, Geology of parts of Texas, Indian Territory and Arkansas adjacent to Red River region: Geol. Soc. America, Bull., vol. 5, p. 297-338.

————1901, Geography and geology of the Black and Grand prairies, Texas: U. S. Geol. Survey, 21st Ann. Rept., pt. 7, 666 p.

HILSEWECK, W. J., 1941, Walnut Bend pool, Cooke County, Texas, *in* Levorsen, A. I., ed., Stratigraphic type oil fields: Tulsa, Amer. Assoc. Petroleum Geologists, p. 776-805.

IMLAY, R. W., 1944, Correlation of Lower Cretaceous formations of the Coastal Plain of Texas, Louisiana, and Arkansas: U. S. Geol. Survey, Oil and Gas Inv. Prelim. Chart 3.

JORDAN, LOUISE, 1964, Petroleum-impregnated rocks and asphaltite deposits of Oklahoma: Okla. Geol. Survey, Map GM-8.

LARKIN, PIERCE, 1909, A preliminary report on the Cretaceous of Oklahoma: Okla., Univ., unpublished Bachelor of Arts thesis.

LOZO, F. E., 1944, Biostratigraphic relations of some north Texas Trinity and Fredericksburg (Comanchean) foraminifers: Amer. Midland Naturalist, vol. 31, p. 513-582.

————1949, Stratigraphic relations of Fredericksburg limestones, north-central Texas, *in* Cretaceous of Austin, Texas, area: Shreveport Geol. Soc., Guidebook, 17th Ann. Field Trip, p. 85-91.

————1959, Stratigraphic relations of the Edwards limestone and associated formations in north-central Texas, *in* Symposium on Edwards limestone in central Texas: Texas, Univ., Pub. 5905, p. 1-19.

MARCOU, JULES, 1856, Resumé and field notes, No. 2 *of* Report on the geology of the route, Pt. IV *of* Reports of explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, vol. 3: U. S. 33d Cong., 2d sess., Senate Exec. Doc. 78, p. 121-175.

MCBEE, W. D., JR., and VAUGHN, L. G., 1956, Oil fields of the central Muenster-Waurika arch, Jefferson County, Oklahoma, and Montague County, Texas, *in* Petroleum geology of southern Oklahoma, vol. I: Tulsa, Amer. Assoc. Petroleum Geologists, p. 355-372.

MISER, H. D., 1927, Lower Cretaceous (Comanche) rocks of southeastern Oklahoma and southwestern Arkansas: Amer. Assoc. Petroleum Geologists, Bull., vol. 11, p. 443-453.

__________1954, Geological map of Oklahoma: Okla. Geol. Survey and U. S. Geol. Survey.

O'HERAN, W. B., 1957, Notes on the Southwest Enville field, T. 7 S., R. 3 E., Love County, Oklahoma, *in* Criner Hills field conference: Ardmore Geol. Soc., Guidebook, p. 40-41.

PERKINS, B. F., 1960, Biostratigraphic studies in the Comanche (Cretaceous) Series of northern Mexico and Texas: Geol. Soc. America, Mem. 83, 138 p.

PREWIT, B. N., 1961, Subsurface geology of the Cretaceous coastal plain, southern Oklahoma: Okla., Univ., unpublished Master of Science thesis.

RAMAY, C. L., 1957, Clarification of Desmoinesian stratigraphy in the Criner Hills: Okla., Univ., unpublished Master of Science thesis.

REDFIELD, J. S., 1929, Differentiation of the Bokchito formation, Love County, Oklahoma: Okla., Univ., unpublished Master of Science thesis.

REED, B. K., 1959, Pre-Atokan unconformity of portions of Love and Carter Counties, Oklahoma, *in* Petroleum geology of southern Oklahoma, vol. II: Tulsa, Amer. Assoc. Petroleum Geologists, p. 127-141.

REEVES, C. C., JR., and BRAZELTON, W. F., 1961, The Stockton field—Key to the Marietta basin?: Okla. Geol. Survey, Okla. Geology Notes, vol. 21, p. 118-127.

ROEMER, F. V., 1852, The Cretaceous formations of Texas and their organic remains, with an appendix containing a description of Paleozoic and Tertiary fossils: Bonn, Germany, Adolph Marcus, 100 p.

SCOTT, GAYLE, and ARMSTRONG, J. M., 1932, The geology of Wise County, Texas: Texas, Univ., Bull. 3224, 77 p.

SHANNON, C. W., and others, 1917, Love County, *in* Petroleum and natural gas in Oklahoma: Okla. Geol. Survey, Bull. 19, pt. 2, p. 305-314.

SHELBURNE, O. B., 1959, A stratigraphic study of the Kiamichi formation in central Texas, *in* Symposium on Edwards limestone in central Texas: Texas, Univ., Pub. 5905, p. 105-130.

SHELL OIL COMPANY, 1957, Geologic map, southern Ardmore basin, Carter County, Oklahoma, *in* Criner Hills field conference: Ardmore Geol. Soc., Guidebook, pocket.

SHUMARD, B. F., 1860, Observations upon the Cretaceous strata of Texas: Acad. Science St. Louis, Trans., vol. 1, p. 582-590.

SHUMARD, G. G., 1854, Remarks upon the general geology of the country passed over by the exploring expedition to the sources of Red River, *in* Marcy, R. B., Exploration of the Red River of Louisiana in the year 1852: U. S. 33d Cong., 1st sess., Senate Exec. Doc., p. 167-190.

STEPHENSON, L. W., 1918, A contribution to the geology of northeastern Texas and southern Oklahoma: U. S. Geol. Survey, Prof. Paper 120-H, p. 129-163.

STEPHENSON, L. W., KING, P. B., MONROE, W. H., and IMLAY, R. W., 1942, Correlation of the outcropping Cretaceous formations of the Gulf Coastal Plain and trans-Pecos Texas: Geol. Soc. America, Bull., vol. 53, p. 435-448.

TAFF, J. A., 1902, Description of the Atoka quadrangle [Indian Terr.]: U. S. Geol. Survey, Geol. Atlas, Folio 79.

__________1903, Description of the Tishomingo quadrangle [Indian Terr.]: U. S. Geol. Survey, Geol. Atlas, Folio 98.

THOMPSON, S. A., 1935, Fredericksburg Group of Lower Cretaceous with special reference to north-central Texas: Amer. Assoc. Petroleum Geologists, Bull., vol. 19, p. 1508-1536.

TOMLINSON, C. W., 1929, The Pennsylvanian System in the Ardmore basin: Okla. Geol. Survey, Bull. 46, 79 p.

TOMLINSON, C. W., and MCBEE, W. D., JR., 1959, Pennsylvanian sediments and orogenies of Ardmore district, Oklahoma, *in* Petroleum geology of southern Oklahoma, vol. II: Tulsa, Amer. Assoc. Petroleum Geologists, p. 3-52.

VANDERPOOL, H. C., 1928, A preliminary study of the Trinity Group in southwestern Arkansas, southeastern Oklahoma, and northern Texas: Amer. Assoc. Petroleum Geologists, Bull., vol. 12, p. 1069-1094.

__________1933, Upper Trinity microfossils from southern Oklahoma: Jour. Paleontology, vol. 7, p. 406-411.

WALKER, K. F., and MARKLEY, L. C., 1957, Northeast Greenville field, Love County, Oklahoma, *in* Criner Hills field conference: Ardmore Geol. Soc., Guidebook, p. 32-36.

WESTHEIMER, J. M., 1936, Correlation of Pennsylvanian sediments of the Ardmore basin with the Franks graben, *in* Conference on Pennsylvanian of Oklahoma, Kansas, and north Texas: Sigma Gamma Epilson, mimeographed proceedings, unnumbered pages.

__________1948, Diagrammatic sections showing development of the Overbrook anticline, *in* Study of Pennsylvanian formations, Ardmore area, Oklahoma: Ardmore Geol. Soc., Guidebook, Field Conf., June 18-19, p. 11-12.

WESTHEIMER, J. M., and SCHWEERS, F. P., 1956, Southwest Lone Grove field, Carter County, Oklahoma, *in* Petroleum geology of southern Oklahoma, vol. I: Tulsa, Amer. Assoc. Petroleum Geologists, p. 144-153.

WINTON, W. M., and ADKINS, W. S., 1919, The geology of Tarrant County: Texas, Univ., Bull. 1931, 123 p.

APPENDIX TO PART I

MEASURED SECTIONS

LA-1. ANTLERS FORMATION. SE¼ SE¼ sec. 31, T. 6 S., R. 2 E.; 3.2 miles north of Marietta, on U. S. Highway 77 in road cut.

	Feet
Goodland Formation	
Antlers Formation	
Shales, gray to red, 0.1 to 0.5 feet thick; sandstones, buff to red, poorly cemented, 0.5 to 2.0 feet thick	25.0
Sandstone, gray, hard, concretionary; yellow sulfur on weathered surface	0.2
Sand, shaly, gray to buff	11.0
Sandstone, buff to white; shaly sandstone; lower 3.0 feet contains numerous red ferruginous lenses	13.3
Base of exposed section	
Measured total	49.5

LA-2. ANTLERS FORMATION. NW¼ NW¼ sec. 27, T. 6 S., R. 2 E.; on east side of U. S. Highway 77 (Scenic) road cut. Section is incomplete.

	Feet
Top of exposed section (soil profile)	
Antlers Formation	
Sandstone, buff to red, friable to well-indurated, ferruginous; locally concretionary	21.0
Sandstone, red, well-indurated, ferruginous; locally cross-bedded	2.8
Sandstone, shaly, buff to red; containing many ferruginous concretions	7.0
Sandstone, buff to red; locally an orthoquartzite	7.0
Base of exposed section	
Measured total	37.8

LW-1. UPPER PART OF ANTLERS FORMATION AND WALNUT FORMATION. SW¼ sec. 36, T. 6 S., R. 1 W.; north side of E-W section-line road at base of Goodland escarpment. Section measured along road ditch. Measured by Logan L. Urban and Andrew J. Robinson.

	Feet
Goodland Formation	
Antlers Formation (Fredericksburg)	
Clay, orange-tan to brown, marly, silty	1.9
Sand, tan, fine, friable, clayey	0.5
Silt, dark-gray, orange- and white-mottled, sandy	1.5
Silt, dark-gray, sandy; interbedded thin yellow ferruginous sandstone beds	2.0
Sandstone, gray, silty; 0.5-inch zone of white marl at base	0.6
Sandstone, gray, orange-streaked, silty, clayey	0.8
Siltstone, light-gray, clayey	0.2
Shale, buff, laminated, waxy	0.6
Limestone, white, marly	1.4
Sandstone, light-gray, silty, clayey, friable	0.6
Clay, dark-gray	0.2
Sandstone, gray, orange-mottled, silty; clayey white marl nodules	2.4
Clay, dark-brown	0.1
Sandstone, maroon	1.2
Sandstone, gray to buff, orange-streaked, clayey; thin gray clay lenses	2.6
Sandstone, tan, hard	1.0
Sandstone, gray; interbedded thin shale zones	1.5
Sandstone, gray to buff, cross-bedded; ferruginous concretions	2.5
Total upper Antlers Formation	21.6
Walnut Formation	
Limestone, gray to buff, sandy, fossiliferous; platy fracture, ledge former	3.2
Total Walnut Formation	3.2
Antlers Formation (Trinity)	
Sandstone, gray, fine, silty, clayey, fossiliferous; limestone nodules	3.5

W-2. UPPER PART OF ANTLERS FORMATION AND WALNUT FORMATION. NW¼ sec. 19, T. 7 S., R. 1 E. Exposure of Walnut limestone in bed of creek south of State Highway 32. Antlers Formation measured at base of Goodland Limestone exposed on east. Measured by Logan L. Urban and Andrew J. Robinson.

	Feet
Goodland Limestone	
Antlers Formation (Fredericksburg)	
Clay, brown to gray, silty; calcareous nodules	0.6
Siltstone, gray, clayey; reddish-orange at top	1.0

	Feet
Clay, gray, orange-mottled	0.7
Sand, gray, silty; orange stringers; 2-inch clay seam 3 inches above base	1.3
Siltstone, gray, poorly cemented; 2-inch clay zone at top	1.1
Sand, gray, silty; orange at top	1.0
Covered interval; easily eroded	10.7
Total upper Antlers Formation	16.4
Walnut Formation	
Limestone, buff, coarsely crystalline, fossiliferous, sandy	1.5
Limestone, gray; shell bed	1.5
Shale, gray	1.0
Limestone, gray; shell bed as above	1.5
Shale, gray	0.4
Marl, buff, fossiliferous	1.0
Total Walnut Formation	6.9

LG-3. GOODLAND FORMATION. SW¼ SW¼ sec. 16, T. 7 S., R. 1 E.; on east bank of Rock Creek, about 30 yards north of State Highway 32. Section is continuously exposed in vertical bluff above stream; overlain by soil (Kiamichi?).

	Feet
Kiamichi Formation	
Goodland Formation	
Bed 1	
Limestone, massive, white to gray, fossiliferous; exhibits conchoidal exfoliation fractures	1.0
Shale, brown	0.1
Limestone, massive, white, fossiliferous; contains solution cavities filled with brown calcite	3.1
Bed 2	
Shale, gray	0.1
Limestone, massive to nodular, white, fossiliferous	3.5
Shale, white to brown; platy limestone	0.6
Shale, dark-gray	0.1
Bed 3	
Limestone, white to gray, fossiliferous	6.1
Limestone, white, fossiliferous, shaly	1.0
Limestone, massive, white, fossiliferous; slightly argillaceous	4.5
Bed 4	
Limestone, nodular, white, fossiliferous; lower 0.2 foot slightly sandy; lower contact sharp and regular and marked by yellow sulfur on weathered surface	2.4

	Feet
Antlers Formation	
Clay, marly, brown	0.4
Measured total	22.9

LK-1. KIAMICHI FORMATION. NE¼ SW¼ sec. 5, T. 7 S., R. 2 E.; from east side of Jerry Branch tributary to top of hill.

	Feet
Caddo Limestone	
Kiamichi Formation	
Limestone, gray to buff; oyster-shell coquina; dip irregular due to slumping	0.8
Shale, gray to brown; interbedded with thin limestone and sandy limestone	27.6
Limestone and sandy limestone, brown, crystalline	0.1
Goodland Formation	
Measured total	28.5

LC-1. CADDO LIMESTONE. SW¼ SW¼ sec. 15, SE¼ SE¼ sec. 21, T. 8 S., R. 2 E. A composite section along bluffs of Horseshoe Bend on the northwest side of Red River. The entire section is fossiliferous. Incomplete section.

	Feet
Denton Clay	
Caddo Limestone	
Limestone, marly, yellow to buff; interbedded with thin buff calcareous shale; limestone predominant (80 percent)	10.0
Shale , marly gray	5.0
Shale, gray; interbedded with white limestone 0.2 to 0.9 foot thick; shales predominant (75 percent)	20.0
Limestone, white, ledge-forming; approximate base of Fort Worth equivalent	1.5
Shale, gray; interbedded with white limestone; shale 60 percent	20.0
Limestone, gray to buff	1.3
Shale, gray; interbedded with gray limestone; shale 85 percent	26.0
Limestone, gray; interbedded with thin gray shale; ledge former	2.0
Shale, gray; several thin limestones	19.1
Limestone, gray; interbedded with shale, shale 50 percent; this horizon contains many large ammonities; ledge former	8.2

	Feet
Water level of Red River	
Measured total	113.1

LD-2. DENTON CLAY. SW¼ SW¼ sec. 13, T. 8 S., R. 2 E.; on bluff on the northeast side of Red River. Same location as measured section LWE-1 (Weno Clay).

	Feet
Weno Clay	
Denton Clay	
Limestone, shaly, gray, fossiliferous	0.8
Limestone, platy, gray to tan; calcareous shale; extremely fossiliferous	4.0
Sandstone, buff, poorly indurated; contains thin ferruginous lenses	2.3
Limestone, sandy, red; interbedded with gray shales	31.0
Limestone, gray, hard, fossiliferous	0.1
Sandstone, ferruginous; interbedded with gray shale	13.0
Limestone, platy, buff, argillaceous, fossiliferous	0.8
Sandstone, red, thin-bedded; interbedded with thick gray shales	15.9
Shale, gray, fossiliferous, calcareous	2.5
Caddo Limestone	
Measured total	70.4

LWE-1. WENO CLAY. SW¼ SW¼ sec. 13, T. 8 S., R. 2 E.; on bluff on northeast side of Red River. Same location as measured section LD-2 (Denton Clay).

	Feet
Soil profile	
Weno Clay	
Limestone, brown, fossiliferous, crystalline; "Quarry limestone" of Hill	2.0
Shale, gray; interbedded with red ferruginous sandstones; sandstones contain ferruginous concretions	10.0
Shale, gray, calcareous, fossiliferous	1.0
Shale, gray; interbedded with red ferruginous sandstone; sandstones contain more concretions than above; about 13.0 feet from top are several thin gypsum beds	29.0
Limestone, sandy, red, fossiliferous	0.3
Denton Clay	
Measured total	42.3

LP-1. PAWPAW SAND. SE¼ SW¼ sec. 34, T. 7 S., R. 2 E.; on south slope of hill capped by the Main Street Formation; north of the county road. Same locality as measured section LM-2 (Main Street Formation).

	Feet
Main Street Formation	
Pawpaw Sand	
Sandstone, buff to red; interbedded with gray to yellow shales and clays; sandstones are from 0.5 to 1.5 feet thick; near middle of this interval are several dark-red ferruginous sandstones, well-indurated and extremely fossiliferous; fossils have been replaced by ferruginous material	36.0
Limestone, sandy, gray, fossiliferous	0.7
Shale, gray to red; interbedded with thin red sandstones; many of the sandstones contain yellow to red ferruginous concretions	16.0
Weno Clay	
Measured total	52.7

LM-1. MAIN STREET FORMATION. NE¼ SW¼ sec. 34, T. 7 S., R. 2 E. Same locality as measured section LP-1 (Pawpaw Sand). Incomplete section.

	Feet
Main Street Formation (eroded top)	
Limestone, sandy, buff to yellow, fossiliferous; this unit is about 30.0 feet thick east of this locality in Marshall County; this is the thickest section in Love County	13.2
Pawpaw Sand	
Measured total	13.2

INDEX

(*Italic number* indicates main reference)

ERRATA

Figure 3: Bochito Fm. *should read* Bokchito Fm.

Figure 27: Sivels *should read* Sivells

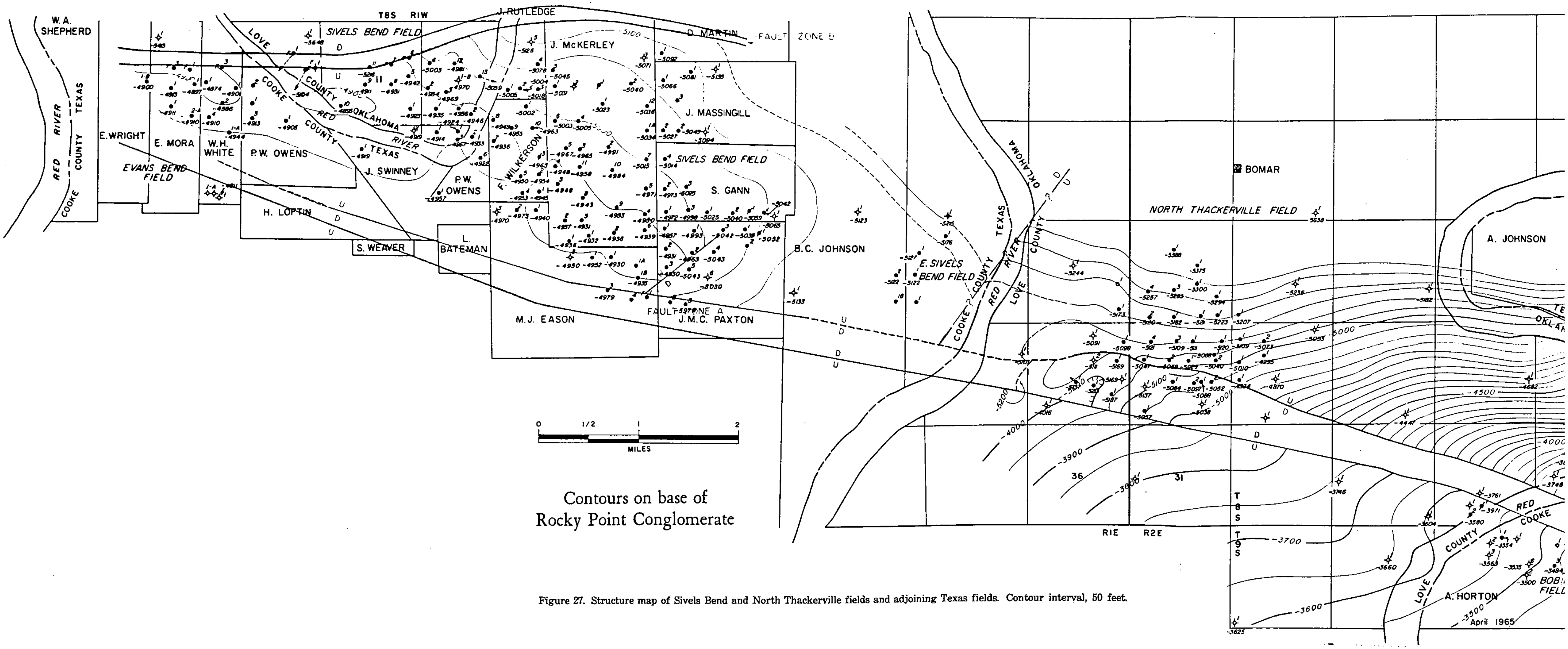
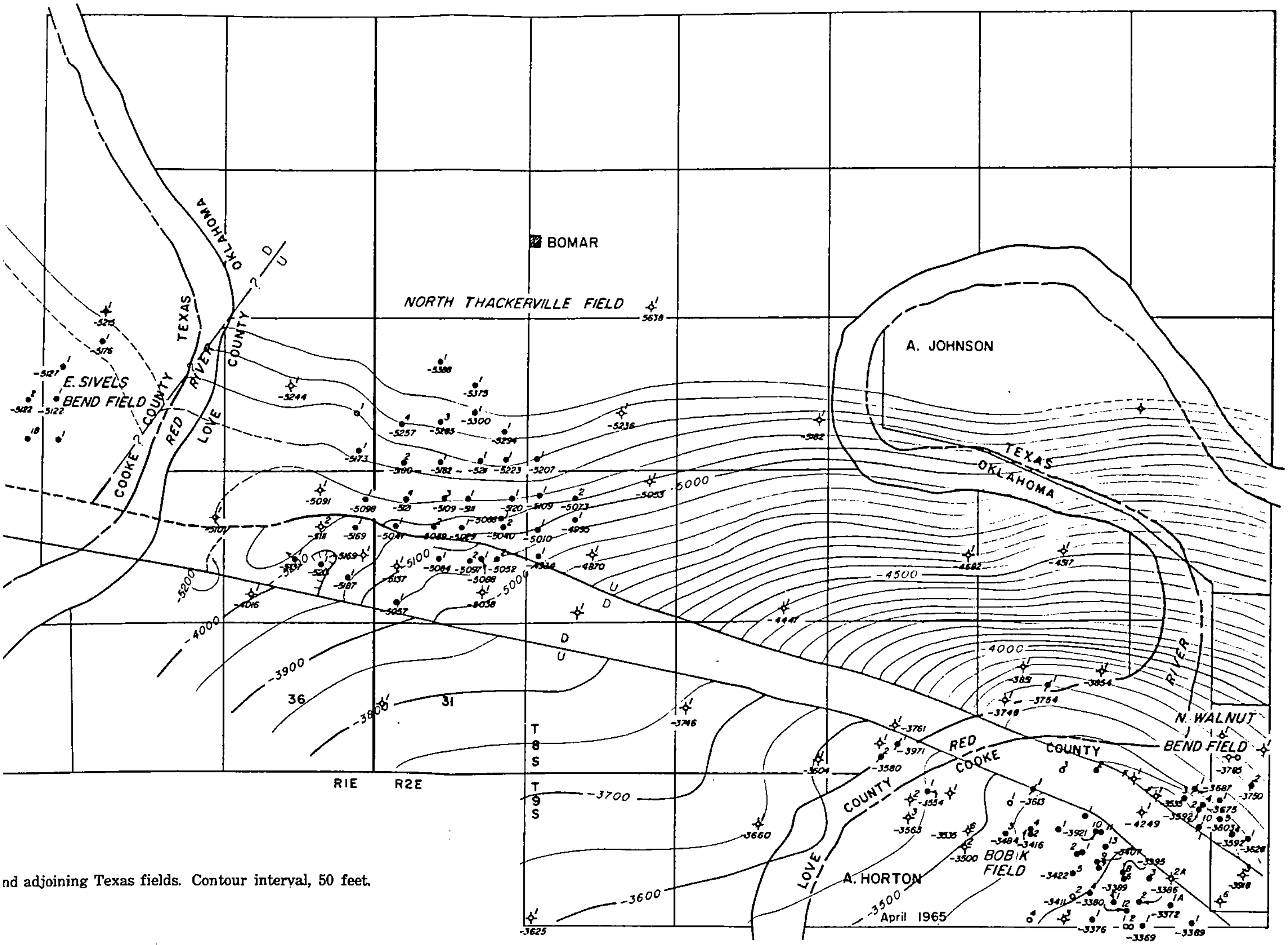


Figure 27. Structure map of Sivels Bend and North Thackerville fields and adjoining Texas fields. Contour interval, 50 feet.



nd adjoining Texas fields. Contour interval, 50 feet.