Stratigraphy of the Wichita Group in Part of the Brazos River Valley North Texas

By PHILIP T. STAFFORD

CONTRIBUTIONS TO GENERAL GEOLOGY

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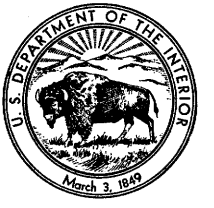

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STRATIGRAPHY OF THE WICHITA GROUP IN PART OF THE BRAZOS RIVER VALLEY, NORTH TEXAS

By Philip T. Stafford

ABSTRACT

Rocks comprising the Wichita group (Permian) crop out in Texas in a north-southward-trending area extending from the Red River on the Oklahoma-Texas border to the Llano uplift in central Texas. The outcrop area of the Wichita group discussed in this report lies in the southern part of the Brazos River drainage basin, extending from central Callahan and Eastland Counties northward to central Throckmorton and southwestern Archer Counties.

Most rocks in the mapped area belong to the Wichita group, which includes about the lower half of the rocks of the Leonard series (Permian) and all of the rocks of the Wolfcamp series (Permian). The group consists of seven units, which are, in ascending order: The Pueblo, Moran, Putnam, Admiral, Belle Plains, and Clyde formations, and the Lueders limestone. Each formation is divided into as many as six members.

Gray and red shale predominate in the Wichita group, but limestone, sandstone, siltstone, conglomerate, and coal are also present. Most of the sandstone and conglomerate forms lenticular, channel-fill deposits. The thickness of the group ranges from 1,550 to 1,800 feet; locally, channel deposits near the base increase the thickness as much as 200 feet.

The lithology of the Wichita group gradually changes from central to north Texas. In the Colorado River valley area in central Texas, a marine shale and limestone facies predominates. Northward, the marine beds decrease in number and red beds become predominant. In north Texas, near the Red River, most of the section is comprised of a marginal marine red-bed facies of shale and sandstone.

Rocks of the Cisco group (Pennsylvanian), Clear Fork group (Permian), and Trinity group (Cretaceous), and Quaternary alluvium and terrace deposits also are present in the mapped area.

The outcropping Pennsylvanian and Permian strata have a regional dip of less than 1° to the west-northwest. In southern Throckmorton County an east-west line of northwestward-trending faults is exposed. The Cretaceous rocks seem to have been less deformed than the Paleozoic rocks.

INTRODUCTION

Rocks comprising the Wichita group of Permian age crop out in Texas in a north-south-trending area extending from the Llano uplift in the south to the Red River on the Oklahoma-Texas border (fig. 15). The marine limestone and shale facies of the Wichita group are exposed in central and north-central Texas north of the Llano uplift; north of these areas the marine limestone and shale beds interfinger and grade into a sandstone and shale facies indicative of a marginal

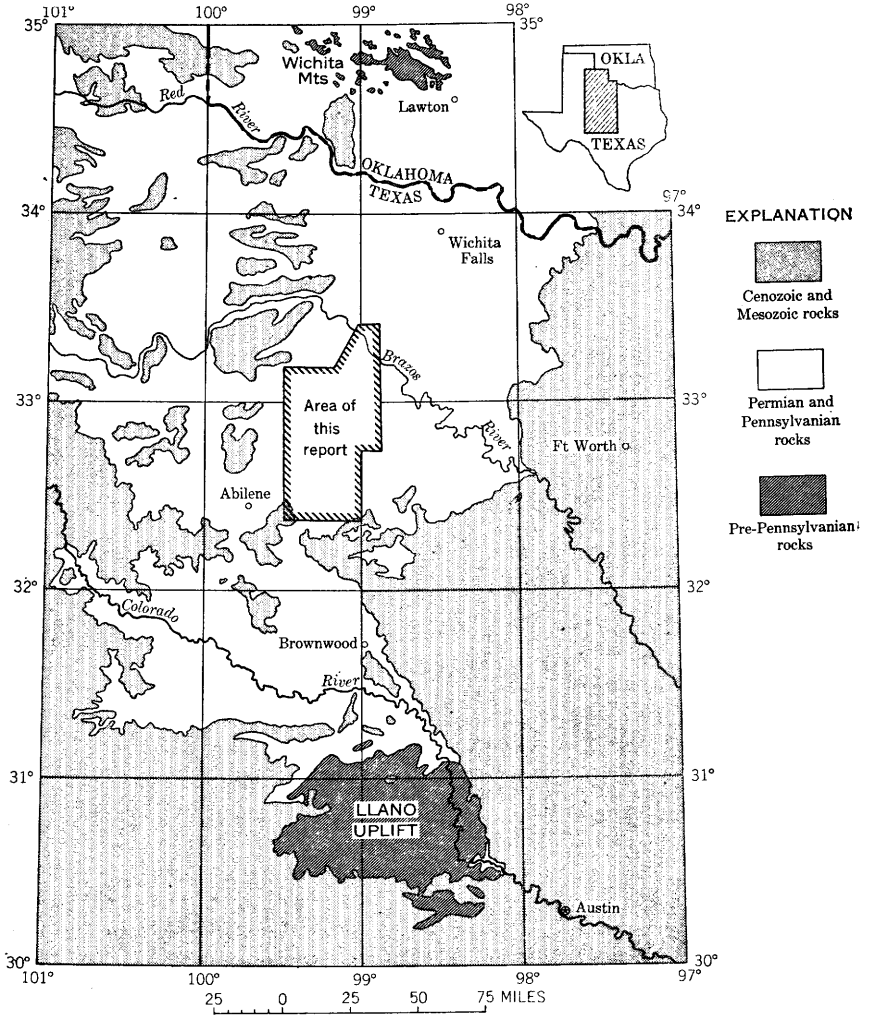

FIGURE 15.—Index map of north-central Texas, showing location of the mapped area and generalized geology of part of Texas and Oklahoma. (Geology modified after Stose and Ljungstedt, 1932 [1933].)

marine depositional environment. These marginal marine deposits include the red-bed facies of the Wichita group in north Texas and southern Oklahoma.

This study was undertaken by the U.S. Geological Survey with the cooperation of the Bureau of Economic Geology, The University of Texas, as part of a program of stratigraphic studies of the rocks of Pennsylvanian and Permian age in Texas. The area mapped for this report, located in the northern half of the area of outcropping rocks of Pennsylvanian and Permian age, includes about 2,065 square miles in the southern part of the Brazos River drainage basin (fig. 15). It is roughly rectangular and lies within parts of Archer, Baylor, Callahan, Eastland, Haskell, Shackelford, Throckmorton, Stephens, and Young Counties.

PREVIOUS GEOLOGIC STUDIES

Early workers (Tarr, 1890; Dumble, 1890; Cummins, 1891) named and described the large subdivisions (groups) which are now used in the Pennsylvanian and Permian stratigraphic nomenclature of north-central Texas (pls. 11 and 12). Each of the units was referred to as a series, a division, or beds (for example, Waldrip-Cisco series, Cisco division, or Wichita beds). Drake (1893), in a geologic report on part of the Colorado River drainage area, named most of the rock units which are now considered members of formations of the Pennsylvanian and Permian in the area. He referred to each unit as a bed (Camp Colorado bed). The formations of this sequence were named much later by Wrather (1917), Plummer (1919), and Plummer and Moore (1921). In subsequent years, the nomenclature has been revised, expanded, and summarized by Cheney (1929, 1940, 1948, 1949, and 1950), Sellards (1932), Lee and others (1938), Moore (1949), Cheney and Eargle (1951a and 1951b), Eargle (1960), and others.

The Bureau of Economic Geology, The University of Texas, in cooperation with the American Association of Petroleum Geologists, compiled geologic maps of the following countries in the mapped area: Baylor (Garrett and others, 1930), Callahan (Plummer and Hornberger, 1932), Eastland (Wender, 1929), Shackelford (Hedrick and others, 1929), Stephens (Bradish, 1929), Throckmorton (Hornberger, 1932), and Young (Plummer and Fuqua, no date). Smaller scale maps include those of Plummer and Moore (1921) and Darton and others (1937).

PRESENT INVESTIGATION

Field studies were made by the writer in October and November, 1955. Selected stratigraphic sections were measured and described in detail. Stratigraphic units were determined by diagnostic lith-

ologic and paleontologic differences, and the lithology was related to characteristic topographic and vegetative differences. Thus, it was possible to delineate mappable sequences over the area. The mappable units were then extended on aerial photographs by standard photogeologic techniques. The aerial geologic mapping was done on Army Map Service aerial photographs at a scale of about 1:63,000. A planimetric base was made from the Abilene and Wichita Falls, Tex., Army Map Service sheets, 1:250,000 scale, 1° by 2°-series topographic maps. The geology was transferred from the photographs to the planimetric base with a vertical projector.

DESCRIPTIVE TERMINOLOGY

The term "shale" is used in this report for rocks of grain size finer than siltstone, regardless of the presence or absence of lamination or fissility.

In referring to the bedding of the rocks, the following standard is used: Massive, greater than 4 feet thick; thick-bedded, 2 to 4 feet; medium-bedded, 6 inches to 2 feet; thin-bedded, 2 to 6 inches; and very thin bedded, ½ to 2 inches. Platy refers to beds 1/16 to ½ inch thick, and fissile, less than 1/16 inch.

Limestone is classified according to grain size into the following three types (after Grabau, as described by Pettijohn, 1949, p. 300–307): Calcilutite, limestone composed mainly of clay-sized particles—less than 1/16 mm in diameter; calcarenite, limestone composed mainly of sand-sized particles—1/16 to 2 mm in diameter; and calcirudite, limestone composed mainly of particles greater than 2 mm in diameter. The grain size of noncarbonate rocks is classified according to the Wentworth scale.

In describing the relative abundance of fossils, and a few rock types or other material, the following standard is used: Very abundant, the fossils (or other constituents) being discussed compose most of the rock or unit; abundant, they make up a large part; plentiful, they can be found with ease; common, they can be found in most hand specimens of rocks; rare, they are generally difficult to find; and very rare, much searching is necessary.

STRATIGRAPHY

Most of the rocks exposed in this area belong to the Wichita group of the Permian system. Small areas, however, include rocks of the underlying Cisco group of the Pennsylvanian system, the overlying Clear Fork group of the Permian system, and the Trinity group of the Cretaceous system. Alluvium and terrace deposits of the Quaternary system are present along the major streams (pl. 11).

CARBONIFEROUS: PENNSYLVANIAN SYSTEM

CISCO GROUP

The Cisco group consists mainly of gray limestone and gray and red shale. Some sandstone and siltstone is present. Eargle (1960) assigns two formations to this group; in ascending order they are the Graham and Thrifty formations. Only the Thrifty crops out in the area of this report.

THRIFTY FORMATION

The individual members of the Thrifty formation were not separately mapped because this investigation was primarily a study of the rocks of the Wichita group. In a complete stratigraphic sequence the Thrifty consists of five members, which, in ascending order, are: the Speck Mountain limestone member, unnamed shale member, Breckenridge limestone member, unnamed shale member, and Chaffin limestone member. All members except the Speck Mountain (locally known as the Blach Ranch limestone member) crop out in the area (pl. 12). The Thrifty, averaging about 115 feet in thickness, is underlain by the Graham of the Cisco group and overlain by the Pueblo of the Wichita group.

About the upper 25 feet of the unnamed shale member between the Speck Mountain limestone member and the Breckenridge limestone member occurs in the mapped area, although to the east its total thickness averages about 50 feet (Lee and others, 1938). It predominantly consists of nonfossiliferous shale of light-red and light-gray shades and contains small amounts of siltstone and sandstone.

The Breckenridge limestone member is 8 to 30 feet thick and consists of a lower and an upper limestone bed separated by a shale bed. The lower limestone bed is 1 to 5 feet thick, light- to medium light-gray calcarenite in which fusulinids are abundant, brachiopods are common to rare, and unidentified organic fragments are common. The upper limestone bed is 1 to 5 feet thick, light-gray to medium light-gray argillaceous limestone. It weathers to lumpy masses as much as 1 foot in diameter, and is sparsely fossiliferous except for locally abundant fusulinids. The upper and lower limestone beds are separated by 3 to 20 feet of light-red and light-gray shale.

The unnamed shale member between the Breckenridge and Chaffin limestone members, which ranges in thickness from about 20 to 35 feet, consists mainly of light-red and light-gray shale containing small amounts of siltstone and sandstone.

The Chaffin limestone member, known in this area as the Lower Crystal Falls limestone member, ranges in thickness from about 3 to 10 feet. It is light- to medium-gray calcarenite which locally has a

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shale parting as much as 2 feet thick. Fusulinids and crinoid stems are abundant to rare; brachiopods and corals are rare.

PERMIAN SYSTEM

WICHITA GROUP

The Wichita group in north-central Texas includes the rocks between the base of the Waldrip shale member of the Pueblo formation and the top of the Lueders limestone (pl. 12). The group consists of seven formations, which are, in ascending order: The Pueblo, Moran, Putnam, Admiral, Belle Plains, and Clyde formations, and the Lueders limestone. It includes all rocks assigned to the Wolfcamp series (Permian), and about half of those assigned to the Leonard series (Permian). In addition, some rocks assigned to the Pennsylvanian system are included in the Wichita group; rocks of the Pennsylvanian-Permian transition zone are included in the lower part of the Waldrip shale member of the Pueblo formation (Eargle, 1960; Moore, 1949).

Gray and red shale predominates in the rocks of the Wichita group. Limestone is the second most common rock type, and is more abundant in the upper half of the group than in the lower half (pl. 12). Sandstone is the next most abundant, being common in the lower half of the group, but rare in the upper half. Siltstone, commonly found in the lower half of the group and rarely in the upper half, is generally associated with sandstone. Conglomerate is rare. Coal beds are thin and few. The shale beds are commonly persistent but poorly exposed; the limestone beds are persistent and well exposed. Arenaceous or argillaceous limestone beds, however, are poorly exposed. Most of the sandstone and conglomerate is well exposed and forms part of lenticular, channel-fill deposits. A few evenly bedded sandstones extend the length of the mapped area.

The thickness of the outcropping rocks of the Wichita group ranges from about 1,650 feet in northern Callahan and northwestern Eastland Counties to 1,550 feet in central Shackelford and west-central Stephens Counties, and to 1,800 feet north of the Clear Fork of the Brazos River in Young and Throckmorton Counties (pl. 12). Channel deposits near the base of the group locally may increase the thickness as much as 200 feet.

The nomenclature of Eargle (1960) is used for the lower half of the Wichita group and that of Moore (1949) for the upper half.

PUEBLO FORMATION

The Pueblo formation, ranging from 275 to 400 feet in thickness, consists of 6 members, which in ascending order are: The Waldrip shale member, Saddle Creek limestone member, Camp Creek shale member, Stockwether limestone member, Salt Creek Bend shale member, and Camp Colorado limestone member. The Pueblo is overlain by the Watts Creek shale member of the Moran formation and underlain by the Chaffin limestone member of the Thrifty formation (Pennsylvanian). Locally, the Chaffin and underlying shale members of the Thrifty formation were removed by erosion during early Permian time, and the Pueblo rests on rocks as old as the Breckenridge limestone member of the Thrifty formation.

The boundary between the Pueblo and Moran formations was not mapped north of Elm Creek (east-central Throckmorton and west-central Young Counties). This boundary is difficult to discern in this area because of the probable absence of the Camp Colorado limestone member or recognizable changes in lithology.

WALDRIP SHALE MEMBER

The Waldrip shale member consists largely of red and gray shale with 3 to 5 thin limestone beds. Bedded siltstone, sandstone, and coal are also present. Extensive channel-fill deposits of conglomerate, sandstone, siltstone, and gray shale are in the lower part where much of the Pennsylvanian-Permian transitional rocks and some of the underlying Thrifty formation were removed by widespread erosion during earliest Permian time.

The thickness of the Waldrip ranges from about 80 to 225 feet except where locally increased by channel-fill deposits. For example, near Cisco in northwestern Eastland County the thickness is increased from 80 to 200 feet by channel-fill deposits (R. J. Burnside, written communication, 1957). Local studies of the channel-fill deposits and their stratigraphic relations in adjacent areas have been included in other reports (Lee and others, 1938; Stafford, 1960; and Terriere, 1960).

SADDLE CREEK LIMESTONE MEMBER

In the southern part of the area, the Saddle Creek limestone member is 8 to 12 feet thick and commonly consists of light-gray, thin- to medium-bedded calcilutite having a conchoidal fracture. Clear calcite stringers of organic origin are plentiful to abundant, and tetracorals, crinoid stems, bryozoans, brachiopods, and algae(?) are rare to common.

In southern Stephens County, the lower half of the Saddle Creek grades into light-gray calcareous shale having thin layers of fossilif-

erous limestone which contain abundant fragmented fossils including tetracorals, crinoid stems and plates, brachiopods, and fenestellid bryozoans.

From southwestern to west-central Stephens County the member is thinner (from 2 to 5 feet thick) and changes to a very light gray calcarenite with much insoluble clay- to sand-sized material, principally quartz. Only one layer is present from the town of Eolian in Stephens County northward to the Clear Fork of the Brazos River. It ranges from a sandy limestone to a limy quartz sandstone. Fusulinids and fossil fragments are abundant at many outcrops of the Saddle Creek.

North of the Clear Fork of the Brazos River, there is some doubt whether the Saddle Creek limestone member is present; consequently the relation of the Saddle Creek to underlying and overlying sandstone beds and to channel-fill deposits is obscure.

In many places the Saddle Creek was removed by erosion preceding the deposition of the Camp Creek shale member. Channel-fill conglomerate, sandstone, siltstone, and shale now occupy the original position of the Saddle Creek in those areas.

CAMP CREEK SHALE MEMBER

The Camp Creek shale member consists of 50 to probably 70 feet of shale containing some beds of sandstone and siltstone. The shale is largely medium to light gray, but various shades of red and greenish gray are common. Locally it is calcareous. The only fossils in the Camp Creek are plant fragments, found along bedding planes in some of the light-gray shale. The sandstone and siltstone beds are commonly lenticular and may be largely channel-fill deposits. Channels filled by coarse-grained sandstone and conglomerate are common and easily differentiated from the underlying Saddle Creek limestone member.

STOCKWETHER LIMESTONE MEMBER

In northwestern Eastland and southwestern Stephens Counties, the Stockwether limestone member is commonly 2 to 3 feet thick. It is a very light to medium-light, greenish-gray calcarenite to calcilutite having an irregular fracture. It is thin bedded and weathers to smooth-surfaced slabs.

In west-central Stephens County, the Stockwether is an argillaceous limestone ½ to 1½ feet thick. It weathers as a single, smooth-surfaced bed containing crinoid stems, brachiopods, and unidentified fossil fragments. Northward from west-central Stephens County to the Throckmorton County line, the Stockwether seems to grade to a nonfossiliferous, calcareous quartz sandstone as much as 3 feet thick.

Throughout the mapped area, the member was locally removed by erosion preceding the deposition of the overlying Salt Creek Bend shale member. Its original position is now occupied by conglomerate, sandstone, siltstone, and shale. Because of this erosion and change to sandstone to the north, the Stockwether is difficult to trace and was mapped with other members of the Pueblo formation.

SALT CREEK BEND SHALE MEMBER

The Salt Creek Bend shale member ranges from 40 to 100 feet in thickness and consists of variegated shale with minor amounts of sandstone and siltstone. The shale is various shades of gray, red, and greenish gray. It is largely noncalcareous and weathers to chunky or tabular pieces. No fossils were noted. Generally, the member is poorly exposed except for beds of sandstone.

Well-exposed channel-fill sandstone and conglomerate are locally present and at many places these channels are cut into the underlying Stockwether limestone and Camp Creek shale members.

CAMP COLORADO LIMESTONE MEMBER

The Camp Colorado limestone member ranges from about 10 to 25 feet in thickness, and is thickest in the southern part of the mapped area. The base of the member is easily distinguished but the top is not; thus, the Camp Colorado was mapped with the overlying Watts Cheek shale member of the Moran formation.

In northwestern Eastland and southeastern Shackelford Counties, the Camp Colorado consists of as many as three limestone beds separated by gray and red shale. The upper limestone beds become sandy and grade into calcareous quartz sandstone beds to the north, but were not observed north of central Throckmorton County.

The lower limestone bed is the only resistant unit of this member, and commonly caps a prominent escarpment. South of west-central Stephens County the lower bed is light-gray, thin-bedded calcilutite having a conchoidal fracture and weathering to smooth-surfaced slabs. Tetracorals are rare, unidentified fossil fragments are abundant. From west-central Stephens and east-central Shackelford Counties to about the Stephens-Throckmorton County boundary, this bed is a 1½- to 3-foot-thick, medium-gray to medium light gray calcarenite commonly containing algae(?), crinoid stems, brachiopods, and abundant unidentified fossil fragments.

Northward, the amount of fine sand to clay-sized insoluble material progressively increases in the lower limestone bed. In part of southwestern Young County, it is a calcareous quartz sandstone. North

of Elm Creek and along the Brazos River, the bed is largely obscured by Quaternary terrace and alluvial deposits.

The upper limestone beds of the Camp Colorado, which are poorly exposed, range from argillaceous or arenaceous limestone in the south to calcareous sandstone in most of the area north of the Clear Fork of the Brazos River. These beds are medium to light gray and pale red, and commonly fossiliferous (crinoid stems, fenestellid bryozoans, and *Marginifera* and other brachiopods are abundant at many localities).

Erosion preceding deposition of the Watts Creek shale member of the Moran formation has locally removed the upper part of the Camp Colorado. In southwestern Young County this erosion removed the lower bed of the member and cut into the underlying Salt Creek Bend shale member. Sandstone, siltstone, and shale of the Watts Creek shale member fill the channels.

MORAN FORMATION

The Moran formation, which is 155 to 220 feet thick, overlies the Pueblo formation and underlies the Putnam formation. It is mostly shale with some limestone, sandstone, and siltstone (pl. 12). Moore (1949) divided the formation into four members, which are, in ascending order: The Watts Creek shale member, Gouldbusk limestone member, Santa Anna shale member, and Sedwick limestone member. The lower three members are grouped together in this report.

WATTS CREEK SHALE MEMBER, GOULDBUSK LIMESTONE MEMBER, AND SANTA ANNA SHALE MEMBER

These units, which constitute the lower three-fourths of the Moran formation, consist of about 90 percent shale; the remainder is limestone, sandstone, and siltstone. The shale ranges from pale red to greenish gray and seems to be nonfossiliferous and noncalcareous.

Near the middle of the Moran formation is a persistent, fossiliferous and calcareous sandstone bed which is tentatively correlated with the Gouldbusk limestone member in southeastern Callahan County. Between the sandstone bed and the underlying Camp Colorado member of the Pueblo formation is a persistent limestone bed which was mapped as the Dothan limestone by Plummer and Hornberger (1932) and Wender (1929). However, the name "Dothan" was preoccupied and the bed is locally known as the Ibex bed of Cheney (1948).

SEDWICK LIMESTONE MEMBER

The Sedwick limestone member, ranging from 40 to 55 feet in thickness, consists principally of alternating thin limestone and thick shale beds. South of the Clear Fork of the Brazos River, one or more of

the limestone beds are topographically prominent. The basal limestone grades laterally to a calcareous sandstone in part of Shackelford County.

The limestone beds range from a few inches to 5 feet in thickness and are commonly iron-stained calcilutite or calcarenite. They are colored pale red, light yellowish gray, grayish orange pink, light brown, and dark yellowish orange. In fresh exposures, which are rare, they are light to medium gray. Brachiopods, gastropods, cephalopods, and pelecypods are rare.

The shale in the Sedwick limestone member seems to be mostly light gray to medium light gray and nonfossiliferous.

PUTNAM FORMATION

The Putnam formation is 140 to 210 feet thick, and is composed of the Santa Anna Branch shale member, below, and the Coleman Junction limestone member, above. Among the rocks of Wolfcamp age this formation forms the most prominent escarpment in the mapped area.

SANTA ANNA BRANCH SHALE MEMBER

The Santa Anna Branch shale member, which ranges from 75 to 205 feet in thickness, is about 90 percent shale; the remainder is limestone, sandstone, and siltstone. The lower half is commonly poorly exposed and underlies soil-covered lowlands; the upper half is better exposed than most shale beds. The lower part is mostly a fissile, medium-light to light-gray shale, which is nonfossiliferous. In the upper part, the shale is commonly nonfissile, pale red and light-greenish to greenish gray, and locally contains an abundant marine fauna composed of bryozoans, brachiopods, and pelecypods.

COLEMAN JUNCTION LIMESTONE MEMBER

The Coleman Junction limestone member ranges from 4 to 15 feet in thickness and forms a prominent and persistent outcrop. South of the Brazos River it consists of a lower bed of medium- to light-gray calcarenite, 4 to 10 feet thick, which weathers to various shades of light and yellowish brown and yellowish orange. In central Shackelford County the lower bed of brown-weathering limestone is overlain by a 3-foot thick medium light gray shale, and this by light-gray limestone 2 feet thick. South of the Brazos River, tetracorals, crinoid stems, fenestellid bryozoans, brachiopods, and cephalapods are rare; unidentified fragmented marine fossils are plentiful to abundant.

A short distance north of the Brazos River the Coleman Junction is about 5 feet thick and consists of a light-gray calcarenite containing abundant foraminiferal and algal material. The brown weathering, a characteristic of the member south of the Brazos River, is not found north of the river.

ADMIRAL FORMATION

The Admiral formation includes all rocks between the underlying Coleman Junction limestone member of the Putnam formation, and the base of the overlying Jim Ned shale member of the Belle Plains formation (Moore, 1949). Moore divided the Admiral into four members in the Colorado River drainage. In ascending order they are: The Lost Creek shale member, Hords Creek limestone member, Wildcat Creek shale member, and Overall limestone member. In the Brazos River drainage area, the Admiral formation cannot easily be distinguished from the underlying Putnam formation or the overlying Belle Plains formation. Therefore, the Coleman Junction limestone member of the Putnam formation, the four members of the Admiral, and the Jim Ned shale member of the Belle Plains formation have been mapped as a unit (pl. 11).

The Admiral formation in the mapped area commonly consists of about 130 feet of poorly exposed shale, siltstone, and limestone, and may be only 100 feet thick in central Shackelford County. It is about 90 percent medium light gray to very light gray shale. Light-red shale is also present at some localities. Limestone and siltstone and a few nonpersistent sandstone beds about 2 feet thick comprise the remainder.

The individual members of the Admiral are not discussed in this report. This part of the Wichita group was not studied in detail as poor exposures make correlation uncertain with rock units of Moore (1949) in northern Callahan County.

BELLE PLAINS FORMATION

The Belle Plains formation, as defined by Moore (1949), consists of six members. In ascending order they are: The Jim Ned shale member, Elm Creek limestone member, Voss shale member, Jagger Bend limestone member, Valera shale member, and Bead Mountain limestone member. These units extend throughout the mapped area. The Jim Ned shale member, however, is difficult to distinguish from the underlying Admiral formation and was mapped with the Admiral (pl. 11). An unnamed shale member that probably belongs to the lowest unit of the overlying Clyde formation is mapped as a unit with the Bead Mountain.

The Belle Plains formation, 525 to 640 feet thick, consists mainly of alternating gray limestone and gray and red shale, with small amounts of bedded siltstone and sandstone. With the exception of some of the limestone beds, exposures of this formation are commonly poor.

JIM NED SHALE MEMBER

The Jim Ned shale member, the lowest member of the Belle Plains formation, is composed mainly of shale, colored light shades of gray, greenish gray, and red. In northern Callahan County the upper 20 feet of the member contains 2 argillaceous limestone beds about 1 and 2 feet thick. Locally, siltstone as much as 10 feet thick is present in the upper third of the member. More rarely, very fine grained, nonresistant sandstone beds are found in the lower half.

The member is 130 feet thick in northern Callahan County, and may be as much as 165 feet thick in central Throckmorton County. In central Shackelford County it is less than 100 feet thick.

ELM CREEK LIMESTONE MEMBER

The Elm Creek limestone member is from 55 to 95 feet thick. It forms a prominent escarpment and individual beds are easily delineated on aerial photographs. The member consists mostly of alternating beds of limestone and shale. In Callahan and Shackelford Counties, limestone is predominant; northward, in central Throckmorton County, more shale than limestone is present. The thickness of limestone beds ranges from less than 1 foot to 35 feet; the thickness of shale beds ranges from less than 1 foot to 25 feet. The limestone is a medium- to light-gray, rarely yellowish-brown, calcarenite. Some beds are argillaceous, especially in their northward extension. Algae, calcitornellid foraminifers, fenestellid bryozoans, *Marginifera* and other brachiopods, pelecypods, cephalopods, gastropods, ostracodes, and unidentified marine fossil fragments are rare to common. Some very fine grained sandstone and siltstone, commonly calcareous, is present in the lower part of the member.

VOSS SHALE MEMBER

The Voss shale member is 20 to 85 feet thick and commonly poorly exposed. The member is mostly light-gray shale with some pale-red shale. Pale- to dark-yellowish-orange limestone, in discontinuous beds as much as 2 feet thick, was observed locally in the area west of Albany in Shackelford County.

JAGGER BEND LIMESTONE MEMBER

The base of the Jagger Bend limestone member, which is 60 to 120 feet thick, forms a continuous low-lying escarpment through the map area. The boundary between this member and the overlying Valera shale member cannot be distinguished so the two members were mapped as a unit.

The Jagger Bend is comprised of three units, a lower and an upper part of alternating limestone and shale, separated by a shale unit. The limestone beds of the lower part are 1 to 8 feet thick, and consist of locally argillaceous light-gray calcarenite. Locally the lower part contains algae and unidentified fossil fragments. The upper limestone beds, ranging from less than 1 to 5 feet in thickness, are commonly argillaceous, relatively nonresistant, light-gray calcarenites. The shale of this member, where exposed, is medium light gray to light gray, greenish gray, and pale red. It is calcareous and nonfossiliferous.

VALERA SHALE MEMBER

The Valera shale member is 65 to 180 feet thick. It consists of light-gray, light-greenish-gray, and light-red shale and contains some sandstone, siltstone, and limestone.

BEAD MOUNTAIN LIMESTONE MEMBER

The Bead Mountain limestone member forms a prominent escarpment in the Brazos River drainage area. The base and most of the individual beds are readily delineated on aerial photographs. The member consists of alternating beds of limestone and shale; the limestone beds range in thickness from less than 1 to about 15 feet, and the shale beds range in thickness from less than 1 to 65 feet. The limestone beds are composed of medium-dark to light-gray calcarenite containing rare to abundant unidentified fossil fragments and algae. *Aviculopinna*-like pelecypods were noted in several beds. Northward, the limestone beds become more argillaceous. The shale beds are medium gray to very light gray, greenish gray to light greenish gray, and pale red. They are commonly noncalcareous and nonfossiliferous.

CLYDE FORMATION

The Clyde formation includes all rocks between the top of the Bead Mountain limestone member of the underlying Belle Plains formation and the base of the overlying Lueders limestone. It ranges in thickness from 220 feet in northwestern Callahan County to 255 feet in west-central Throckmorton County. In the mapped area it includes five members which are, in ascending order: An unnamed shale member, the Grape Creek limestone member, an unnamed shale

member, the Talpa limestone member, and an unnamed shale member. The unnamed shale members are considered parts of the limestone members in the Colorado River valley area (Moore, 1949). The subdivision used in this paper roughly parallels that of previous reports covering the mapped area (Hedrick and others, 1929; Hornberger, 1932; Plummer and Hornberger, 1932).

The Clyde formation consists almost entirely of alternating gray limestone and shale. Shale is predominant but more so in the north than in the south. A very small amount of sandstone and siltstone is also present.

UNNAMED SHALE MEMBER UNDERLYING THE GRAPE CREEK LIMESTONE MEMBER

The lowest unnamed shale member of the Clyde formation consists of medium light gray to very light gray and greenish-gray to light-greenish-gray shale which ranges in thickness from 50 to 65 feet. The member is calcareous in part and nonfossiliferous. On plate 11 this member is mapped with the underlying Bead Mountain limestone member of the Belle Plains formation.

GRAPE CREEK LIMESTONE MEMBER

The Grape Creek limestone member ranges from 20 to 45 feet in thickness and consists of upper and lower limestone beds separated by shale. The limestone beds range from 2 to 8 feet in thickness and the shale ranges from 15 to 40 feet in thickness. The lower limestone beds are more resistant and topographically more prominent than those in the upper part of the member.

The lower limestone beds are a light-gray calcarenite and the upper beds are argillaceous calcarenite. The shale is poorly exposed but commonly is light gray, nonfissile, nonfossiliferous, and in part calcareous.

UNNAMED SHALE MEMBER OVERLYING THE GRAPE CREEK LIMESTONE MEMBER

The unnamed shale member between the Grape Creek and Talpa limestone members consists principally of gray shale 30 to 90 feet thick. It is noncalcareous and nonfossiliferous, except for pelecypods in the upper 5 feet. Siltstone, as much as 6 feet thick, was noted in the upper 10 feet. It is pale red, greenish gray, and light greenish gray, nonfossiliferous, and noncalcareous.

TALPA LIMESTONE MEMBER

The Talpa limestone member is 45 to 55 feet thick and consists of alternating gray limestone and shale beds with less siltstone. The limestone beds range from less than 1 foot to about 10 feet in thick-

ness, the shale beds from less than 1 foot to about 20 feet, and the siltstone beds from less than 1 foot to about 6 feet. The limestone is light-gray calcarenite that has a rough fracture and weathers to earthy, nodular pieces and small slabs. Fossils are absent to plentiful, and include unidentified fragments, algae, *Marginifera* and other brachiopods, cephalopods, and pelecypods. Although the limestone beds are argillaceous, most of them form cuestas that are conspicuous on the aerial photographs. The shale beds of the Talpa are very light to light gray, commonly fissile, calcareous, and nonfossiliferous. The lower part of the member contains a persistent layer of shale with abundant ostracodes. The siltstone of the Talpa is sandy to clayey, pale red and greenish gray, nonfossiliferous, and noncalcareous.

UNNAMED SHALE MEMBER OVERLYING THE TALPA LIMESTONE MEMBER

The unnamed shale member between the Talpa limestone member and the Lueders limestone is 30 to 70 feet thick and locally contains some limestone. The shale is light gray to light greenish gray, nonfossiliferous, and noncalcareous. In west-central Shackelford County, 8½ feet of limestone was noted in the member. This limestone bed is argillaceous in part, comparatively nonresistant, and contains algae, calcitornellids, and unidentified fossil fragments of marine organisms.

LUEDERS LIMESTONE

The Lueders limestone consists of persistent alternating beds of limestone and shale whose thickness ranges from 75 feet in northwestern Callahan County to 50 feet in west-central Throckmorton County. The limestone beds are medium-light to light-gray calcarenites. Some are argillaceous. Fossil fragments and algal pellets are abundant. The algae in equivalent beds to the south have been called *Osagia* by Moore (1949). The shale beds are light shades of gray or greenish gray.

CLEAR FORK GROUP

ARROYO FORMATION

A thickness of about 20 feet of the lower part of the Arroyo formation was present in the mapped area, although the total average thickness of the formation to the west is shown on geologic maps as 112 feet in Jones County (Meyers and Morley, 1929) and 140 feet in Taylor County (Meyers and others, 1929).

The lower 20 feet of the Arroyo consists of light-gray and light-red shale. To the west, younger parts of the formation contain several thin limestone beds. The contact between the Lueders and the Arroyo formations seems conformable, the boundary being the top of the distinctively resistant Lueders limestone.

CRETACEOUS SYSTEM

Of the three groups belonging to the Comanche series (Lower Cretaceous) only the lower one, the Trinity group, is exposed in the area of this report. An angular unconformity separates the Paleozoic from the Cretaceous rocks. The relief on the Paleozoic surface is as much as 150 feet in adjacent areas (Stafford, 1960).

TRINITY GROUP

Only the lower 35 feet of the Trinity group is exposed in the mapped area. Southward in Callahan County where the entire group is exposed, it is 200 to 350 feet thick (Stafford, 1960).

The Trinity consists of about 90 percent sandstone and 10 percent conglomerate. It is very poorly exposed and weathers to loose sand and gravel which creep down the slopes. Thus, it is difficult to map the contact between the Paleozoic and Cretaceous rocks, although the Trinity gives rise to a very distinctive vegetation of post oak and shin oak in contrast to other types of vegetation on most of the Pennsylvanian and Permian rocks. This distinction is marked on the aerial photographs.

The basal 2 to 10 feet of the group consists of conglomerate interbedded with sandstone. At many localities, it consists entirely of well-rounded quartz and quartzite granules and pebbles in a matrix of very fine to very coarse sand, which is commonly cemented with calcium carbonate.

The sandstone of the Trinity is mostly very fine to coarse grained, very light gray to white, friable, noncalcareous, nonfossiliferous, nonresistant, well sorted, and comprised almost entirely of quartz grains. Some sandstone, however, is pale red to reddish brown and calcareous.

QUATERNARY SYSTEM

ALLUVIUM AND TERRACE DEPOSITS

Surficial deposits of alluvium and terrace gravel, sand, silt, and clay were mapped along the major streams. The small deposits present along most streams could not be shown at the map scale.

At least 20 feet of alluvium composed of clay- through boulder-sized material is exposed along the banks of the Brazos River. Older terrace deposits as much as 15 feet thick were seen at levels as high as 75 feet above the present flood plain. The gravels consist of pebbles, cobbles, and boulders mainly derived from limestone, sandstone, and conglomerate of the Pennsylvanian, Permian, and Cretaceous systems.

All alluvium and terrace deposits shown on plate 11 are probably Pleistocene to Recent in age. Some small, isolated deposits at higher elevations, which were not mapped, may be of earlier Pleistocene age.

REGIONAL FACIES CHANGES

A gradual change in the lithology of the Wichita group from the Colorado River drainage area (Moore, 1949) to the area just south of the Red River is indicated in the columnar sections accompanying this report (pl. 12). In the Colorado River area (pl. 12, sec. 1), Moore shows a generalized section containing about 35 percent limestone and 65 percent clastics. The clastics include gray shale and siltstone and some sandstone and red shale. Northward through the area covered by this study, a marked decrease from a predominantly marine shale and limestone section to a predominantly marginal marine, red-bed sequence of sandstone and shale takes place in the Wichita group. Section 4 of plate 12 shows about 8 percent limestone and 92 percent clastics. Although the sandstone percentage is about the same in section 4 as in section 1, the percentage of red beds is far greater in section 4. Much farther northward, as shown in section 5, marine sediments comprise a very small proportion of the stratigraphic column. For example carbonates comprise less than 1 percent of the thickness in the core of the Magnolia Petroleum Co., Honaker 78 well.

In the red-bed facies between the Red and the Brazos Rivers, many land plants and vertebrate fossils have been collected from the Wichita group, but relatively few marine fossils have been found. From the Brazos River southward to the Colorado River, however, progressively more marine fossils and fewer land plants and vertebrate fossils were found.

STRUCTURE

The mapped area lies along the west flank of the Bend arch, a structural feature extending north from the Llano uplift to a short distance south of Wichita Falls, Tex. In north-central Texas, outcropping Pennsylvanian and Permian rocks have a regional dip of less than 1° to the west-northwest. However, minor structures cause local variation in the direction and amount of dip. Many of the structures seem to be primarily the result of differential compaction over lenticular channel-fill sandstone and conglomerate deposits of the lower part of the Wichita group and the Strawn, Canyon, and Cisco groups of the Pennsylvanian system.

In southern Throckmorton County an east-west line of northwestward-southeastward-trending faults is present at the surface (pl. 11). Lee and others (1938) show several other faults along this line in southern Young County, east of the mapped area. One fault not along this line is present in northern Shackelford County. These faults were first noted on aerial photographs, and, although not

studied in detail, were verified by field checking. The geologic map of Throckmorton County (Hornberger, 1932) and of Texas (Darton and others, 1937) show several faults in this county, but some of them were not found either in the field or on the aerial photographs. Detailed field mapping may reveal additional faults; however, only verified ones are shown on plate 11. A detailed surface-subsurface study of the area along this line of faults is needed for a better understanding of their relation to other regional structural features.

The Cretaceous rocks seem to have been very slightly deformed. Detailed mapping of the Cross Plains quadrangle (Stafford, 1960), a few miles south of the area of this report, indicates that the evenly bedded limestone of the Fredericksburg group (Cretaceous) seems to dip from horizontal to about 20 feet per mile in a general northeasterly direction.

The amount and direction of dip of the Trinity group (Cretaceous) cannot be determined in the area of this report or in adjacent areas, because the Trinity lies on a surface having a relief of at least 150 feet. Generally poor exposures and lack of traceable beds in the Trinity make determination of its structure difficult.

A more detailed summary of the regional structure of the rocks in north-central Texas is presented by Cheney (1940) and Cheney and Goss (1952).

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