Stratigraphy of Pennsylvanian and Lower Permian Rocks in Brown and Coleman Counties, Texas

GEOLOGICAL SURVEY PROFESSIONAL PAPER 315-D

Prepared in cooperation with the
Bureau of Economic Geology
The University of Texas

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By D. HOYE EARGLE

PENNSYLVANIAN AND LOWER PERMIAN ROCKS OF PARTS OF WEST AND CENTRAL TEXAS

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By D. Hoye Eargle

ABSTRACT

Rocks of Pennsylvanian and early Permian age crop out in a roughly triangular area in the Colorado River valley in central Texas, immediately north of the Llano Uplift. The apex of this triangular area is about 70 miles northwest of Austin; its base trends north-northeastward from an overlap of Lower Cretaceous rocks near Brady to another overlap of Lower Cretaceous rocks that lies along the divide between the Colorado and Brazos River valleys. Brownwood and Coleman are the two largest cities in or near this area.

Only outcropping rocks of Middle Pennsylvanian to early Permian age are considered in this study. The Pennsylvanian rocks belong to three groups—Strawn, Canyon, and Cisco. The Permian rocks belong to the lower part of the Wichita group. The beds dip gently west-northwestward about 50 to 80 feet to the mile. Of these rocks, only those of the lower part of the Strawn group are appreciably disturbed by folding or faulting in the Colorado River valley. The limestone beds generally occupy the tops of cuestas whose back slopes are dip slopes slightly truncated by erosion. The shale and thin sandstone beds are less resistant to erosion than the limestone and occupy the frontal slopes of the cuestas and the valley bottoms. Thick beds of standstone or conglomerate also locally form cuestas.

Rocks of the Strawn group in Brown and Coleman Counties are probably the equivalents of thicker deposits to the northeast, east, and southeast in the Fort Worth basin and the Ouachita geosyncline. Although a few beds are limestone containing marine fossils, most of the beds are nonmarine shale and sandstone. The Strawn group has not been divided into formations on the outcrop in the Colorado River valley as it has been in the Brazos River valley to the northeast; nor can equivalent beds be traced, with the exception of the Capps limestone lentil of Plummer and Moore (1921), from one valley to another. The Strawn is accordingly considered in this paper as one mappable unit.

The Strawn becomes thinner from Central Brown County, where it is reported to be 1,100 feet thick in wells, to 500 feet in northcentral Coleman County; and from 1,235 feet in northern Brown County to about 250 feet in southwestern Brown County and southeastern Coleman County.

Rocks of the Canyon group are about 600 feet thick in the Colorado River valley. They consist chiefly of thick beds of limestone that form the most prominent cuestas of the region, and of intervening beds of shale and sandstone that generally occupy the frontal slopes of the cuestas and the valley bottoms. The Canyon group has been divided into four formations: from bottom to top, the Graford, the Winchell, the Brad, and the Caddo Creek.

The Cisco group, about 400 feet thick, consists chiefly of shale containing channel-fill deposits of chert conglomerate and sandstone, and thin beds of limestone. It has been divided into the Graham and Thrifty formations.

The Wichita group consists chiefly of formations composed of a shale unit underlying a prominent, but generally thin, limestone unit. Deeply cut channels filled with sandstone and conglomerate are present in the lower formations of the group, the Pueblo and Moran formations. The stratigraphy of only the lower part of the Pueblo formation is discussed.

INTRODUCTION

This report presents correlations of the exposed rocks of Late Pennsylvanian and early Permian age across a triangular area in central Texas that extends from the Colorado River northeast to the Callahan Divide in Callahan and Eastland Counties (figs. 11 and 12). The Callahan Divide, which separates the drainage basins of the Brazos and Colorado Rivers, is capped with Lower Cretaceous rocks. This belt of Cretaceous rocks interrupts the continuity of outcrop of the underlying Pennsylvanian and lower Permian rocks, thereby making definite correlation of beds between central and north-central Texas difficult. The purpose of this report is to present detailed information on stratigraphic units south of the Callahan Divide as an aid in resolving some of the differences in nomenclature and in establishing correlations with equivalent rocks north of the Callahan Divide and in the subsurface to the west.

Differences in the usage of names of rock units in these areas have arisen because the formations were first named and described in the Brazos River valley, whereas most of the members of these formations were named and described as beds by Drake (1893) in the Colorado River valley. Inaccuracy in correlating some of Drake's beds with stratigraphic units in the Brazos River valley has brought about confusion and changes

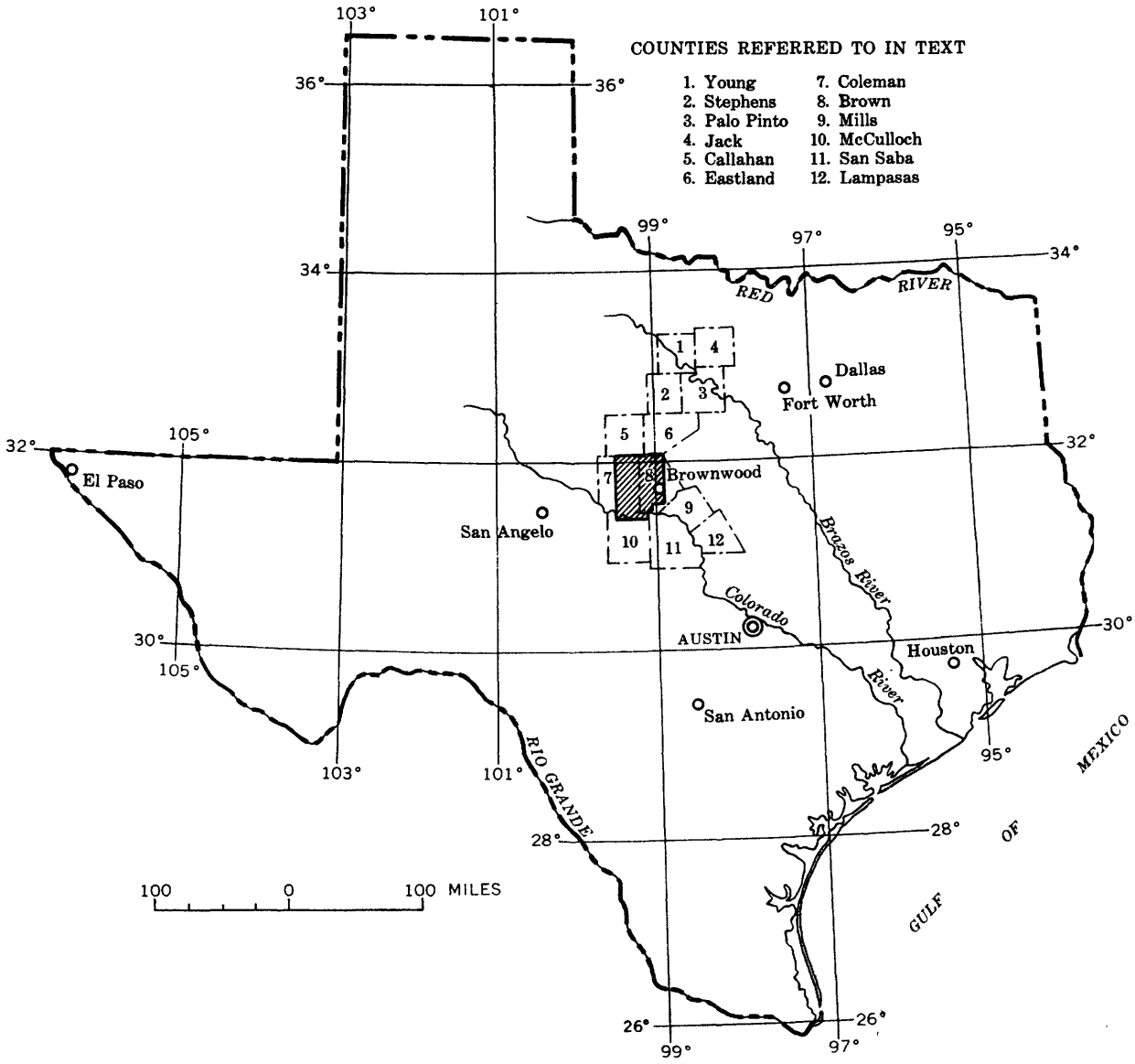

FIGURE 11.—Index map of Texas showing location of area described in this report.

in groupings in both areas. In addition, miscorrelation of some surface units with the subsurface has resulted in further confusion. In the present study the relations of the various units were determined by carefully measuring and tracing stratigraphic units in the field, and by examining the lithologic characteristics and faunal content of all the beds.

Stratigraphic data presented in this report were accumulated by detailed geologic mapping in the Colorado River valley during the years 1950–54. The author gratefully acknowledges the important contributions by other geologists to this study. D. A. Myers and K. A. Yenne, of the U.S. Geological Survey, studied the fusulinids and other fossils, and assisted in measuring stratigraphic sections; P. T. Stafford and R. T. Terriere, also of the U.S. Geological Survey, measured most of the sections north of Jim Ned Creek in northwestern Brown County, and Terriere measured several sections in southeastern Coleman County. W. A. Jenkins, Jr., then a graduate student at The University of Texas, generously contributed sections 11 and 18 (pls. 25 and 26), though his nomenclature of the beds has been slightly altered to conform to that proposed herein. The author acknowledges the benefit of collaboration with the late Monroe G. Cheney in working out the stratigraphy of the area. The project was carried on with the cooperation of the Bureau of Economic Geology, The University of Texas.

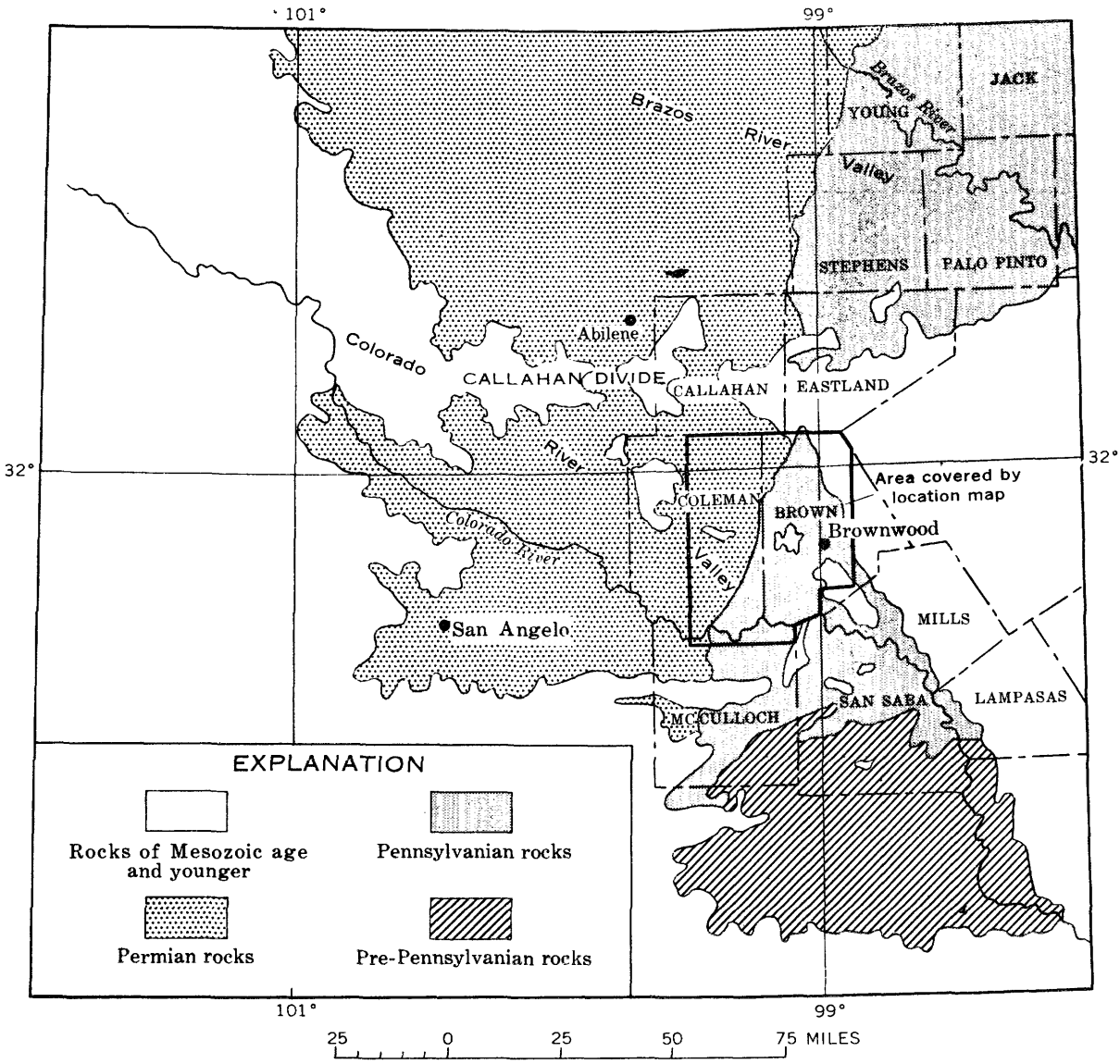

FIGURE 12.—Map showing generalized geology of central Texas.

GENERAL RELATIONS AND NOMENCLATURE OF STRATIGRAPHIC UNITS

Stratigraphic units of Pennsylvanian and early Permian age which crop out in Brown and Coleman Counties between the Colorado River and the Callahan Divide belong to the Strawn, Canyon, and Cisco groups of the Pennsylvanian system and to the Wichita group of the Permian system. The names, lithologic characteristics, thicknesses, and correlations of the formations and members in each of these groups, together with the distribution of fusulinids and ammonoids in these sections, are shown on the chart of measured sections (pl. 26). Table 1 summarizes the nomenclature of the rocks as recognized in this paper.

The Strawn group in the area considered in this report represents only the upper part of this group elsewhere; it has a prominent ridge-forming limestone at the top but consists chiefly of shale and lenticular beds of sandstone with some conglomerate. The Canyon group consists of ridge-forming beds of limestone separated by less-resistant beds of shale and of sandstone that is locally conglomeratic. The Cisco group consists of thin beds of limestone, relatively thick beds of shale, and some lenticular beds of sandstone and other channel-fill sedimentary deposits. The Wichita group consists of sandstone, shale, and limestone, and in the lower part contains sequences of gray and red shale, sandstone, and coal.

TABLE 1.—*Nomenclature of rocks of Pennsylvanian and Permian ages in Brown and Coleman Counties, Tex.*

System	Group	Stratigraphic unit	
Permian	Wichita (in part)	Pueblo formation (lower part)	Saddle Creek limestone member. Waldrip shale member.
Pennsylvanian	Cisco	Thrifty formation	Chaffin limestone member. Parks Mountain sandstone member. Breckenridge limestone member. Speck Mountain limestone member.
		Graham formation	Ivan limestone member. Wayland shale member. Gunsight limestone member. Bluff Creek shale member.
	Canyon	Caddo Creek formation	Home Creek limestone member. Colony Creek shale member.
		Brad formation	Ranger limestone member. Placid shale member.
		Winchell limestone	Upper unnamed limestone member. Lower unnamed limestone member.
		Graford formation	Cedarton shale member. Adams Branch limestone member. Brownwood shale member.
	Strawn	Undifferentiated	Capps limestone lentil of Plummer and Moore (1921). Ricker sandstone member of Nickell (1938). Ricker Station limestone of Cheney (1949).

The nomenclature of the principal stratigraphic units in the area was set up in connection with early studies by geologists interested chiefly in the coal deposits. The large divisions were named and described by Tarr (1890), Dumble (1890), and Cummins (1891) (pl. 27); whereas most of the beds (later termed members) were first named and described by N. F. Drake (1893). Formational names were added by Plummer and Moore (1921), chiefly from localities in the Brazos River valley. The nomenclature was summarized and partly revised by Sellards (1933). Cheney (1929, 1940, 1945, 1948, 1949, and 1950) and Cheney and Eargle (1951a) cleared up past miscorrelations and revised the nomenclature to accord with time-rock units. Studies of individual areas have been made by Bullard and Cuyler (1935), Lee, Nickell, Williams, and Henbest (1938), Moore (1949), and Jenkins (1952, unpublished doctoral dissertation, University of Texas), Terriere (1960), and Stafford (1960).

PENNSYLVANIAN SYSTEM

STRAWN GROUP

The standstone and shale beds that constitute the Strawn group in the Colorado River valley were first called the Richland sandstone division by Tarr (1890, p. 204). These and correlative beds in the Brazos River valley were called the Richland-Gordon sandstones by Dumble (1890, pl. 3). Later Drake (1893, p. 16), separated these rocks into 20 units of alternating sandstone and shale beds. He gave local names to these units, or "beds" as he termed them, and numbered those of the Strawn group, from bottom to top, 4 to 23. (See pl. 27.) Only Drake's name for the upper unit, the Ricker, is in common use today, but that name has been restricted to the prominent standstone at the base of Drake's Ricker bed. Drake referred these units to the Strawn division of Cummins (1891, p. 16), which he considered to include all rocks above the limestone

and black shale of the Bend division, and below his Coral limestone bed, the Capps limestone of later authors.

Plummer and Moore (1921, table 2, and p. 61–68) considered the Strawn in the Colorado River valley to be equivalent to their Mineral Wells and Millsap formations of the Brazos River valley section, but believed that accurate correlations of individual layers in one valley with those of the other were impossible. They limited the Strawn group to the rocks that overlie the Smithwick shale of the Bend group and underlie the Rochelle conglomerate. This placed Drake's Coral limestone bed, which Plummer and Moore renamed the Capps limestone lentil, in the Canyon group. The Capps was thought to overlie the Rochelle conglomerate, and was regarded as a part of the Brownwood shale member of the Graford formation. Sellards (1933, p. 109) did not follow this classification, but transferred the Capps back to the Strawn group, and considered it the upper member of the Mineral Wells formation. Nickell (1938, pl. 8) assigned not only the Capps but also about 100 feet of the overlying shale (the Brownwood bed of Drake and the Brownwood shale of Plummer and Moore) to the Strawn group. Cheney (1940, p. 66), Cheney and Eargle (1951a, p. 55), and Plummer (1950, p. 88), however, affirmed the placing of the Capps limestone in the Strawn group on the basis of the presence of *Fusulina* sp. and the brachiopod *Mesolobus* sp. in the beds, and considered its top as the top of the Strawn group.

Cheney's work in 1940 changed much of the nomenclature and the rank of the units of this region. He considered the Pennsylvanian to be of systemic rank and divided it into five series called, from oldest to youngest, the Morrow, Lampasas, Strawn, Canyon, and Cisco; the Permian he divided into the Wolfcamp and Leonard series and the post-Leonard Whitehorse group. In his Lampasas series Cheney (1940, fig. 1) included the lower part of the Strawn and the upper part of the Bend of earlier authors. His Strawn series he divided (Cheney, 1940, p. 88) into the Millsap Lake group, below, and the Lone Camp group, above.

Cheney (1940) believed that an important disconformity existed at the boundary between the Strawn and the Canyon and that separate formational names should be given the rocks of those ages. Accordingly, he advocated the abandonment of the name Mineral Wells because that formation in the Brazos River valley includes rocks of both Strawn and Canyon ages. He assigned the beds of Strawn age in the old Mineral Wells formation to his Lone Camp group and those of Canyon age to his Whitt group. In his Lone Camp group he included the Brazos River conglomerate of the Brazos River valley and the Rochelle conglomerate of the Colorado River valley, which he considered to be correlative. Later he also included in the Lone Camp group the Ricker conglomerate (the Ricker sandstone of Nickell), which he and others then correlated with the Rochelle. At the top of his Lone Camp group he placed Plummer's Village Bend limestone of the Brazos River valley and Plummer and Moore's Capps limestone lentil of the Colorado River valley.

The most recent work in the Strawn group of the Colorado River valley has been done by university students and oil-company geologists. This work has brought to light some additional features of the Strawn and has clarified parts of the stratigraphy, especially the correlations with the rocks of the Brazos River valley. W. A. Jenkins, Jr. (1952, unpublished doctoral dissertation, University of Texas) mapped the Mercury quadrangle which lies chiefly south of the Colorado River, but extends into southern Brown County. He did not differentiate the Strawn group and placed the Rochelle conglomerate as probably at the base of the Canyon group. He found that, although Plummer and Moore's Capps limestone lentil does not extend as far south as the northern limit of the Rochelle, the Rochelle lies at the approximate position of the Capps and probably should be considered a channel-fill basal conglomerate of the Brownwood shale member of the Graford formation in the Canyon group. Shelton (1958) studied the boundary between the Strawn and Canyon groups from the vicinity of Rochelle in the Colorado River valley northeast to the easternmost extremity of the Pennsylvanian rocks in Parker County in the Brazos River valley. He found that the top of the Strawn coincided generally with the top of the Capps limestone lentil of Plummer and Moore (1921) in the Colorado River valley and with the top of the East Mountain shale member of the Mineral Wells formation in the Brazos River valley. He traced the Capps almost to the Eastland-Palo Pinto County line in the Brazos River valley but could not definitely recognize it farther north.

Rocks of the Strawn group in the Brazos River valley have been studied in considerable detail and have been classified into units. Those of the Colorado River valley, however, have been only locally observed or superficially studied since Drake's initial work. Hence, their structure and depositional history, the environmental conditions of their deposition, and their relation to underlying rocks are imperfectly understood. The Strawn is known to be thinner to the west and southwest, but there is little agreement among geologists as to the position of the basal boundary or to the relation of the Strawn to underlying rocks. If

Drake's measurements of individual beds of the outcropping Strawn are totaled, they make an impressive thickness of 4,100 feet (Plummer and Moore, 1921); yet in wells where there is a complete section of Strawn, no more than 1,200 feet of it has been drilled. It is believed that the lower thicker beds cropping out in the eastern part of the Colorado River valley have been overlapped to the west (Sellards, 1933, p. 109) or that equivalent units, if present to the west, are considerably thinner there.

Only the upper part of the Strawn group will be discussed in detail here, because the lower and middle parts do not crop out in the area studied.

UPPER PART OF THE STRAWN GROUP

The term "Strawn group" is used here for all rocks in the Colorado River valley between the top of the Smithwick shale of the Bend group and the base of the Brownwood shale member of the Graford formation of the Canyon group. The term "Mineral Wells formation" is not used in this area because of the marked range in thickness and lithology that occurs in the Strawn between the Brazos and Colorado River valleys.

Drake's original description of the rocks of the Strawn group (1893, p. 16–27) and his classification of them constitute the most complete discussion of their lithologic character, areal extent, facies changes, and relation to other units that has been published. Drake (1893, p. 17) found that, in the vicinity of the Colorado River in San Saba and Lampasas Counties, the Smithwick shale of his Bend division grades upward at "nearly all points" into reworked shale of the basal bed of the Strawn (his Lynch Creek bed). This bed of reworked shale, in turn, grades upward into sandstone beds differing from place to place in thickness, in amount of included shale, and in resistance to erosion. Locally, however, Smithwick shale is absent, and a basal conglomerate of the Strawn containing reworked limestone pebbles lies directly on Marble Falls limestone of the Bend group.

During the deposition of approximately the upper third of the Strawn group, a sudden change in conditions and type of sedimentation occurred. Conglomeratic beds containing conspicuous subangular pebbles of chert were laid down as broad channel-fill deposits. The base of the conglomerate is irregular; locally the bases of the conglomerate lenses cut sharply into the underlying shale. At most places along the outcrop, the upper third of the Strawn contains a higher percentage of sandstone in relation to shale than the lower part. To the west, in the subsurface, the section is thinner and contains a higher percentage of shale.

The upper part of the Strawn crops out in western Mills and northern San Saba Counties and up the Colorado River and its tributary from the north, Pecan Bayou, into southeastern Brown County. This part of the Strawn consists chiefly of gray to greenish-gray clayey shale, which weathers to bright-red clayey soil, and contains considerable plant material, mostly prints of stems and leaves. Several beds of sandstone form prominent eastward-facing cuestas. The sandstone beds are thick to thin bedded and generally gray, but weather light reddish to yellowish brown. Surfaces of the sandstone beds have ripple marks, burrows or trails, and impressions of plants. One bed of sandstone found by Robert Pavlovic, of the Magnolia Petroleum Company (personal communication), on Farm Road 45 in cuts north of the bridge over Wilbarger Creek, is profusely fossiliferous, with abundant brachiopods and mollusks and a few ammonoids. About 200 feet below the top of the Strawn in central Brown County is the thin and discontinuous fusulinid-bearing limestone bed that was called the Ricker Station limestone by Cheney (1949). More detailed descriptions of this and the uppermost beds of the Strawn group follow.

RICKER STATION LIMESTONE OF CHENEY (1949)

The limestone unit that Cheney (1940, p. 66) called the Ricker Station limestone was listed as the Ricker limestone in his table of strata of Paleozoic age of north-central Texas but was not described. He listed it again in a similar table (1949, opposite p. 8), but called it the Ricker Station limestone apparently to avoid confusion with the Ricker bed described previously by Drake. The limestone, although only a thin discontinuous bed, is an important stratigraphic unit. It is the lowermost limestone bed of the Strawn group found to the date of this survey in the Colorado River valley and contains an abundance of fusulinids.

The outcrop of the Ricker Station limestone of Cheney (1949) is indicated by scattered blocks of the limestone as much as 3 feet across in a pasture about one-tenth of a mile south of the road crossing at the Ricker railroad siding, 5½ miles S. 76° E. of the courthouse at Brownwood, on the Gulf, Colorado, and Santa Fe Railroad (pl. 28 *A*, *B*, and *C*). The outcrop of the limestone may be traced discontinuously for 5 miles southwest of this locality but has not been found to the northeast. Fusulinids constitute about half of the limestone near Ricker siding, but grains of sand, fossil fragments (chiefly mollusks, especially *Bellerophon*-type gastropods, and some crinoid columnals), and scattered subrounded chert pebbles are also present in the rock. Thompson (1945, p. 452–453) described and

named the fusulinid from this locality as *Fusulina*(?) *rickerensis*. Ashworth (1954, unpublished master's thesis, The University of Texas) found the same fusulinid in a thin sandy limestone bed that he called the Gibson limestone in the Garner formation in the Brazos River valley. If his identification is correct and if the fossil has correlative value, the rocks in which this fossil is found are equivalent to the Garner formation of the Brazos River valley.

The best exposure of the Ricker Station limestone of Cheney (1949) is 6 miles southeast of the courthouse at Brownwood along the Brownwood-Elkins road, 1.6 miles southeast of the crossing of this road with the military road to Camp Bowie. The exposure is on the southeast face of a cuesta locally called Six-Mile Mountain. In the road cuts and in the bed of an abandoned section of the road 200 feet to the west, the unit, a 4-foot thick bed of grayish-brown limestone containing fine-grained sand, crops out. Fusulinids, crinoids, and other components are abundant as at the Ricker siding locality. The limestone is overlain by 12 feet of greenish-gray clay that in turn is overlain by gray fine-grained slabby thin-bedded calcareous sandstone. The limestone bed is underlain by silty or sandy greenish-gray shale containing plant fossils. Also in the greenish-gray clay, obviously of later age than the limestone, but lying at lower elevations, are blocks of limestone, lithologically similar to the solid bed of limestone above, which were apparently carried to lower levels by postdepositional slumping that accompanied the cutting of channels through the bed and into the underlying shale.

RICKER SANDSTONE MEMBER OF NICKELL (1938)

Drake's Ricker bed, which he placed at the top of his Strawn division, is separated from the underlying Ricker Station limestone of Cheney (1949) by 50 to 70 feet of interbedded gray shale and sandstone. Drake (1893) stated that the sandstone and conglomerate of his Ricker bed caps an isolated butte north of Ricker Station, 5½ miles east of Brownwood. Other exposures, he said, were found along the west side of Steppes Creek and along the crest of a high escarpment west of Pecan Bayou. Nickell (1938, plate 9) correlated a bed of sandstone along the Colorado River, 5 to 9 miles east of Winchell, with this unit. In his stratigraphic section of rocks in the Brownwood area, Nickell (1938) placed the Ricker sandstone member in the Mineral Wells formation of the Strawn group. Cheney (1949) and Cheney and Eargle (1951a) suggested the correlation of this sandstone with the Brazos River conglomerate member of the Garner formation of the Brazos River valley. Cordell and Zimmerman (1954) have pointed out, however, that, on the basis of a study of ostracodes, it is quite likely that this sandstone unit lies stratigraphically below the Brazos River conglomerate member.

The best exposure of the basal sandstone of the Ricker bed of Drake is in a cut on the recently relocated Fort Worth division of the Gulf, Colorado, and Santa Fe Railroad 5 miles east of the courthouse at Brownwood and three-tenths of a mile south of U.S. Highway 84 in a spur of the west valley wall of Steppes Creek. At this locality the bed is a 25- to 35-foot brown sandstone containing chert pebbles. It irregularly overlies 17 feet of greenish-gray shale. The lower part of the Ricker in this cut locally occupies channels cut 10 to 12 feet into the underlying shale. An excellent exposure of the top of the conglomeratic Ricker sandstone member is in the face of a borrow pit north of the crossing of the Santa Fe Railroad and the military road to Camp Bowie, 2 miles south of the junction of this road with U.S. Highway 84. At this locality, reddish-brown and gray shale is interbedded with thin lenticular beds of sandstone containing chert pebbles and reworked fragments of the coral *Chaetetes*.

SHALE BETWEEN THE RICKER SANDSTONE MEMBER OF NICKELL (1938) AND THE CAPPS LIMESTONE LENTIL OF PLUMMER AND MOORE (1921)

The shale between the Ricker sandstone member of Nickell (1938) and the Capps limestone lentil of Plummer and Moore (1921) is gray and generally silty. Locally it contains "stumps" or cylindrical colonies of *Chaetetes*, thin beds of argillaceous limestone, and conglomerate composed of limestone pebbles. At some places near the Colorado River a 2-foot bed of gray limestone has been found in this part of the Strawn group, about 70 feet below the Capps limestone lentil of Plummer and Moore (1921). The same stratigraphic position in nearby exposures is occupied by channel-fill sandstone.

The shale and sandstone in this part of the Strawn are notably lenticular and contain extensive channel-fill deposits with associated slumping. The sandstones are generally thin bedded. Lenticular sandstones in a similar stratigraphic position in the subsurface west of the outcrop area are among the most prolific oil-bearing sands of the region.

Shale between the Ricker sandstone member of Nickell (1938) and the Capps limestone lentil of Plummer and Moore (1921) in the upper part of the Strawn group (pl. 28c) is best exposed in the steep escarpment west of the military road half a mile south of the bridge over Pecan Bayou, 4 miles southeast of the courthouse in Brownwood and 5 miles south-southeast of Early School (section 45, pl. 26). A cuesta as much

as 140 feet above the adjoining lowland of Pecan Bayou is formed by the Capps limestone lentil of Plummer and Moore (1921) and 50 to 60 feet of underlying shale and sandstone are well exposed in cuts on the military highway. The Capps limestone lentil of Plummer and Moore (1921) is here about 25 feet thick and consists of dense gray nodular limestone containing fusulinids, crinoids, and various types of brachiopods. Below it, is thin-bedded sandstone, 3 to 4 feet in thickness, underlain by silty and sandy shale containing many bryozoans, gastropods, and pelecypods. This grades downward into shale that is thinly interbedded with sandstone. The shale shows extensive channel erosion, slump structures, and crossbedding.

CAPPS LIMESTONE LENTIL OF PLUMMER AND MOORE (1921)

The Capps limestone lentil as used by Plummer and Moore (1921), originally called the Coral limestone bed by Drake because it contains an abundance of *Chaetetes*, extends across Brown County north of the Colorado River, except where removed locally by channel erosion. The community of Early encompasses the type locality of the Capps limestone lentil which was named by Plummer and Moore (1921) for exposures on the nearby Capps farm. The unit was classified by Sellards (1933) as the Capps limestone member of the Mineral Wells formation, but for reasons previously stated, it is not considered feasible to extend use of the term "Mineral Wells formation" into the Colorado River valley.

The Capps limestone lentil of Plummer and Moore is represented by blocks of limestone in a pasture one-tenth of a mile south of the Early High School, and by a bedrock surface of limestone in a drainage ditch leading from U.S. Highways 67 and 84 two-tenths of a mile southwest of the school. Numerous other exposures of the limestone are found within a mile of this locality along the dip slope of a cuesta formed by the limestone.

South of the Colorado River a channel-fill conglomerate, termed by Drake (1893) the Rochelle conglomerate, has been found by Jenkins (1952, unpublished doctoral dissertation, University of Texas) to be equivalent to, or slightly younger than, the Capps limestone lentil of Plummer and Moore (1921). Plummer (1950, p. 90) reported that a rich fauna of Des Moines (Strawn) age is found in shale underlying Drake's Rochelle; whereas shale above Drake's Rochelle contains a fauna typical of Missouri (Canyon) age. Plummer therefore placed the top of the Strawn at the base of the Rochelle conglomerate and its equivalent sandstone. Studies by K. A. Yenne in preparation for this report showed that the Capps contains *Fusulina* sp., which is indicative of Des Moines age (Thompson, 1945, p. 443).

The Capps limestone lentil is gray, is wavy-bedded to nodular, and in some places is conglomeratic at its base. It is abundantly fossiliferous, containing especially *Fusulina* sp., *Chaetetes*, and brachiopods, chiefly of the genus *Composita*. In places, beds of shale as much as 10 feet in thickness separate individual beds of limestone. Near Brownwood the unit ranges from about 10 to 30 feet in thickness. Locally it lies on the truncated edges of silty and sandy shale which have been eroded and have undergone contemporaneous slumping. In places where it has been removed by channel erosion, pebbles of the Capps have been found in the conglomerate of the channel-fill sedimentary rock.

CANYON GROUP

The sequence of rocks now assigned to the Canyon group includes most of the rocks assigned to the Milburn shales and the Brownwood division by Tarr (1890) and to the Brownwood-Ranger series by Dumble (1890). Tarr's Brownwood division and Dumble's Brownwood-Ranger series were described as lying above their Milburn shales (later called the Brownwood shale) and as including the rocks that are barren of coal and that consist chiefly of limestone (Tarr, 1890, p. 206; Dumble, 1890, p. lxvii). The upper limit of this sequence of rocks was not accurately identified but appears to have been the top of the Gunsight limestone member of the Graham formation, Cisco group, of the present classification.

In 1893 Drake, adopting Cummins' divisions of the rocks of the Brazos River valley (1891, p. 361–374), applied the term "Canyon" to the prominent beds of limestone and intervening beds of shale of the Colorado River valley, to which he gave local names and which he classified as beds. He considered the base of the Canyon to be the top of his Coral limestone bed (Capps limestone lentil of Plummer and Moore), and the top of the Canyon to be his *Campophyllum* bed (Gunsight limestone member of present usage). Plummer and Moore (1921, table 1) called the Canyon a group, divided it into formations named for Brazos River valley localities, and further divided these into members bearing the nomenclature of Drake's beds. This terminology is still widely used, though some renaming, reorganization, and redefining of the units have been accomplished. The following nomenclature is recommended for the formations and members, in descending order:

Canyon group

Caddo Creek formation:
- Home Creek limestone member
- Colony Creek shale member

Brad formation:
- Ranger limestone member
- Placid shale member

Winchell limestone:
- Upper unnamed limestone member
- Lower unnamed limestone member

Graford formation:
- Cedarton shale member
- Adams Branch limestone member
- Brownwood shale member

GRAFORD FORMATION

The Graford formation, here redefined, consists of the following members in descending order:

Cedarton shale member
Adams Branch limestone member
Brownwood shale member

The formation was originally named by Plummer and Moore (1921, p. 95) for a locality in Palo Pinto County and was intended to include a thick limestone forming a prominent cuesta in that county, which they considered to be the Adams Branch, and the underlying shale down to the Palo Pinto limestone. They showed the Palo Pinto to be absent in the Colorado River valley, and they defined the basal member of the Graford as the Brownwood shale (Drake's Brownwood bed), in which they included their Capps limestone lentil (Drake's Coral limestone bed), and the Rochelle conglomerate. They considered the Rochelle to underlie their Capps limestone lentil, although later workers have found it to be in the position of the Capps, or to be a channel-fill conglomerate and sandstone of later age which has replaced their Capps limestone lentil.

Cheney (1929, p. 26, 27) showed that the limestone at the top of the Graford in Palo Pinto County was not correlative with the Adams Branch, but with part of the limestone now called the Winchell limestone in the Colorado River valley. Sellards (1933, p. 111) redefined the Graford to include his Merriman limestone (equivalent to part of the Winchell as later defined) and the underlying Cedarton shale of Moore and Plummer (1922) as well as their Adams Branch limestone and Brownwood shale. He included, therefore, in one formation all units he considered equivalent in both valleys. The treatment of the Graford by later authors is shown in the classification chart (pl. 27). Cheney (1940, 1945, 1948, 1949, 1950) considered the Brownwood to be the one and only formation of a new group, which he named the Whitt. Cheney and Eargle (1951b) defined the Whitt of Cheney (1940) to include the Adams Branch and the Brownwood units whereas the Graford included only the Winchell limestone and Cedarton shale.

The classification recommended here for the Colorado River valley would define the Winchell as a formation overlying the Graford. The Graford formation would include the Brownwood shale member, the Adams Branch limestone member, and the Cedarton shale member. It is here recommended that the name Palo Pinto be abandoned in the Colorado River valley, and that the beds called Palo Pinto with question by Nickell (1938, p. 95) and the shale unit between it and the Capps limestone member be included in the Brownwood shale member, in accordance with general current usage in Texas.

The Graford formation is about 285 feet thick in the southern part of Brown County and about 340 feet thick in the central part of Brown County. Most of the formation is concealed beneath Cretaceous rocks north of central Brown County.

BROWNWOOD SHALE MEMBER

The name "Brownwood shale member" is proposed for formal adoption because of the lateral continuity of the member, its conspicuous topographic expression, and its consistent relationship to other traceable units; also, because of the wide usage of the name at the present time. It is recommended that the base of the member be drawn at the top of the Capps limestone lentil of Plummer and Moore (1921). This boundary is more widely traceable than any other horizon in the interval between the highest rocks that bear lithogenetic and fossil affinities with the Strawn group below and affinities with the Canyon group above. It is proposed that the top of the Brownwood be drawn at the base of the Adams Branch limestone member.

Drake (1893, p. 28–30) described the Brownwood bed, placing it in the Canyon division of Cummins (1891, p. 373). In his Brownwood bed he included shale and some sandstone which overlie both the Rochelle conglomerate and his Coral limestone bed (Capps limestone lentil of Plummer and Moore (1921)). His Brownwood bed is thus practically identical with the unit that has been considered by later geologists as the Brownwood shale member. Hill (1901, p. 98) and Gordon (1911, p. 117) used the name "Brownwood division" to include also all of the Milburn division of Tarr, approximately equivalent to the present Brownwood shale member. Plummer and Moore (1921, p. 97–101) used the term "Brownwood shale" in the sense that Drake had used it earlier, but considered the Rochelle conglomerate to underlie their Capps limestone lentil (1921, p. 96, 97).

Nickell (1938, p. 100–103) did not use the term

"Brownwood shale" and referred the base of the Canyon group to the base of a limestone provisionally correlated by Cheney with the Palo Pinto limestone of the Brazos River valley. Nickell described this bed as 1 foot of yellow dense limestone lying 111 feet above the Capps limestone lentil in the Brownwood area. Nickell stated that this classification was unsatisfactory and that further definition of the Palo Pinto in the Colorado River valley was necessary. He discussed the upper part of the sequence now included in the Brownwood shale member as the lower shale member (of the Graford formation), and described it as composed of shale, sandstone, and a thin fusulinid coquina that lies 54 feet below the Adams Branch limestone member.

Cheney (1940, 1945, 1948, 1949, 1950), Cheney and Eargle (1951a, 1951b), and Jenkins (1952 unpublished doctoral dissertation, University of Texas) have considered the base of their Brownwood shale to be the top of the Capps limestone lentil. Most geologists have considered the base farther south, where the Capps is absent, to be the base of the Rochelle conglomerate.

The position of the Rochelle conglomerate south of the Colorado River and its correlatives north of the river has concerned most geologists who have worked in the region. The Rochelle has been mentioned variously as being below the Capps limestone lentil, in the position of the Capps limestone lentil (at the base of the Brownwood), and in the Brownwood shale member. Jenkins (1952, unpublished doctoral dissertation, University of Texas) found in mapping the Mercury quadrangle that the Rochelle appears to be a channel-fill deposit originating in the Brownwood shale member just above the position of the Capps limestone lentil. The Capps limestone lentil, however, cannot be traced continuously to the type locality of the Rochelle, which is about 14 miles south of the Colorado River in San Saba County. In southern Brown County extensive channel erosion has locally removed the Capps limestone lentil and the channels have been filled with conglomerate, sandstone, and reddish-brown claystone. Some of the pebbles and boulders of the conglomerate are limestone lithologically similar to the Capps. These deposits are considered as perhaps equivalent to the Rochelle conglomerate, although the channel-fill sandstones are not continuous.

The basal beds of the Brownwood shale member, immediately overlying the Capps limestone lentil in Brown County, are gray shale containing marine fossils. They grade upward into red shale containing several beds of impure limestone and beds of sandstone. About 50 feet above the base are additional beds of gray shale containing an abundant marine fauna, including the brachiopod genus *Chonetina*. Fossiliferous shale in this part of the member is well exposed in the pit of the Texas Brick Co. in the western part of the city of Brownwood. This shale is overlain alternately by lenticular beds of sandstone and a calcareous bed that appears in different places to be a desiccation breccia of limestone fragments, a cemented mass of algal(?) limestone pebbles, an impure clastic limestone, a sandy limestone, or (as in the Winchell area of southern Brown County) a bed of gray limestone 2 feet in thickness containing fusulinids. This is the limestone considered to be the Palo Pinto equivalent by Nickell (1938, p. 95) and by Cheney and Eargle (1951a, p. 54).

Lying above this carbonate bed, and in many places cutting into it, is conglomeratic sandstone. In the subsurface of northern Brown County extensive lenses of oil-bearing sandstone at about this stratigraphic position are known locally as the Cross Cut sands. Mostly gray silty shale and some lenticular beds of sandstone occupy the interval from the conglomeratic sandstone, near the middle of the Brownwood shale member, to the base of the Adams Branch limestone member. This part of the Brownwood was called the lower shale member of the Graford formation by Nickell (1938, p. 100–103). About 50 feet below the top of the unit is a zone containing abundant fossils, chiefly brachiopods and bryozoans, and a thin coquina of fusulinids. Immediately below the Adams Branch limestone member the shale is red and silty or sandy.

The Brownwood shale member is approximately 225 feet thick along the Colorado River and about 300 feet thick in the central part of Brown County, where the entire unit is exposed.

ADAMS BRANCH LIMESTONE MEMBER

The Adams Branch limestone member is stratigraphically the lowest of several limestone units of the Canyon group producing prominent asymmetric ridges or cuestas. It was named by Drake (1893) for exposures along the head of Adams Branch, west of Brownwood. It is a light-gray wavy-bedded slabby limestone that is brittle and easily crushed and consequently is extensively quarried for use as a source of crushed stone. A basal 2-foot bed, however, is massive, tough, and sandy, and is usually left unquarried. A few miles northeast of Brownwood the Adams Branch limestone member grades laterally into shale, calcareous sandstone, and, in some places, a coquina of brachiopod, mollusk, and crinoid fragments. A similar lithologic change takes place in the subsurface of northern Brown County. In most places this limestone contains abundant fusulinids of a larger species than is common in the rocks stratigraphically below.

About 1 mile west of Brownwood the Adams Branch limestone member is about 15 feet in thickness, but it thickens to about 40 feet in wells downdip toward the west. In northeastern McCulloch County immediately south of the Colorado River it appears to be at least 50 or 60 feet in thickness. Jenkins (1952, unpublished doctoral dissertation, University of Texas) has found that it becomes thinner south of that point and changes to shale near the town of Rochelle.

CEDARTON SHALE MEMBER

The Cedarton shale member generally consists of gray shale near the base, grading upward into red shale that contains, near the top, thin lenticular bodies of sandstone only 15 to 25 feet below the lowermost bed of the Winchell limestone. Locally near the middle of the member are thin beds of argillaceous limestone containing abundant productid brachiopods and crinoids. According to Cheney (1949, p. 11), a sandstone at this stratigraphic position in the subsurface produces oil in southeastern Callahan County, only a few miles north of the Brown-Coleman County line. The producing sand there is known to petroleum geologists as the Cross Plains sand. The member ranges from 60 to 80 feet in thickness.

WINCHELL LIMESTONE

The lowermost rocks in the sequence here included in the Winchell limestone were described originally as the Clear Creek bed by Drake (1893, p. 31, 32), and later called the Clear Creek limestone by Plummer and Moore (1921, p. 109, 110). The upper strata in this sequence were part of Drake's bed 7, later named the Placid shale by Plummer and Moore (1921, p. 110). Inasmuch as the name "Clear Creek" had been preempted, Sellars (1933) suggested that the term Merriman limestone, a term applied by Reeves (1922, p. 120) to a bed in a similar stratigraphic position in the Brazos River valley, be substituted. The Merriman as used locally in the Brazos River valley is lithologically similar to, and presumed to be correlative with, a distinctive brown limestone which had been designated the topmost bed of the Clear Creek of Plummer and Moore (1921) in the Colorado River valley. Nickell (1938, p. 105) applied the name Winchell member of the Graford formation to a

> group of thin limestones separated by thick shale beds and thin sandstones in the Winchell area, in Brown County, which to the west develop into a conspicuous limestone bed, as recorded in logs of wells drilled in central Coleman County.

This member included not only the Clear Creek limestone of Plummer and Moore but also prominent beds of limestone in the lower part of the Placid shale of Plummer and Moore (Drake's bed 7).

This formation is about 100 feet thick, of which about one-third is limestone. It consists of two sequences of resistant limestone beds, which form escarpments, separated by less resistant beds of shale, which form an intervening gentle slope. Because these two limestone sequences coalesce into a single limestone downdip, making a lithologic unit that is easily recognizable as a strong deflection on electric logs, and because this unit is of the same order of thickness, consistency, and continuity as the other formations of the Canyon group, it is here recommended that it be given formation rank, and the two limestone sequences at its top and bottom be unnamed members, here referred to informally as the upper unnamed limestone member and the lower unnamed limestone member.

LOWER UNNAMED LIMESTONE MEMBER

The lower unnamed limestone member, separated from the upper by 30 to 40 feet of shale and thin sandstone beds, forms a ridge that is generally less prominent than the one formed by the upper unnamed limestone member. The lower limestone member consists of several limestone beds from 1 to 10 feet thick. The lower part of this member is commonly calcareous gray shale in which several thin lenticular limestone beds occur locally. One of these, a bed of nodular limestone plastered with bryozoans, mainly fenestellids, and abundant brachiopods of the *Neospirifer* type, crops out in the spillway at Lake Brownwood (pl. 29), in roadcuts 2½ miles northwest of Brownwood on State Highway 279, and in roadcuts 2 miles northwest of Brownwood on U.S. Highways 67 and 84. Overlying this shale is a massive dense dark-gray limestone bed whose smooth upper surface contrasts with the lower surface which is a network of fucoidlike markings. A few feet of shale separates this limestone bed from the uppermost and generally thickest bed of the member. This limestone, which was called the Clear Creek limestone by Plummer and Moore (1921), is light gray, nodular, and irregular in thickness, and contains abundant structures that are apparently of algal origin.

A channel-fill sandstone, locally conglomeratic, is present discontinuously above the massive dark-gray fucoidal limestone bed. In several places it cuts through all underlying limestone beds of the member and locally extends downward almost to the Adams Branch limestone member.

UPPER UNNAMED LIMESTONE MEMBER

The upper unnamed limestone member of the Winchell limestone was included in the Placid shale by

Plummer and Moore (1921, p. 109, 110) and by Bullard and Cuyler (1935, p. 207–210) before the two sequences of ridge-forming limestone were renamed the Winchell member by Nickell (1938). This member consists of two beds of limestone totaling more than 20 feet in thickness, separated by a 4- to 10-foot bed of shale. The bed of shale forms a grass-covered slope conspicuous on aerial photographs as an almost-white band between darker bands produced by the growth of live-oak trees on the surfaces of limestone. These bands can be clearly traced across the whole outcrop area in Brown County.

The limestone beds of the upper member generally contain few fossils, but shells of several distinctive species of brachiopods can be broken out of the limestone.

BRAD FORMATION

The Brad formation consists of the following members in descending order: Ranger limestone member, Placid shale member.

The formation was named by Plummer and Moore (1921, p. 107–109) for a locality in southwestern Palo Pinto County and was defined to include not only the two members listed above but also their Clear Creek limestone and the Cedarton shale member. These two members were assigned to the Graford formation by Sellards when it was shown that their equivalents had been included in the sequence of rocks assigned to the Graford at its type area.

The Brad formation is about 130 feet thick in the southwestern part of Brown County, where it is somewhat thicker than farther north because the limestone thickens in the Brad formation along the Colorado River. It is about 105 feet in thickness in central Brown County, but northeast of Pecan Bayou this formation is not completely exposed at any locality and thicknesses can be determined only from well logs.

PLACID SHALE MEMBER

The Placid shale was named by Plummer and Moore (1921, p. 110) for a town in northeastern McCulloch County and was defined to include Drake's bed 7 and his Cherty limestone bed. Nickell described Drake's bed 7 as a shale member (of the Brad formation).

Jenkins (1952, unpublished doctoral dissertation, University of Texas) described the Placid as a formation and, in the Mercury quadrangle, named prominent and persistent limestone beds in the unit the Corn Creek limestone member. These beds can be traced north into Brown County to a point about 2 miles west of the village of Brookesmith, beyond which they seem to have been removed by channel erosion and replaced by sandstone and conglomerate. Northward throughout Brown County, red shale and sandstone—and in some places conglomerate—occupy the position of the Corn Creek limestone of Jenkins.

Nickell showed that the Cherty limestone of Drake lithologically changes to shale from southwestern Brown County toward the northeast and presumed that the northeastward fingering out of the cherty limestone "represents the pulsating advance and retreat of conditions favorable to deposition of shale and unfavorable to that of limestone" (1938, p. 111-114). Thick cherty limestone masses (constituting Drake's Cherty limestone) at the type locality of the Home Creek limestone member of the Caddo Creek formation about 4 miles west of Winchell, are apparently parts of a conspicuous and thick limestone complex that is present in most of the beds of the Canyon group in the general area where Brown, Coleman, and McCulloch Counties meet. Cheney (oral communication, 1951), however, considered the cherty limestone of the Home Creek locality to be the Ranger limestone member, and he followed Drake's original designation of the Home Creek limestone as the noncherty limestone overlying the cherty limestone in the walls of the creek. Cheney and Eargle (1951b) considered the cherty limestone at the Home Creek locality to be the lower part of their Ranger limestone, interfingering with shale to the northeast in southern Brown County. Jenkins (1952, unpublished doctoral dissertation, University of Texas) showed that the cherty limestone is above his Corn Creek member of the Placid shale.

The thickness of the Placid shale member ranges from 120 to 145 feet along the Colorado River to about 95 feet in the central and north-central parts of Brown County.

RANGER LIMESTONE MEMBER

The Ranger limestone, named by Plummer and Moore (1921, p. 111) for the town of Ranger in Eastland County to replace Drake's term Cherty limestone, was mapped from there to southwestern Brown County where it became a limestone complex at least 35 feet thick and possibly thicker. Normally, it is about 12 to 20 feet thick, fine grained, and gray to pale yellowish brown; locally it contains fusulinids and brachiopods. At the type locality of the overlying Home Creek limestone member in southeastern Coleman County, the rocks included in the upper part of the Ranger are noncherty, as pointed out by Nickell (1938, p. 114); whereas the lower part of the Ranger is a thick massive cherty limestone, the Cherty limestone of Drake. In the subsurface to the north and west, the Ranger limestone member produces a sharp, distinctive

A

B

C

A. EXPOSURE OF THE RICKER STATION LIMESTONE OF CHENEY (1949) AT THE TYPE LOCALITY

One-tenth of a mile south of the railroad crossing at Ricker siding on the Gulf, Colorado, and Santa Fe Railroad, 5½ miles S. 76° E. of the courthouse at Brownwood, Tex.

B. BLOCK OF THE RICKER STATION LIMESTONE OF CHENEY (1949) AT THE LOCALITY SHOWN IN *A*

Surface of the rock, etched by weathering, shows abundant fusilinids, scattered crinoid stems and gastropods, and one subangular chert pebble

C. UPPERMOST BEDS OF THE STRAWN GROUP

Apparent crossbedding in the shale underlying Capps limestone lentil of Plummer and Moore (1921) half a mile south of Pecan Bayou in cut on the military road from U.S. Highway 84 to Camp Bowie, 4.1 miles southeast of the courthouse at Brownwood, Tex.

ROCKS OF THE STRAWN GROUP

ROCKS OF THE CANYON GROUP.

The lowermost four limestone beds and the intervening shale that make up the lower unnamed member of the Winchell limestone. The upper unnamed member of the Winchell caps the hills on the skyline. Spillway of Lake Brownwood, 8½ miles north of the courthouse in Brownwood, Tex.

A

B

C

A. BLOCKS OF BROWN CHANNEL-FILL SANDSTONE OVERLYING SILTY SHALES NEAR THE TOP OF THE WAYLAND SHALE MEMBER OF THE GRAHAM FORMATION

3.6 miles southwest of Bangs, Tex.

B. THIN-BEDDED LIMESTONE OF THE IVAN LIMESTONE MEMBER OF THE GRAHAM FORMATION

Four-tenths of a mile east of the Brown-Coleman County line, 3.8 miles west-southwest of Bangs, Tex.

C. CHARACTERISTIC EXPOSURE OF THE SPECK MOUNTAIN LIMESTONE MEMBER OF THE THRIFTY FORMATION

Shows slumping of angular blocks over the face of an escarpment. Locality is 1.6 miles southwest of Obregon siding of the Gulf, Colorado, and Santa Fe Railroad, 1 mile west of the Coleman-Brown County line.

ROCKS OF THE CISCO GROUP

deflection on the electric logs because it is thin and lies between beds of shale.

CADDO CREEK FORMATION

The Caddo Creek formation was named by Plummer and Moore (1921, p. 117–118) for strata exposed in a creek in the Brazos River valley. As originally defined, it included Drake's Hog Creek shale below and the Home Creek limestone member above, named for localities in north-central Brown County and southeastern Coleman County, respectively. Because of miscorrelations in the past, as described below, the name Hog Creek shale member should be replaced. As redefined here, the formation includes, in descending order, the Home Creek limestone member and the Colony Creek shale member.

Unusual thickening of the limestone units in the uppermost part of the Canyon group near the junction of Home Creek and the Colorado River has resulted in much confusion in correlations with limestone units in the Caddo Creek and Brad formations as mapped elsewhere. Drake originally applied the term "Home Creek bed" to the upper noncherty limestone in the walls of the creek, and the name "Cherty bed" to the lower massive limestone, which contains abundant rounded nodules of chert. The chert-bearing limestone is now included in the Brad formation, as described above. Plummer and Moore (1921, p. 118–121) applied the name "Home Creek" to the prominent limestone at the top of the Canyon group in the Brazos and Colorado River valleys. This nomenclature has been in general use by geologists since that time. By tracing this member across northern McCulloch County to the type locality, and by studying the stratigraphy of northern Brown County, however, Nickell (1938, p. 116–118) found that the limestone called the Home Creek limestone by most geologists correlated with one higher on the slope than the one to which Drake had originally applied the term "Home Creek" at the type locality. Drake's Home Creek limestone, he found, was the one that Plummer and Moore had subsequently named the Ranger. Nickell's conclusions have recently been corroborated by Jenkins (1952, unpublished doctoral dissertation, University of Texas) in his mapping of the Mercury quadrangle.

Other miscorrelations to the north have been made in the past. Beds mapped as Home Creek across southern Brown County north to the outlier of Cretaceous rocks on which the town of Bangs is located were mapped as Ranger limestone member of the Brad formation (Plummer and Moore, 1921) north of the outlier. Thus, the Hog Creek shale of Drake (1893), named for a creek north of the outlier—in which the Bluff Creek shale as used by Cheney (1948, p. 20) is exposed—was believed to lie below Plummer and Moore's Home Creek limestone. Actually the Hog Creek shale of Drake lies above the Home Creek, and because of this confusion, Cheney (1948, p. 20) recommended discarding the term "Hog Creek" for the unit underlying the Home Creek and substituting the term "Colony Creek" shale. This name is taken from a stream in Eastland County between the towns of Ranger and Eastland. The author suspects that some of the miscorrelations in northern Brown County result from the misconception that the Ranger (probably the Cherty limestone of Drake at the Home Creek locality) is cherty throughout Brown County; whereas actually the Home Creek has considerably higher chert content in northern Brown County than the Ranger.

The thickness of the Caddo Creek formation at the outcrop ranges from about 55 feet along the Colorado River to about 75 feet in central Brown County. This northward increase in thickness apparently continues, and in northern Brown County, where the Caddo Creek is covered by Cretaceous rocks, its thickness as determined from well logs averages about 115 feet.

COLONY CREEK SHALE MEMBER

Because of the confusion that has resulted from the miscorrelations of the Home Creek limestone member and misapplication of the term "Hog Creek," adoption of Cheney's term "Colony Creek shale" (1948, p. 20) is recommended here for the shale member below the Home Creek limestone member. The unit is a gray shale that contains a generally conspicuous fine-grained thinly to thickly and irregularly bedded sandstone near its top. In the Lake Brownwood area the shale contains abundant fossils—chiefly crinoids, bryozoans, gastropods, and brachiopods—near the base, and grades upward into silty shale and sandstone. Generally, greenish-gray shale immediately underlies the Home Creek limestone member.

In the southern part of the area the Colony Creek shale member attains a thickness of about 25 feet, but locally the member is absent and the Home Creek limestone member is contiguous with limestone members of the Brad formation. In north-central Brown County the member averages about 60 feet in thickness; to the northeast, it is covered by rocks of Cretaceous age where its thickness in the subsurface is 75 to 80 feet.

HOME CREEK LIMESTONE MEMBER

The Home Creek limestone member extends northeast from its type locality in the southeastern corner of Coleman County across Brown County, and is covered by sandstones of the Lower Cretaceous series just

west of the town of May in northeastern Brown County. It ranges from a light-gray cherty vugular solid limestone to nodular irregularly bedded limestone containing partings of shale. Fossils are generally scarce in the outcrop area, but they consist of fusulinids, crinoid columnals, and some brachiopods of the *Composita* type.

Detailed thicknesses of the Home Creek in various places in the vicinity of the Colorado River have not been obtained because of irregular thickening of the limestone there. In most places in the southern part of Brown County the member consists of several beds of limestone as much as 8 to 10 feet thick separated by several feet of shale, the whole averaging about 30 feet thick; along the Colorado River, however, the member is estimated to exceed 50 feet in thickness. In the northern part of Brown County the Home Creek, consisting chiefly of massive to nodular limestone, averages from 10 to 15 feet in thickness.

CISCO GROUP

Drake (1893, p. 37–39) referred the lower part of what is now considered the Cisco group, including his Bluff Creek and *Campophyllum* beds, to Cummins' Canyon division. To Cummins' Cisco division he referred the rocks from the base of his Trickham bed up to the base of his Coleman Junction bed (Coleman Junction limestone of the Putnam formation, Wichita group, Moore, 1949). Plummer and Moore (1921, table 2) reclassified Drake's beds as members and considered his Bluff Creek bed to be a member of their Graham formation. The Gunsight limestone (Plummer, 1919) and the newly named Wayland shale were also included in the Graham formation which they placed in the Cisco group. Plummer and Moore (1921, table 2) placed the upper boundary of the Cisco at the top of their Coleman Junction limestone. Thus they considered the Cisco group to consist of all beds from their Home Creek Limestone to the top of their Coleman Junction limestone. They placed in the Thrifty formation all beds between their Wayland shale and the top of the Breckenridge limestone (Drake's Chaffin bed). Their Harpersville formation consisted of Drake's Waldrip and Saddle Creek beds. They also included the Pueblo, Moran, and Putnam formations in this Cisco group.

Hudnall and Pirtle (1929, 1931) placed the Graham formation in the Cisco group, agreeing that the base of the Cisco is the top of the Home Creek limestone. Sellards (1933, p. 113) also considered the top of the Home Creek as the base of the Cisco group, but he lowered the top of the Cisco to the top of Plummer and Moore's (1921) Camp Colorado limestone of the Pueblo formation. Bullard and Cuyler (1935, p. 221) retained these boundaries, but raised the Graham-Thrifty boundary to the top of the Speck Mountain limestone member. Cheney (1940, p. 91) suggested that the top of the Cisco

> should be placed at some widespread disconformity in the Harpersville formation above the Waldrip-Newcastle coal zone and below the *Schwagerina*-bearing 'Waldrip limestone No. 3' and the Saddle Creek limestone.

Moore (1949) lowered the top of the Cisco to the base of a sandstone in the Waldrip shale member of the Pueblo group, and discontinued the use of the name "Harpersville formation." The present report places the top of the Thrifty formation of the Cisco group at the top of the Chaffin limestone member, the most persistent mappable unit found in that part of the stratigraphic sequence, and the uppermost unit in which distinctive Pennsylvanian fusulinids have been found.

As the boundary between the Permian and the Pennsylvanian is obscure and probably gradational, no definite upper boundary between the two systems has been drawn.

The formations and members of the Cisco group as recommended in this report are as follows, in descending order:

- Thrifty formation:
  - Chaffin limestone member
  - Parks Mountain sandstone member
  - Breckenridge limestone member
  - Speck Mountain limestone member
- Graham formation:
  - Ivan limestone member
  - Wayland shale member
  - Gunsight limestone member
  - Bluff Creek shale member

GRAHAM FORMATION

The Graham formation was named by Plummer and Moore (1921, p. 125) for the county seat of Young County in the Brazos River valley. The base of the Graham in the Brazos River valley has been described as an unconformity by Lee and others (1938, p. 12–16) at the base of the deep sandstone-filled "Kisinger channel" in southeastern Young County. The channel erosion is described as cutting out the underlying Caddo Creek formation of the Canyon group and a part of the Ranger limestone member of the Brad formation. Channel erosion has cut to the lower part of the Bluff Creek shale member also in Brown County, and these channel-fill sandstones are reported to be the so-called Overall oil sand as recognized by petroleum geologists in the Overall oil field in Coleman County (Cheney and Eargle, 1951a, p. 1). In the western part

of that field, Cheney (1940, p. 90) reported that channel erosion has removed the Home Creek limestone member of the Caddo Creek formation. Red shale, which Cheney interpreted as indicating a zone of weathering associated with an unconformity, is found locally at the base of the Bluff Creek shale member of the Graham.

The boundary between the Graham and the Thrifty formations has been defined as the base of the Avis sandstone member (Sellards, 1933, p. 114; Nickell, 1938, p. 122), a prominent sandstone in the Brazos River valley. In the Colorado River valley, however, this boundary is not mappable because only discontinuous lenses of sandstone are present at the stratigraphic position of the Avis. Furthermore, the limestone next above the Avis, the Ivan limestone member, is also discontinuous. The terms "Avis" and "Ivan" were brought into the Colorado River valley from the Brazos River valley where the members are bettter developed. It is therefore recommended that the base of the Speck Mountain limestone member of the Thrifty formation, a persistent member throughout the whole Colorado River valley and most likely equivalent to the Blach Ranch limestone of Plummer and Moore (1921) in the Brazos River valley, be designated the boundary between the Thrifty and Graham formations. In places where the Speck Mountain limestone member has been replaced by a channel-fill conglomeratic sandstone, as by the Parks Mountain sandstone member in southeastern Coleman County, the boundary of the Graham and Thrifty is considered the base of the sandstone.

The thickness of the Graham formation, as defined here, is about 265 feet in southeastern Coleman County, and about 290 feet in northern Brown County.

BLUFF CREEK SHALE MEMBER

The Bluff Creek shale member was first described by Drake (1893, p. 37, 38) as the Bluff Creek bed from exposures along a tributary of the Colorado River in northeastern McCulloch County. Plummer and Moore (1921, p. 137) called the member the Bluff Creek shale and said that a thin yellow limestone in the middle of the unit may be equivalent to the Bunger limestone member in Young and Stephens Counties. Bullard and Cuyler (1935, p. 223–225) retained the name "Bunger" for a characteristic bed in northern McCulloch County that they said is unlikely to be continuous with the one at the type locality in Young County but occupies the same stratigraphic position. The shale above this Bunger they termed the Upper Bluff Creek shale and the shale below, the Lower Bluff Creek shale. In addition, they named a persistent ferruginous limestone bed lying 15 to 20 feet below their Bunger limestone and 35 to 45 feet above the base of their Lower Bluff Creek shale the White Ranch limestone, from exposures on the ranch of that name in northern McCulloch County, particularly along Bluff Creek.

Hudnall and Pirtle (1929) called a limestone unit in this interval in Brown County the North Leon limestone, believing it to be correlative with a thin limestone bed in central Eastland County named North Leon by Reeves (1922, p. 117). Cheney (1950, table following p. 11) and Cheney and Eargle (1951b) added the North Leon and Gonzales limestones to the list of names of limestones in the lower part of the Graham formation in Brown County. The Gonzales was first described by C. S. Ross (1921, p. 307) as a local bed in southeastern Stephens County, but its identity outside of a very local area and its correlation with other beds are questionable.

As many as six thin limestone units in the lower part of the Bluff Creek shale member are traceable for considerable distances across Brown and Coleman Counties, but most of these are discontinuous. Lenticular beds of sandstone are also found in several stratigraphic positions. One of these is above the limestone mapped as Bunger in Brown County by Cheney and Eargle (1951b), and another is near the base of the member. The sandstone lenses near the base of the member fill channels in many places and range from 1 or 2 feet to as much as 30 feet in thickness within short distances; they apparently are near the stratigraphic position of the "Kisinger channel" in Young County.

The exact correlation of the limestone beds in the lower part of the Bluff Creek shale member could not be determined because of lateral changes in lithologic character and because of the abrupt changes in intervals of shale between them. Inasmuch as they cannot definitely be mapped for long distances or traced to the type localities of the named beds, the formal usage of individual names for these beds whose type localities are chiefly in the Brazos River valley is not recommended for the Colorado River valley until more definite correlations can be established.

The Bluff Creek shale member is a gray marine shale; locally, the basal 10 to 30 feet is red shale, generally near channels. The more continuous beds of limestone are medium gray and dense; the less continuous are light gray, wavy bedded, and nodular. Some of the limestones are ferruginous and are yellowish brown in color. Fusulinids are found in most of the limestones except in those that are nodular or those that contain abundant algal structures. An ammonoid

zone is found near the top of the member in southeastern Coleman County and in southwestern Brown County. Colonies of horn corals are found at the top of the member in many places, generally immediately under the Gunsight limestone member. The Bluff Creek shale member ranges in thickness from about 90 feet along the Colorado River to about 140 feet in north-central Brown County.

GUNSIGHT LIMESTONE MEMBER

This member, called the *Campophyllum* bed by Drake (1893, p. 38, 39) and the Gunsight limestone by Plummer (1919), was divided into two beds, the Upper Gunsight and the Lower Gunsight limestones, by Hudnall and Pirtle (1931). It was later called the Gunsight limestone by Sellards (1933, p. 103), Bullard and Cuyler (1935, p. 225, 226), Nickell (1938, p. 119, 120), Cheney (1950, table following p. 11), and Jenkins (1952, unpublished doctoral dissertation, The University of Texas). It was again divided into Upper Gunsight limestone and Lower Gunsight limestone by Cheney and Eargle (1951b). Stafford (1960) and Terriere (1960), however, have shown by recent mapping in northern Brown County that the Upper Gunsight limestone as mapped by Cheney and Eargle is discontinuous to the north more than 1 or 2 miles east of Pecan Bayou. Locally, there are several limestone beds in the sequence; Terriere has shown that as many as three can be traced for considerable distance throughout Brown County. The limestones that are separated by only thin beds of shale, especially those above the banks of horn corals at the top of the Bluff Creek shale member and immediately below the Wayland shale member, are included in the Gunsight limestone member.

The Gunsight limestone member is generally fine grained and pale brownish yellow to gray. The upper bed commonly contains clear crystalline wavy structures believed to be of algal origin. In the shale below the uppermost of the three beds of limestone in this member in Brown County is a zone containing relatively abundant ammonoids. The zone generally contains a rich fauna of uncoiled cephalopods, brachiopods, corals, and crinoids. In southeastern Coleman and southwestern Brown Counties a shale rich in the same fauna, but notably containing, in addition, *Conularia* sp., lies near the top of the Bluff Creek shale member and underlies the lowermost of the two limestone beds of the Gunsight of that region. The sequence of beds included in the Gunsight limestone member ranges from about 17 feet along the Colorado River to 25 feet in north-central Brown County. Toward northern Brown County the upper part of the Gunsight changes to sandstone and the member is as thin as 13 feet.

WAYLAND SHALE MEMBER

The thick shale that forms broad lowlands above the Gunsight limestone member, part of which was termed the Trickham bed by Drake (1893, p. 39–42), was first correlated by Plummer and Moore (1921, p. 138) with their Wayland shale of Stephens County. They also listed and illustrated the highly distinctive fauna. Most authors have followed Plummer and Moore in bringing the term "Wayland" into the Colorado River valley. Although the term "Trickham" has priority, retention of the name Wayland shale member is recommended on the basis of this usage, and on the similarity in lithologic character, fossil content, and thickness to the Wayland of the Brazos River valley. The name "Wayland" is used generally in subsurface correlations to the west and north.

Above the Wayland shale member in the Brazos River valley is a sandstone that is very prominent and that fills channels cut into the Wayland. It was called the Avis sandstone by Plummer and Moore (1921), who considered the base of the sandstone the boundary between the Graham and Thrifty formations. The term Avis was first used in the Colorado River valley by Nickell (1938, p. 123, 124) who applied it to lenticular beds of sandstone at one or more positions below the Ivan limestone member. Inasmuch as sandstone is present only locally and the sandstone lenses occupy several stratigraphic positions in the Wayland, the name Avis sandstone member probably should not be brought into the Colorado River valley.

Some of the sandstone lenses are conglomeratic and fill channels (pl. 30*A*). Near Thrifty a channel sandstone cuts down within 50 feet or less of the Gunsight limestone member. It forms two high flat-topped mesas: one, called Keeler Knob, about half a mile east of Thrifty, and the other about a mile southeast of Thrifty (section 49, pl. 26).

The Wayland shale member is chiefly gray, commonly silty to sandy near the top, and contains abundant sideritic platy concretions. Locally, shale in the vicinity of the sandstone channel deposits is red. Several layers in the Wayland shale member contain abundant fusulinids. The richest of these layers is near the base of the member. Mollusks, mostly gastropods, are found in great numbers in scattered localities of limited areal extent near the base of the member. Along the Colorado River the member is about 100 feet in thickness, in the vicinity of Pecan Bayou it is about 75 feet in thickness, and in northern Brown County it is about 105 feet in thickness.

IVAN LIMESTONE MEMBER

The name "Ivan limestone member" is here recommended for the member that was described as the *Bellerophon* bed by the earlier authors (Nickell, 1938, p. 123, 124), the Ivan [limestone] by Cheney and Eargle (1951a, table following p. 11), and the Ivan limestone by Cheney and Eargle (1951b). As the name of a characteristic fossil found in a member does not constitute a satisfactory name for a member, and because the Ivan limestone member at its type locality in Stephens County in the Brazos River valley occupies the same general stratigraphic position as the *Bellerophon* limestone of early workers in the Colorado River valley, the extension to this area of the name Ivan limestone member is recommended even though it cannot be continuously traced from the Brazos River valley to the Colorado River valley.

Locally the Ivan limestone member changes in lithologic character from limestone to calcareous sandstone and (or) shale within short distances. In southeastern Coleman County the Ivan is a massive oolitic and algal(?) limestone, medium gray in color and about 8 feet thick. In this area it is overlain by a few feet of gray shale and a partly nodular limestone about 2 feet thick (pl. 30*B*). In eastern Coleman County, at a locality about 9½ miles southeast of Santa Anna and a mile east of Mukewater School, the Ivan consists chiefly of a single bed of limestone 12 feet thick; a quarter of a mile to the north this member consists of two beds of limestone, each 4 feet thick, separated by 4 feet of shale containing horn corals. Another quarter of a mile northwest it grades into shale and sandstone containing a zone of calcareous shale having abundant fusulinids.

In places the Ivan limestone member is as much as 18 feet thick, as at section 37 (pl. 26) on the Brown-Coleman County line 4 miles west-southwest of Bangs; but within short distances it becomes much thinner and has been locally removed by channel erosion. In northern Brown County the member consists chiefly of a calcareous sandstone and shale, in places containing masses of syringoporoid corals.

SHALE OVERLYING THE IVAN LIMESTONE MEMBER

The shale overlying the Ivan limestone member and underlying the Speck Mountain limestone member of the Thrifty formation was called the Speck Mountain clay bed by Drake (1893, p. 43, 44), and was discussed as a separate shale member by Nickell (1938, p. 123, 124). It is chiefly silty or sandy, and red and contains locally abundant limonite concretions. The basal part of this shale unit contains lenticular sandstone and conglomerate, filling channels that locally cut through the Ivan limestone member.

Immediately below the Speck Mountain limestone member is a thin bed of coal that extends over a wide area in northwestern Brown County. In the bed of Mud Creek, a short distance above its junction with Jim Ned Creek 3½ miles northwest of Thrifty (section 38, pl. 26), the coal bed is 3½ inches thick and is underlain by a thin bed of clay that grades downward into gray shale. The shale overlying the Ivan limestone member ranges in thickness from about 45 to 65 feet in southeastern Coleman County to about 25 to 40 feet in the northern part of Brown County.

THRIFTY FORMATION

The Thrifty formation was named by Plummer and Moore (1921, p. 152, 153) for the small village of Thrifty in northwestern Brown County which is located on the outcrop of the Gunsight limestone member. Good exposures of the formation are from 1 mile to several miles west of the village. Plummer and Moore (1921) originally described this formation as including sandstone, shale, and limestone overlying their Wayland shale and extending to the top of their Breckenridge limestone (the limestone at the top of Drake's Chaffin bed). The various usages of the name by later authors are shown in the classification chart, plate 27.

As redefined here, the Thrifty formation consists of two persistent beds of limestone, another less persistent bed of limestone, and a lenticular channel-fill sandstone, which have been given the member names listed below. Relatively nonresistant sandstone and shale occupy the intervals between the more resistant units here considered members. The Thrifty formation consists of the following members in descending order:

- Chaffin limestone member
- Parks Mountain sandstone member
- Breckenridge limestone member
- Speck Mountain limestone member

The Thrifty formation has been redefined to facilitate mapping in the Colorado River valley. The formation is here considered to lie between the base of the Speck Mountain limestone member and the top of the Chaffin limestone member, the uppermost persistent limestone of Pennsylvanian age as determined by fusulinids. The Speck Mountain and the Chaffin are traceable across the entire area except locally where channel erosion has cut through one or the other. Where such channel erosion exists, the base of the channel-fill sandstone has been used for the limit of the formation.

Along the Colorado River in southern Coleman County the thickness of the Thrifty formation is about 55 feet and in northern Brown County the average thickness is about 100 feet.

SPECK MOUNTAIN LIMESTONE MEMBER

The Speck Mountain limestone member, named by Drake (1893, p. 39), is generally continuous across the whole area. It has been called the Breckenridge limestone by Hudnall and Pirtle (1929, 1931), but the Speck Mountain limestone member by most other authors. It has been correlated with Plummer and Moore's (1921) Blach Ranch limestone of the Brazos River valley by Cheney (1948, 1949, 1950), and this correlation has been verified in reconnaissance with P. T. Stafford during this survey. Its type locality is Speck Mountain, a mesa capped with the limestone member in southern Coleman County about a mile north of the Home Creek crossing of Whon-Santa Anna road. It is a firm massive dark-gray limestone that breaks along vertical joints, forming blocks that creep down the scarp of the cuesta it forms (pl. 30*C*). It contains Foraminifera, of which fusulinids are common but not generally abundant, and abundant minute algal(?) structures. It ranges from 1 to 3 feet in thickness.

SHALE OVERLYING THE SPECK MOUNTAIN LIMESTONE MEMBER

Because Drake's descriptions apply chiefly to beds in the vicinity of the Colorado River and southward, his terminology may not apply perfectly to the beds to the north where differences exist in the stratigraphy. He described as one unit the shale and sandstone sequences overlying the Speck Mountain limestone member which extend up to the next highest persistent limestone, the Chaffin limestone member. He named the unit the Lohn bed for a locality south of the Colorado River in northern McCulloch County (1893, p. 44, 45). This terminology applies to the sequences as they crop out south of Home Creek in southern Coleman County. He concluded that the Chaffin limestone member spilts into two beds north of Home Creek; his Lohn bed from there northward extends up to his lower Chaffin limestone bed. In the present survey, however, Drake's lower Chaffin was found to be the Breckenridge limestone member, which does not extend south of the vicinity of Home Creek. His Lohn bed, therefore, includes a thicker stratigraphic interval south of Home Creek than that north of the creek. For that reason the name Lohn is being discarded as a stratigraphic name for use in eastern Coleman and northwestern Brown Counties. The Lohn bed of Drake was called the Lohn shale by Sellards (1933, p. 103) and by Nickell (1938, p. 125–126).

The shale immediately above the Speck Mountain limestone member in eastern Coleman and northwestern Brown Counties is generally gray and contains abundant and characteristic marine fossils. It contains especially a concentric cup-shaped bryozoan that apparently began growth attached to another object, commonly a shell or a crinoid columnal. Other types of bryozoans, brachiopods of several genera, abundant crinoids, horn corals, and, more rarely, fusulinids and trilobites are also found. This gray shale grades upward into red and variegated shale which extends up to the base of the Breckenridge limestone member. Southward from the vicinity of Home Creek the Breckenridge limestone member has not been found, and most of the interval from the Speck Mountain limestone member to the Chaffin limestone member consists of red to gray shale, in places silty and sandy, and in places containing sandstone and conglomerate of the Parks Mountain sandstone member.

BRECKENRIDGE LIMESTONE MEMBER

The Breckenridge limestone member was named by Plummer and Moore (1921, p. 155) for a gray massive resistant limestone, 3 or 4 feet thick and forming a prominent escarpment in and about Breckenridge, the county seat of Stephens County. They considered it easily traceable to the northeast and south and possibly identifiable with the upper Chaffin bed of Drake in the Colorado River valley. It was traced as far northeast as the northeastern quarter of Jack County and as far southwest as northwestern Eastland County by the American Association of Petroleum Geologists cooperative mapping committee, as shown on the geologic maps of Jack (Armstrong, 1929), Young (Plummer and Fuqua, 1937), Stephens (Bradish, 1929), and Eastland (Wender, 1929) Counties. The bed here correlated with the Breckenridge is shown on the geologic map of Coleman County (Hudnall and Pirtle, 1929) as the Lower Crystal Falls limestone. Bullard and Cuyler (1935) followed Plummer and Moore's correlations, and the bed they mapped as Breckenridge through northern McCulloch County is therefore the Chaffin limestone of Drake. Cheney and Eargle (1951b) mapped the Breckenridge throughout northwestern Brown County and showed it in the interval between their Chaffin and Speck Mountain limestones.

During the preparation of this report, the Breckenridge limestone member was mapped as far southwest as Home Creek, and was found to be correlative with the bed Drake considered the lower Chaffin limestone. From the vicinity of Home Creek southwest to the

Colorado River in southeastern Coleman County, this limestone and the shale immediately above and below it is removed by channel erosion and the channel filled by the Parks Mountain sandstone member. The Breckenridge limestone member has not been recognized south of the Colorado River; however, the rocks were not studied in detail more than a mile south of the river.

The member termed Breckenridge by Cheney and Eargle (1951b) has recently been mapped through inliers in overlapping Cretaceous rocks in southern Eastland County by P. T. Stafford and through northern Eastland County by R. J. Burnside. By reconnaissance, Stafford and Eargle traced this and the underlying shale and Speck Mountain limestone member north to the town of Breckenridge where it was definitely correlated with the Breckenridge limestone described by Plummer and Moore (1921). Thus, the outcrop of the Breckenridge limestone member has been traced from the vicinity of Home Creek to the vicinity of Breckenridge, an airline distance of nearly 90 miles. If mapping and correlations to the northeast by the American Association of Petroleum Geologists cooperative mapping committee are correct, it may extend an additional 70 miles in that direction.

The Breckenridge limestone member is 20 to 40 feet above the Speck Mountain limestone member. Drake, considering it a lower bed of the Chaffin limestone (1893, p. 47), described it as "white, and at places pink" and "being friable, appears less prominent than the upper [bed]." Characteristically it is pale greenish gray to almost white, blotched with pale reddish purple. At the most southerly place where it was found, in southeastern Coleman County in the vicinity of Home Creek, it consists of about 1 foot of nodular limestone overlying 1 foot of firmer limestone. This member is continuous to the north, except locally where removed by channel erosion, and is generally a nodular bed a foot or two in thickness. It gradually increases to a thickness of about 3 feet in northern Brown County where it forms a ledge of firm limestone.

The Breckenridge limestone member in the area of this report is thickest in northern Brown County near the community of Blake. The exposure where the limestone and underlying beds can best be observed is at the western end of a breached dam on Red River, 1½ miles S. 35° W. of Rudco Gas and Oil Co.'s gasoline plant, 2½ miles northwest of Blake church. There, 3 feet of light-gray algal(?) limestone, some of which is nodular, overlies about 20 feet of greenish-olive-gray to purplish-red mottled clay. Overlying the limestone is about 5 feet of shale and above that is a 1-foot limestone bed that is generally fusulinid bearing. Another more accessible place where the formation can be seen is at the eastern end of the bridge over the Red River on the road from Cross Cut to Williams School, about 2.4 miles west-northwest of Blake church. Good exposures are also found under the bridge over Pecan Bayou on State Highway 279 between Brownwood and Abilene, and half a mile east of the bridge on the ranch of Bransford Eubank.

CLAY OVERLYING THE BRECKENRIDGE LIMESTONE MEMBER

The beds that intervene between the Breckenridge and Chaffin limestone members in Brown County and north of Home Creek in eastern Coleman County are red clay containing abundant hematite nodules and plant fossils. Plummer and Bradley (1949) studied its potentialities as a brick clay, and named it the Quinn clay for exposures in Eastland County, where it has been extensively mined. In many places lenticular beds of sandstone are found within this unit, particularly near the base, and some channel-fill conglomerate is also present. The conglomerate may perhaps be correlated with the Parks Mountain sandstone member, described below, inasmuch as it occupies the same stratigraphic interval.

In the vicinity of Home Creek the clay overlying the Breckenridge is pale reddish and purplish brown and contains abundant ferruginous concretions. It contains a 3-foot bed of calcareous sandstone about 5 feet above the Breckenridge limestone member. From Home Creek to the Colorado River the Breckenridge limestone member and some of the shale above and below this limestone have been cut out by the channel erosion that preceded or accompanied the deposition of the Parks Mountain sandstone member, the top of which is only 20 feet below the Chaffin limestone member.

In the area immediately south of the Colorado River no prominent beds intervene between the Chaffin and Speck Mountain limestone members. The interval consists chiefly of gray shale—red near the base—that contains a coal bed at its top. This coal was mined many years ago near the mouth of Little Elm Creek, a tributary entering the Colorado River from the south, about a quarter of a mile south of Chaffin crossing. The interval contains also a thin-bedded sandstone, which thickens to the northwest toward the river and is evidently an extension of the Parks Mountain sandstone member. This shale unit between the Chaffin and Speck Mountain limestone members, about 50 feet thick, has been termed the Lohn bed by Drake (1893, p. 44–45) in McCulloch County. Inasmuch as the term "Lohn" did not apply to exactly the same interval

north of the river, as previously stated, it is not recommended for use in Coleman and Brown Counties.

PARKS MOUNTAIN SANDSTONE MEMBER

A thick unit of conglomeratic sandstone capping Parks Mountain north of the Colorado River in southeastern Coleman County was named and described by Drake as the Parks Mountain conglomerate and sandstone bed "because of its irregular position and relation to the coal beds" (1893, p. 45). It was termed the Avis sandstone by Bullard and Cuyler (1935, p. 232, 233) because that name had been applied to the first conglomeratic sandstone bed above the Wayland shale of Plummer and Moore (1921) in the Brazos River valley and because this conglomerate holds the same relation to the Wayland along the Colorado River. The Avis of Plummer and Moore (1921), however, has been shown by Lee to have originated before the Ivan limestone member was deposited (Lee and others, 1938, p. 56), and, therefore, the name Avis of Bullard and Cuyler (1935) can not be correctly applied to the stratigraphically higher Parks Mountain sandstone member.

In the area where the Parks Mountain is a channel-fill deposit, it has a thickness of at least 60 feet. This member is overlain by carbonaceous shale and coal near the Colorado River, and by ferruginous red shale farther north. The channel-fill conglomeratic facies of this member is of small areal extent along the outcrop, confined chiefly to the area within a few miles north of the Colorado River. It grades laterally into a thin-bedded sandstone of wide extent, ranging in thickness from a few feet to 30 feet or more in the northern part of the area covered by this report. In several places in northern Brown County a channel-fill conglomerate occupies the position of the Breckenridge limestone member and forms high mesas a mile or more in length. This conglomerate and lenticular beds of sandstone elsewhere between the Chaffin and Breckenridge limestone members may be correlated with the Parks Mountain sandstone member.

CHAFFIN LIMESTONE MEMBER

Drake (1893) described and used the name "Chaffin beds" for a distinctive limestone and coal at the now abandoned Chaffin mines about a quarter of a mile southwest of Chaffin crossing on the Colorado River, 1½ miles east of Waldrip, McCulloch County, near the mouth of Little Elm Creek. He found that the limestone was cut out by a channel immediately north of the river, except in one locality, but traced the limestone across the rest of Coleman and Brown Counties. From the vicinity of Home Creek northward he found two limestones and called the lower one the lower Chaffin limestone. The lower Chaffin limestone is here correlated with the Breckenridge limestone member.

The generally persistent upper part of the Chaffin limestone member has been variously called the Breckenridge limestone by Plummer and Moore (1921, p. 155), the Upper Crystal Falls limestone by Hudnall and Pirtle (1929, 1931), the Chaffin limestone by Sellards (1933, p. 103, 115), the Breckenridge limestone by Bullard and Cuyler (1935, p. 233–235), the Chaffin limestone by Nickell (1938, p. 127, 128), the Crystal Falls limestone by Cheney (1950, table following p. 11), and the Chaffin limestone by Cheney and Eargle (1951b).

The Chaffin limestone member immediately south of the Colorado River ranges from about 15 feet in thickness at the Chaffin mines to about 7 feet in thickness at the locality of section 1, plate 25. At this locality it is a slabby irregularly bedded gray limestone, stained purplish red in large spots. It contains abundant fusulinids and thin wavy structures of clear calcite which may have been precipitated by algae. These structures characterize the bed over most of Coleman County.

The limestone becomes thinner and generally darker gray to the north. In Brown County it averages only 1 to 2 feet thick, is massive, and breaks into vertical joints, although weathering usually causes it also to break horizontally into slabs. It is nearly everywhere abundantly fusulinid bearing. It is cut by a channel filled with sandstone, siltstone, and clay in a few places in northern Brown County.

PERMIAN SYSTEM

WICHITA GROUP

Rocks overlying the Cisco group of the Pennsylvanian system in Brown and Coleman Counties are of Wolfcamp age and belong to the Pueblo formation of the Wichita group. Nomenclature of rocks of the Pueblo formation is given on the diagram showing history of classification (pl. 27). These rocks were designated by Sellards (1933, p. 103) as the upper part of the Pennsylvanian Cisco group, but now are considered to be Permian. Moore (1949) assigned the Wichita group to the Permian, and it is his nomenclature that is used for this part of this report except for the addition of the Coon Mountain sandstone member.

The base of the Pueblo formation of the Wichita group has been defined by Moore (1949, sheet 2) as an obscure disconformity that separates the Permian from the Pennsylvanian. The exact boundary between the two systems is in question and no additional evidence

was obtained during this study to clarify its position. As Moore indicated, the beds in which this boundary is presumed to fall show great lithologic variation. A number of lenticular beds of sandstone have been found in the interval between the highest persistent limestone beds of the Waldrip shale member above and the Chaffin limestone member below. Although some of these beds of sandstone can be traced for several miles, none of them has been found to be persistent laterally across the area considered here. Lloyd G. Henbest (written communication, April 13, 1957) reports as follows:

> The paleontological change from the Pennsylvanian to the Permian in the Colorado River area is transitional like that of the lithogenetic change. Studies with D. A. Myers and R. C. Douglass indicate that such characteristic Permian fusulinids as *Pseudofusulina* sp., *Schubertella kingi* Dunbar and Skinner, and *Dunbarinella(?) sp. aff. D.(?) compacta* (White) appeared at different levels in the Thrifty and Waldrip sequence. All three of these fusulinids are first found in direct association in the Waldrip No. 1 bed of Drake. Although it appears that the Pennsylvanian-Permian boundary is within the interval between the top of the Thrifty formation and the base of Drake's Waldrip No. 1 bed, it is recommended that, for practical purposes, the boundary be placed at the base of the Waldrip shale member.

Despite the heterogeneity of the deposits, the lack of traceable units, conclusive paleontologic evidence, and definite structural evidence of an unconformity in this area, the boundary between Permian and Pennsylvanian for practical purposes is drawn at the base of the Waldrip shale member in this report. In this study the term Waldrip shale member is used for the entire unit between the base of the Saddle Creek limestone member of the Pueblo formation and the top of the Chaffin limestone member of the Thrifty formation.

PUEBLO FORMATION

The Pueblo formation consists of the following members in Brown and Coleman Counties, in descending order:

- Camp Colorado limestone member
- Salt Creek Bend shale member
- Stockwether limestone member
- Coon Mountain sandstone member
- Camp Creek shale member
- Saddle Creek limestone member
- Waldrip shale member

All members except the Salt Creek Bend shale member were named and described as beds by Drake (1893, p. 39). Drake's Bed 13 was named Salt Creek Bend shale by Bullard and Cuyler (1935, p. 249, 250). The Coon Mountain sandstone of Drake (1893, p. 51) is retained for this report because the member—chiefly a sandstone and conglomerate deposit which, with finer-grained sediments, fills one or more deep channels—forms a prominent ridge in northwestern Brown and northeastern Coleman Counties. The Pueblo formation thins toward the north along the outcrop from about 200 feet along the Colorado River in southern Coleman County to about 115 feet in northwestern Brown County. The Waldrip shale member, the Saddle Creek limestone member, and locally the Coon Mountain sandstone member are the only members of the Pueblo formation shown in measured sections on the correlation chart (pl. 26) and described in this report.

WALDRIP SHALE MEMBER

The Waldrip shale member was described by Drake (1893, p. 47–50), who called it the Waldrip bed as consisting principally of blue clay, sandstone, coal, carbonaceous shale, and limestone. The beds of sandstone, he found, are mostly near the bottom of the unit and are quite irregular in thickness; three beds of limestone near the top of the Waldrip he designated by the numbers 1, 2, and 3, beginning with the lowest. Plummer and Moore (1921, p. 160–163) included in their Harpersville formation the beds later called Waldrip shale by Moore (1949), together with the Saddle Creek limestone member.

Bullard and Cuyler restricted the term Waldrip to about 115 feet of beds from the base of the No. 1 limestone to the base of the Saddle Creek limestone member. The lower part of the unit to the top of the Chaffin limestone member of the Thrifty formation (their Breckenridge limestone) they found to be about 90 feet in thicknes, and they called this part the Lower Harpersville beds. Nickell (1938, pl. 8) found the Waldrip beds of Drake to be 238 feet thick. Cheney (1940, p. 91) considered that the upper boundary of his Cisco series

> should be placed at some widespread unconformity in the Harpersville formation above the Waldrip-Newcastle coal zone and below the *Schwagerina*-bearing Waldrip limestone No. 3. . . .

The beds underlying this systemic boundary and overlying his Chaffin formation he termed the Obregon formation. Moore (1949) placed the Permian and Pennsylvanian boundary 40 to 55 feet below the top of the Waldrip shale member, between limestones 1 and 2 of Drake.

No traceable horizon was found during this survey which could be considered the boundary between the Permian and Pennsylvanian. The whole interval that Drake called the Waldrip beds is, therefore, for purposes of mapping and description, considered the Waldrip shale member of the Pueblo formation. The

Waldrip lies between the top of the Chaffin limestone member of the Thrifty formation, and the base of the Saddle Creek limestone member of the Pueblo formation. The lower beds of the Waldrip are not completely exposed along the Colorado River and the thickness of some beds in this part of the member could only be estimated. The thickness (85.2 feet) of the interval from the Chaffin limestone member up to the No. 1 limestone of Drake (pl. 26, section 1) is from measurements by Bullard and Cuyler (1935, p. 236). This compares closely with the interval of 93 feet interpreted from the log of a well drilled 2½ miles west of Waldrip (Cheney, 1948, well 6 on cross section).

Whereas most shale in the lower part of the Waldrip is gray, the shale in the upper part is red and variegated. Hematite nodules as large as an inch in diameter are abundant in some zones. Some of the nodules incorporate marine fossils. Several beds of coal have been found in the lower part of the Waldrip shale member.

The lower limestones (Nos. 1 and 2) of the sequence near the top of the Waldrip shale member are not persistent to the north. In many places, however, a fossiliferous zone is found about 25 feet below the No. 3 limestone of Drake. Moore (personal communication) believes this to be the northern extension of the No. 1 limestone. This zone is rich in large crinoid columnals, thick shells of *Chonetina* and other brachiopods, and fusulinids, and contains scattered shark teeth. A light-greenish-gray siltstone that underlies this zone in some places contains abundant pelecypod casts.

The upper limestone, Drake's No. 3, is gray, massive, vertically jointed, and laterally persistent, and forms a conspicuous ledge below the Saddle Creek limestone member. It contains abundant fusulinids, among which Roth (1931, p. 295) found the genus *Schwagerina*.

SADDLE CREEK LIMESTONE MEMBER AND OVERLYING ROCKS

West of the extensive lowland formed in the Waldrip shale member stands a continuous, high cuesta capped by the Saddle Creek limestone member. This limestone is generally dense, very light to medium gray, and only locally fusulinid-bearing. It weathers into rounded blocks or slabs and is moderately resistant to weathering. In many places weathering on the high escarpment has removed all except a few feet of the lower part of the Saddle Creek limestone member.

In northern Brown County extensive channel erosion has removed the Saddle Creek in a number of places, especially over a wide area on Coon Mountain—locally called The Holloway—in northwestern Brown County. In places this channel erosion has cut down to within about 50 feet of the Chaffin limestone member. The sandstone and conglomerate deposited in these channels was called the Coon Mountain bed by Drake. Plummer and Moore (1921, p. 172) considered it of Cretaceous age, but it was again referred to the Pennsylvanian and called the Coon Mountain sandstone by Sellards (1933, p. 103), and by Nickell (1937, p. 133). Inasmuch as it was not extensively exposed in the area mapped by Moore (1949), he did not use the name. The exact relations of the Coon Mountain sandstone member to the beds surrounding it are only partially known, and the thick body may be a complex of two or more channels, the later one or ones superposed on the earlier in the outcrop area. This member is, therefore, tentatively placed in the section where Drake placed it until future detailed work explains its relations more exactly. Other than for the Coon Mountain sandstone member, the nomenclature used by Moore (1949) for the members of the Pueblo formation is recognized by this study and the reader is referred to Moore (1949, sheet 2) for detailed descriptions of the other members of the formation.

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