Geology of the Wayland Quadrangle, Stephens and Eastland Counties, Texas

GEOLOGICAL SURVEY BULLETIN 1201-C

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

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By DONALD A. MYERS

CONTRIBUTIONS TO GENERAL GEOLOGY

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Pennsylvanian and Lower Permian rocks of an area in central Texas

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GEOLOGY OF THE WAYLAND QUADRANGLE, STEPHENS AND EASTLAND COUNTIES, TEXAS

By DONALD A. MYERS

ABSTRACT

The Wayland quadrangle is in north-central Texas about 90 miles west of Fort Worth. Pennsylvanian and Lower Permian sedimentary rocks crop out at the surface and dip gently to the west-northwest; older Paleozoic rocks lie in the subsurface. Rocks belonging to the lower part of the Cretaceous System overlap the Pennsylvanian and Permian rocks in the southeastern part of the quadrangle and occur as isolated patches along the south edge of the area. Quaternary alluvium covers older rocks along stream valleys.

Pennsylvanian rocks comprise the upper part of the Canyon Group and the Cisco Group. Permian rocks are represented by the lower part of the Wichita Group. The extremely thin Chaffin Limestone Member of the Thrifty Formation (Pennsylvanian) was mapped with the overlying Pueblo Formation (Permian). The Pennsylvanian-Permian boundary may be in the lower member of the Pueblo.

The Canyon Group is represented by the Home Creek Limestone Member and the Colony Creek Shale Member of the Caddo Creek Formation.

The Cisco Group is represented by the Graham and Thrifty Formations. The Graham Formation, where measured, contains 53–71 percent shale, 22–35 percent sandstone and conglomerate, and 7–12 percent limestone. The Thrifty Formation contains 39–45 percent shale, 25–33 percent sandstone and conglomerate, and 28–30 percent limestone. The sandstone and conglomerate in both the Graham and Thrifty Formations occur mostly as channel-fill deposits. Some shale and siltstone probably was deposited also in channels.

The Wichita Group is represented by the lower part of the Pueblo Formation. The Pueblo Formation comprises the Waldrip Shale Member, the Saddle Creek Limestone Member, and an overlying chaotic sequence of channel-fill deposits of sandstone and conglomerate.

Cretaceous rocks of early Trinity age are composed of sandstone and conglomerate, some of which have opaline cement.

In the Wayland quadrangle large amounts of oil and gas have been produced from rocks ranging in age from late Middle Pennsylvanian (Strawn Group) to Ordovician (Ellenburger Group).

INTRODUCTION

PURPOSE OF THE STUDY

In 1949 the U.S. Geological Survey, in cooperation with the Bureau of Economic Geology, University of Texas, undertook a study of the Pennsylvanian and Lower Permian sedimentary rocks of central and western Texas to obtain a better understanding of their lithology, distribution, stratigraphic relations, and conditions of deposition. Some of the results of this study have been presented by Burnside (1959), Heck, Yenne, and Henbest (1952), Eargle (1960), Myers (1958; 1960a, b), Myers, Stafford, and Burnside (1956), Stafford (1959; 1960a, b), and Terriere (1960, 1963). This report on the geology of the Wayland quadrangle is another in the series. The geologic map (pl. 1) shows the areal distribution of Upper Pennsylvanian and Lower Permian rocks in their outcrop areas in the Wayland quadrangle, and the text describes the stratigraphic relations of these rocks.

LOCATION AND GEOGRAPHIC FEATURES

The Wayland quadrangle is in north-central Texas about 90 miles west of Fort Worth. It lies almost wholly within Stephens County, but in the southern part of the area (fig. 1) it includes an east-west strip of Eastland County that is about 15 miles long and 1 mile wide. Breckenridge, the county seat of Stephens County, lies just to the north of the quadrangle. The communities of Necessity, Gunsight, and Wayland lie within the quadrangle. Eastland, the county seat of Eastland County, is a few miles to the south.

The area lies north of the Callahan Divide (fig. 1), a broad ridge that separates the Colorado River and Brazos River drainage basins. Upper Pennsylvanian and Lower Permian rocks are exposed on the north and south sides of the divide but are covered at its crest by Cretaceous rocks. Because of this cover and the lack of subsurface information from wells on the divide, many uncertainties have existed in the correlation of the Pennsylvanian and Permian rocks of the two drainage basins. The present study was designed to remove some of these uncertainties.

The quadrangle lies in two distinct physiographic provinces. The southeastern part (pl. 1) is underlain by Lower Cretaceous rocks and is characterized by a gently rolling plain having shallow stream valleys. The remainder of the quadrangle, underlain by Upper Pennsylvanian and Lower Permian rocks, is characterized by more rugged terrain having valleys eroded in shale and intervening cuestas capped by limestone or by sandstone and conglomerate.

The relief in the Wayland quadrangle is about 350 feet; few prominences, however, stand more than about 150 feet above the surrounding

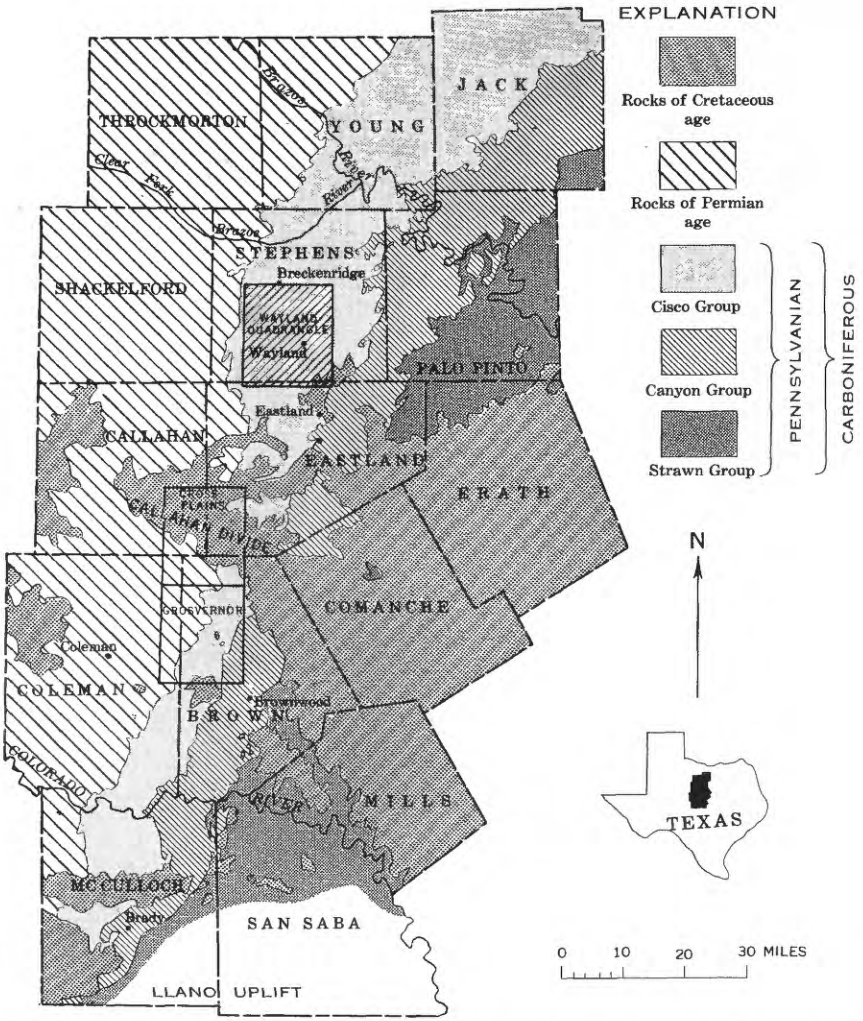

FIGURE 1.—Outcrop areas of major rock units of north-central Texas in relation to the counties and quadrangles mentioned in text.

terrain. The relatively broad, flat major stream valleys drain to the north; meandering stream channels are incised 10 feet or more into the valley floors.

Terrane underlain by shale generally supports sparse vegetation that consists mostly of mesquite and cactus. Most of the terrane underlain by limestone also is sparsely vegetated, but oak trees generally grow along the base of the outcrop and along well-defined bedding planes and joint systems. Most of the terrane underlain by sandstone is densely covered by oak trees. Water holes or tanks for livestock,

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formed by placing earthen dams in ravines or other topographically low areas, are generally found in areas underlain by shale. Those emplaced in sandstone terrane usually will not hold water.

Access within the quadrangle is good. U.S. Highway 183, extending south from Breckenridge, bisects the area. At Breckenridge it intersects U.S. Highway 180, which crosses the northeastern part of the quadrangle. Many county roads and privately owned ranch roads provide access to the rest of the area.

FIELDWORK AND ACKNOWLEDGMENTS

The Wayland quadrangle was mapped intermittently between 1955 and 1958 on aerial photographs at a scale of approximately 1:20,000. The planimetric base map (pl. 1) was compiled by photogrammetric methods from Army Map Service photography at a scale of approximately 1:67,000. Geologic data were transferred from the photographs to the planimetric base at the time of compilation.

The author thanks Robert T. Terriere of the Geological Survey for field assistance during November 1957 and thanks Dr. L. F. Brown, Jr., of the University of Texas Bureau of Economic Geology, for beneficial discussions of the stratigraphy of the upper part of the Thrifty Formation and the lower part of the Permian System and for help in identifying the Gonzales Limestone Member of the Graham Formation.

Throughout the text, reference is made to field locality numbers and to U.S. Geological Survey fossil-collection locality numbers shown on plate 1. Field locality numbers have an "M" prefix followed by four digits and refer to a measured stratigraphic section or to a specific outcrop. U.S. Geological Survey fossil-collection locality numbers have five digits and indicate collections of fossils; those with an "f" prefix indicate collections of Foraminifera.

Stratigraphic sections were measured and described in detail in critical areas or wherever control was deemed necessary. Fusulinid Foraminifera are generally common in the limestone beds, and sufficient collections were made to establish the variety of fusulinids typical of various units through most of the stratigraphic sequence. Once this fauna was established, the fusulinids proved very useful in establishing correlation among the various limestone units. Megafossils were identified by Helen Duncan (corals and bryozoans), Mackenzie Gordon, Jr. (brachiopods and cephalopods), Ellis L. Yochelson (pelecypods and gastropods), and D. H. Dunkle, U.S. National Museum (vertebrate remains) (written commun., 1956, 1957). These fossils are listed in conventional biological arrangement in table 1. A few megafossils were identified in the field by the author, and these are mentioned in the text but are not listed in table 1. Algae were identi-

fied by Richard Rezak (written commun., 1956, 1957). Foraminifera were identified by the author.

The shale and some of the sandstone that crop out in the quadrangle generally are poorly exposed; thus, the limestone beds are the only units that can be traced successfully at the surface. These units were traced and mapped in detail, both by interpretation of aerial photographs and by ground traverses. The thickness of the limestone units is generally exaggerated where represented on the map by a line. Locally, however, as on some hilltops, ridges, and valley bottoms, the outcrop is many times wider than the line. No attempt was made to portray these areas of widened outcrop, and, where they exist, the line on the map represents the base of the limestone unit or member.

Alluvium was mapped almost entirely by photogeologic methods, the contact between alluvium and bedrock being designated at a break in slope along the valley sides; placement of the contact was modified locally, after observations in the field.

LITHOLOGIC TERMINOLOGY

The following terminology was used in describing rock units in the field.

Limestone was classified according to grain size by Grabau's classification as outlined in Pettijohn (1949, p. 300–307). **Calcilutite** is a detrital limestone composed of silt-sized and smaller particles, **calcarenite** is a detrital limestone composed of sand-sized grains, and **calcirudite** is a detrital limestone composed of particles larger than sand size.

The term **"bioclastic limestone"** is used by the author to refer to limestone composed mostly of visible fragmented or unfragmented remains of organisms.

The classification of clastic noncarbonate rocks is based on grain size, following the Wentworth scale. The term **"shale"** is used by the author as an all-inclusive term for any clastic rock composed of smaller than sand-sized grains; however, where grain size could be determined in the field, the terms **"claystone"** and **"siltstone"** were used.

The color of a rock was determined by comparison with the "Rock-Color Chart" (Goddard and others, 1948).

Petrographic thin sections were prepared from samples of limestone and sandstone. Selected samples of each limestone bed were analyzed for calcium-magnesium ratios to determine whether compositional differences among the limestone units are significant enough for use as bases for correlation. The results, summarized in table 2, were negative.

TABLE 1.—*Stratigraphic distribution of some megafossils from the Wayland quadrangle, Stephens and Eastland Counties, Tex.*

[×, definite identification; cf, tentative identification]

Species	Group	Cisco										Wichita				
	Formation	Graham									Thrifty	Pueblo				
	Member	Gunsight Limestone						Wayland Shale		Ivan Limestone	Breckan-ridge Lime-stone	Waldrip Shale			Waldrip(?) Shale	
	U.S. Geol. Survey loc. No.	16630-PC	16631-PC	16632-PC	16633-PC	16759-PC	16762-PC	16634-PC	16761-PC	16757-PC	16763-PC	16792-PC	16789-PC	16790-PC	16760-PC	16791-PC	16793-PC
Coelenterata																	
Lophamplexus sp.													×				
Lophophyllidium plummeri Jeffords									×								
sp.		×			×			✓					×	×			
Lophophyllidid corals, undet.				×		×										×	
Caninia sp.		×	×	×	×												
Syringoporoid coral, undet.					×												
Conularid, undet.		×															
Bryozoa																	
Fistuliporoid bryozoans, undet.		×	×	×	×	×		×		×	×	×	×	×			
Stenoporoid bryozoans, undet.		×	×	×	×		×	×		×	×		×				
Fenestella sp.													×				
Polypora sp.								×					×				
Fenestrate bryozoans, undet.			×		×	×			×	×	×						
Rhombopora sp.							×		×				×				
"*Meekopora?*" sp.													×				
Acanthocladia sp.													×				
Echinodermata																	
Crinoid calyx cf. *Delocrinus*													×				
Crinoid calyx, undet.													×				
Crinoid stems and plates		×	×	×	×	×	×	×	×	×	×		×	×	×	×	
Echinoid spines							×			×	×		×				

Brachiopoda															
Enteletes cf. *E. hemiplicatus* (Hall)	×														
Derbyia crassa (Meek and Hayden)													×	cf	
sp. indet			×		×									×	
Meekella sp. indet															×
Chonetes granulifer Owen	×			cf									×		×
verneuilianus plafsmouthensis Dunbar and Condra						×									
sp		×	×												
Lissochonetes geinitzianus geronticus Dunbar and Condra							×								
Juresania nebrascensis (Owen)					×		×							×	
sp													×		
Juresania? sp. indet								×							
Echinaria moorei Dunbar and Condra				cf	×			×							
Echinoconchus? sp			×					×					×		
Reticulatia huecoensis (R. E. King)					×								×		
cf. *R. newelli* R. H. King													×		
Reticulatia? sp	×	×	×	×		×	×								
sp	×		×				×								
Hystriculina wabashensis (Norwood and Pratten)	×						×						×		
Retaria lasallensis (Worthen)	×			×	×	×		×	×	×					
Linoproductus cf. *L. magnispinus* Dunbar and Condra															×
prattenianus (Norwood, in Norwood and Pratten)													cf	×	
sp. indet				×		×				×					
Cancrinella sp													×		
Rhynchopora illinoisensis (Worthen)	×			cf											
Spirifer sp				×											
Neospirifer dunbari R. H. King	×		×	×	×	cf		cf	×	×		cf	cf	×	
texanus (Meek)			×	×	×		×								
sp		×												×	
Crurithyris planoconvexa (Shumard)		cf	cf			×									
sp	×														
Condrathyris perplexa (McChesney)		×	cf												
Punctospirifer kentuckensis (Shumard)			×	×		×							×	×	
sp												×			
Hustedia mormoni (Marcou)	×				×		×								
Composita subtilita (Hall)						×		×	×	×				×	
sp	×						×					cf			
Mollusca															
Edmondia sp. indet														×	
Nuculopsis girtyi Schenck							×								
ventricosa (Hall)								×							
Polidevcia bellistriata (Stevens)							×	×							
Nuculana cf. *N. attenuata* (Meek)					×										
Myalina (*Orthomyalina*) sp. indet						×			×					×	×
Aviculopinna sp. indet													×		
Pseudomonotis? sp. indet													×		
Aviculopecten? sp							×								
Wilkingia cf. *W. terminale* Hall													×		
sp. indet													×		
Astartella concentrica (Conrad)	cf						×	×							

TABLE 1.—*Stratigraphic distribution of some megafossils from the Wayland quadrangle, Stephens and Eastland Counties, Tex.*—Continued

Species	Group	Cisco										Wichita				
	Formation	Graham									Thrifty	Pueblo				
	Member	Gunsight Limestone						Wayland Shale		Ivan Limestone		Brecken-ridge Lime-stone	Waldrip Shale			Waldrip(?) Shale	
	U.S. Geol. Survey loc. No.	16630-PC	16631-PC	16632-PC	16633-PC	16759-PC	16762-PC	16634-PC	16761-PC	16757-PC	16763-PC	16792-PC	16789-PC	16790-PC	16760-PC	16791-PC	16793-PC
Astartella? sp					×												
Conocardium sp					×	×		×	cf								
Scaphopod? indet									×								
Euphemites cf. *E. vittatus* (McChesney)								×									
Knightites (*Retispira*) cf. *K.* (*R.*) *tenulineata* (Gurley)								×									
cf. *K.* (*Cymatospira*) sp								×									
Bellerophontacean steinkern		×							×								
Straparollus (*Amphiscapha*) *subrugosa* (Meek and Worthen)									×								
(*Amphiscapha*) *muricata* (Knight)						×											
Cylicioscapha tezana (Yochelson)								×									
Worthenia tabulata (Conrad)						×		×	×								
Steinkern cf. *Worthenia*				×													
Trepospira depressa (Cox)						×		×	×								
Steinkern cf. *Trepospira*		×		×	×												
Glabrocingulum (*Glabrocingulum*) *grayvillense* (Norwood and Pratten)						×			×								
(*Ananias*) *marcouianus* (Geinitz)						×											
Steinkern cf. *Glabrocingulum*		×			×												
Phymatopleura brazoensis (Shumard)									×								
Taosia sp								×									
Meekospira cf. *M. peracuta* (Meek and Worthen)								×	×								
Steinkern of subulitacean gastropod		×						×					×	×			
Pseudorthoceras knoxense (McChesney)								×									
Pseudorthoceroid cephalopod, undet						×			×								
Metacoceras sp									×								
Metacoceras? sp								×									
Ammonoid indet								×									
Vertebrata																	
Fish dentition								×									

TABLE 2.—*Calcium, magnesium, total carbonate, and insoluble residue, in percent, in selected limestone samples from the Wayland quadrangle*

[Analyst: R. F. Gantnier]

Formation	Member	Locality (pl. 1)	Calcium	Magnesium	Total carbonate (calculated)	Insoluble residue
Pueblo	Saddle Creek Limestone	[1] M5720	37.5	Trace	93.7+	6.3−
	do	[1] M5720B	38.3	Trace	95.7+	4.3−
	Waldrip Shale	M5742	28.5	0.8	73.9	26.1
	do	M5740	32.0	Trace	80.0+	20.0−
Thrifty	Chaffin Limestone	M5739	36.2	Trace	90.5+	9.5−
	do	M5572	34.1	Trace	85.2+	14.8−
	Breckenridge Limestone	M5701	38.1	Trace	95.2+	4.8−
	do	M5560	33.3	Trace	83.2+	16.8−
	Speck Mountain Limestone	M5768	33.3	Trace	83.2+	16.8−
	do	M5556	36.6	Trace	91.5+	8.5−
Graham	Ivan Limestone	M5800	36.6	Trace	91.5+	8.5−
	do	M5771B	38.2	0.6	97.6	2.4
	do	M5723B	38.2	Trace	95.5+	4.5−
	Wayland Shale (bioherm)	M5581	32.5	Trace	81.2+	18.8−
	Gunsight Limestone	M5771	36.9	1.0	95.7	4.3
	do	[1] M5718	30.1	Trace	75.2+	24.8−
	do	M5575	34.3	0.8	88.4	11.8
	do	M5553	34.6	Trace	86.5+	13.5−
	Bunger Limestone	M5709	31.7	2.8	88.9	11.2
	do	M5580A	35.2	Trace	88.0+	12.0−
Caddo Creek	Home Creek Limestone	[1] M5778	36.4	1.4	95.8	4.2

[1] Lies outside mapped area.

GEOLOGIC SETTING AND STRUCTURE

The Wayland quadrangle lies in the eastern part of an outcrop belt of Pennsylvanian and Permian rocks that begins at the Llano uplift, about a hundred miles to the south, and trends discontinuously northeastward into Oklahoma. It lies on the western flank of the subsurface Bend Arch, near the axis of that feature as described by Cheney (1940, p. 98–113). The rocks in the quadrangle dip less than 1° WNW. Folds of low amplitude may be present locally in the quadrangle, but, as no topographic base was available and no precise determinations of altitudes were made on the outcrops, no such folds were detected.

STRATIGRAPHY

About 790 feet of strata is exposed in the Wayland quadrangle (pl. 1). These rocks comprise those assigned to the upper part of the Canyon Group and to the Cisco Group, both of Late Pennsylvanian age, and those of the lower part of the Wichita Group of Early Permian age (table 3), also included are rocks equivalent to the lower part of the Trinity Group of Early Cretaceous age and alluvial deposits of Quaternary age.

The nomenclature used for the Pennsylvanian rocks is that of Eargle (1960) unless otherwise noted. The nomenclature used for the Permian and Cretaceous rocks is that of Stafford (1960a), who followed, in part, Moore (1949). Some classifications of Pennsylvan-

ian and Permian rocks in and near the Wayland quadrangle are shown on plate 2.

TABLE 3.—*Major upper Paleozoic stratigraphic subdivisions mentioned in this report*

System	Series	Group	Formation
Permian	Leonard	Clear Fork	Arroyo
	Leonard(?)	Wichita	Lueders Clyde Belle Plains
	Wolfcamp		Admiral Putnam Moran Pueblo
Pennsylvanian	Upper Pennsylvanian	Cisco	Thrifty Graham
		Canyon	Caddo Creek Brad Winchell Limestone Graford
	Middle Pennsylvanian	Strawn	Undifferentiated

Examination of sample logs from wells drilled in Stephens and Eastland Counties indicates that between 3,000 and 3,500 feet of pre-Cisco Pennsylvanian rocks is unexposed in the quadrangle. The rocks assigned to the Canyon Group consist of gray shale, a few relatively thick beds of limestone, and minor amounts of sandstone. The pre-Canyon rocks are dominantly gray shale and sandstone but contain minor amounts of limestone. The so-called "Caddo Lime" of drillers, which is near the base of the Pennsylvanian section, is a sequence of limestone and interbedded black shale several hundred feet thick which produces oil.

Rocks of the Canyon Group crop out in the southeast corner of the quadrangle as part of a northeast-southwest-trending belt about 18 miles wide that overlies stratigraphically the outcropping rocks of the Strawn Group. (See Plummer and Hornberger, 1935; Hendricks, 1957; and Ross, 1921, for descriptions of these units.)

As determined from well data, rocks of the Mississippian System in the Wayland quadrangle consist of an upper unit of black shale (Barnett Shale) that is about 150 feet thick and a basal limestone unit of variable thickness that is considered to be of Chester age by many geologists. The oldest Paleozoic rocks penetrated in drill holes belong to the Ellenburger Group of Ordovician age. These rocks consist of dolomite and limestone and are about 1,500 feet thick in

northern Eastland County (Cheney, 1940, fig. 2). The group overlies less than 100 feet of Cambrian sandstone that was assigned to the Hickory Sandstone by Cheney (1940), and this sandstone in turn rests upon Precambrian rocks. The Hickory has been considered to be a member of the Riley Formation since 1943 (Cloud, Barnes, and Bridge, 1943).

PENNSYLVANIAN SYSTEM

Rocks belonging to the Pennsylvanian System in the Wayland quadrangle are represented by the upper part of the Canyon Group and by the Cisco Group (pl. 3). The youngest exposed bed of Pennsylvanian age is the Chaffin Limestone Member of the Thrifty Formation. The oldest bed exposed in the area is the Home Creek Limestone Member of the Caddo Creek Formation.

CANYON GROUP

CADDO CREEK FORMATION

The Canyon Group is exposed in the extreme southeastern part of the quadrangle, where it is represented by the Caddo Creek Formation. The Caddo Creek, consisting of the Colony Creek Shale Member and the overlying Home Creek Limestone Member, has a reported thickness of 120 feet in southern Stephens County (Plummer and Hornberger, 1935, p. 59). The name Colony Creek Shale Member (Cheney, 1948) has replaced the abandoned name, Hog Creek Shale Member (Eargle, 1960, p. 67).

COLONY CREEK SHALE MEMBER

The Colony Creek Shale Member in the Wayland quadrangle is masked by alluvium and vegetation. Probably no more than the upper 10–15 feet of shale is present. Ross (1921, p. 306) described the equivalent unit east of the Wayland quandrangle as "about 70 feet of shale containing several thin-bedded calcareous sandstones and lenticular limestones."

HOME CREEK LIMESTONE MEMBER

The name Home Creek was applied by Drake (1893, p. 398–399) to a limestone bed 25–50 feet thick that crosses Home Creek about 1½–2½ miles north of the Colorado River in southeastern Coleman County.

The Home Creek Limestone Member is incompletely represented in the Wayland quadrangle, the upper beds having been removed by pre-Cretaceous erosion. The 15 feet remaining is exposed in roadcuts in the southeast corner of the quadrangle. The lower 1 foot of this limestone is moderate-yellowish-brown calcilutite; it is brittle, has a hackly fracture, and contains scattered fragments of indeterminate fossils. The upper 14 feet is nodular marly limestone and contains in

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its lower part the fusulinids *Triticites* of *T. consobrinus* White and *Triticites ex gr. T. secalicus* (Say), which were identified by the author. This bed is overlain by Lower Cretaceous sandstone correlative with the Trinity Group of the Gulf Coastal Plain.

Reeves (1922, p. 119) said that the Home Creek Limestone Member in northern Eastland County (just south of the Wayland quadrangle)

> consists of two beds of limestone separated by 10 feet of shale. The upper bed of limestone, which is 3 to 5 feet thick, weathers into light-gray massive slabs and usually forms outcrops some distance back from the lower bed. The lower bed is about 15 feet thick and includes at the top 5 feet of thin layers of soft grayish-white limestone which weathers into chalky fragments or smooth white slabs, underlain by 10 feet of massive rock that forms prominent cliffs along the banks of streams.

CISCO GROUP

The Cisco Group crops out in about two-thirds of the Wayland quadrangle. The group is underlain by the Canyon Group and overlain by the Wichita Group of Permian age. It is represented by two formations: the Graham Formation below, and the Thrifty Formation above. In the southern part of the area, it is about 600 feet thick; in the northern part only the upper 250 feet is exposed (pl. 3), and the total thickness is unknown. The contact with the underlying Canyon Group is covered by overlapping rocks of Early Cretaceous age.

The Cisco Group is dominantly shale but contains some limestone, sandstone, and conglomerate. The thicker sandstone units are found mostly as channel-fill deposits. Their thicknesses are variable, and the fragments composing them range in size from silt to pebbles. The limestone units are generally no more than 5 feet thick and rarely are more than 15 feet thick. Being persistent, resistant to erosion, and generally of uniform thickness and texture, they are fairly easily mapped and are useful for correlation. The shale units generally are poorly exposed, and those overlying the Gunsight Limestone Member of the Graham Formation have been extensively replaced by channel-fill deposits.

The shale units of the group are typically olive-gray to greenish-gray claystone and siltstone and generally are poorly fossiliferous, although some siltstone contains macerated plant fossils. Locally, shale in the Graham Formation is light-gray claystone that commonly contains marine invertebrate fossils. Limestone in nodules or discontinuous beds occurs locally in the gray shale.

The sandstone members of the Graham and Thrifty Formations are mostly crossbedded ripple-marked channel-fill deposits that range in thickness from 0 to 74 feet (Avis Sandstone Member of the Graham Formation). The sandstones are mostly reddish brown, fine to coarse grained, and quartzose. Angular grains of chert are commonly

present, and the sandstones locally contain chert pebbles and clay pellets, especially where near the base of the channels. Macerated fossil plant debris and fragments of fossil wood also have been found in the sandstones.

Crosscutting relations at the base of individual sandstone units that fill channels cut into the shale usually cannot be seen at any one locality. Such relations are inferred by noting from place to place the differing amount of underlying shale and limestone that has been removed and replaced by sandstone. The sandstone bodies grade laterally, presumably along the edges of the channels, into the encasing shale units. Where the sandstone units grade to a featheredge, shale units above and below cannot be separated. The sandstone members commonly form well-defined topographic escarpments on the tops and sides of hills but, as they are discontinuous and of various thickness, cannot be used with confidence for correlations.

The persistent limestone beds are mostly light-olive-gray calcarenite and algal calcilutite. They generally crop out in well-defined escarpments that are easily traced in the field and on aerial photographs.

GRAHAM FORMATION

The Graham Formation was described by Plummer and Moore (1921, p. 125, 126) as

> The lowest division of the Cisco group * * * named from the county seat of Young County where the formation is typically developed * * *. The formation as here defined includes all the strata from the top of the Home Creek limestone in the Canyon group to the base of the first sandstone above the Wayland and Gunsight fossiliferous beds, known as the Avis sandstone * * *. The formation is distinguished from the strata of the Canyon group below by its thinner limestone members and from the strata of the formations above by the very prolific and persistent group of fossils which occur in the shales of the upper members.

In the Wayland quadrangle the gross lithologic differences between the Graham Formation and the overlying Thrifty Formation are slight. The Graham contains somewhat more shale and less sandstone and limestone than does the Thrifty.

The Graham Formation is approximately 525 feet thick in the southern part of the area, but only the upper 350 feet is exposed. The exposed part consists of 71 percent shale, 22 percent sandstone and conglomerate, and 7 percent limestone. The lower part of the formation is overlapped by rocks correlative with the Trinity Group of Early Cretaceous age. In the northern part of the area, only the upper 170 feet of the Graham is exposed. It consists of 53 percent shale, 35 percent sandstone and conglomerate, and 12 percent limestone (pl. 3).

The Graham Formation has been subdivided into the following members, listed in descending order:

Unnamed shale member
Ivan Limestone Member
Avis Sandstone Member
Wayland Shale Member
Gunsight Limestone Member
Unnamed shale member
Bunger Limestone Member
Unnamed shale member
Gonzales Limestone Member
Unnamed shale member

These members express the cyclic sequence (a) shale, (b) channel-fill sandstone, (c) shale, and (d) limestone, which is repeated five times in the Graham Formation. At many places near the top of the formation, there is a thin discontinuous layer of coal and carbonaceous shale.

UNNAMED SHALE MEMBER OVERLYING THE HOME CREEK LIMESTONE MEMBER

The shale unit at the base of the Graham Formation reaches a thickness of 96 feet in the Lacasa area of north-central Texas (Ross, 1921, p. 307), but in the Wayland quadrangle only the upper 1 foot or so of the unit is exposed. As seen in the bed of East Fork Gonzales Creek, it is ferruginous sandstone. South of the quadrangle, near the town of Eastland, the shale unit contains channel-fill sandstone. The shale unit in Jack County was called the Finis Shale by Plummer and Moore (1921, p. 127), but this name is not used in the Wayland quadrangle because too little of the unit is exposed to justify correlation.

GONZALES LIMESTONE MEMBER

The Gonzales Limestone Member was named by Ross (1921, p. 307, 308) for a limestone unit exposed along the headwaters of Gonzales Creek. He described the unit as

> a coarse-grained dark-gray limestone containing large numbers of *Campophyllum*, and locally a thin shaly limestone carrying large numbers of *Myalina subquadrata* lies 8 feet above it. The interval between the top of the Home Creek limestone and the top of the Gonzales limestone cannot be measured directly in this region but is about 100 feet.

The type area of the Gonzales Limestone Member is in the southeastern part of the Wayland quadrangle. The limestone in this member crops out at stream level near the headwaters of East Fork Gonzales Creek, where it consists of about 2 feet of poorly exposed rough-weathering sandy yellowish-gray (5*Y* 7/2) calcarenite that locally weathers grayish red purple (5*RP* 4/2). It contains many

crinoid-stem segments and, in places, bellerophontid gastropods, which are found on the bedding surfaces. Locally, colonies of *Syringopora* were noted. The limestone is overlain by a massive sandstone that has been traced into the area of measured section M5713 (p. 60–61). Because stratigraphic relations are obscured by soil and vegetation, one cannot be certain whether the sandstone replaces the Gonzales Member. Along Gonzales Creek, the basal part of the sandstone locally grades into a sandy limestone facies that seems to be part of the Gonzales Member.

The sandy facies of the Gonzales contains angular to subrounded quartz grains, mostly subangular to subrounded, dispersed in a limestone matrix. Most quartz grains are isolated, but a few lie in sutured contact. The quartz grains average 0.2 mm in diameter and are accompanied by a few grains of porcelaneous white chert about 0.1 mm in diameter. Fossils observed in thin section are worn fragments of *Epimastopora*, *Bradyina*, very rare fusulinids, ostracodes, bryozoans, brachiopods, and crinoid-stem segments.

In some places the Gonzales is a hash of organic debris, being composed of sand-sized fragments of fossils in a crystalline matrix. Many of the organic fragments are coated with algal-appearing material. Fragments of *Epimastopora* are common. Other identifiable organic debris noted in thin section consists of smaller Foraminifera, including *Tetrataxis* and *Tubertina*?, rare fusulinids, bryozoans, ostracodes, crinoid parts, brachiopod spines, and small high-spired gastropods. With the organic material are scattered angular to subrounded quartz grains that average about 0.2 mm in diameter.

UNNAMED SHALE MEMBER OVERLYING THE GONZALES LIMESTONE MEMBER

Shale and sandstone above the Gonzales Limestone Member were called the Gonzales Creek shale and sandstone by Plummer and Moore (1921, p. 127), but, because this name is easily confused with that of the limestone member, it is not used in this report.

The sequence of rocks consists of shale and local thick-bedded channel-fill crossbedded sandstone (fig. 2*A*). A cast of *Sigillaria* was found in a boulder of sandstone near the base of the sandstone unit that crops out at M5713 (fig. 2*B*). The presence of this cast and of macerated plant debris found elsewhere in this sandstone unit suggests that the unit is nonmarine. The measured section on pages 60–61 shows the character of the member.

BUNGER LIMESTONE MEMBER

The Bunger Limestone Member was described by Plummer and Moore (1921, p. 129) as the Bunger Limestone Lentil, although the name was used earlier by Plummer (1919, p. 143, 144) as the Bunger

Limestone Member of the Bunger Formation. The unit was named for the town of Bunger in southern Young County. Plummer and Moore (1921) traced the Bunger from southern Young County across the eastern part of Stephens County into Eastland County as far as the area of Cretaceous overlap. They described the lithology of the limestone (p. 129) as

> * * * in places it is dark yellowish-brown, quite dense and heavy; in other areas it is light gray, impure, and massively bedded. The member is thickest in the South Bend area of Young County and is thinnest in Eastland County. In Stephens County, the limestone has a rusty, dark-gray color and caps a low escarpment. West of the escarpment it has a wide outcrop and forms an excellent key rock for structural mapping * * *.

In the Wayland quadrangle the Bunger Limestone Member is typically light-olive-gray limestone that varies from calcilutite to calcarenite. The thickness of the member is 3–8 feet, averaging about 5½ feet. The beds have a maximum thickness of about 1 foot but more commonly are 2–8 inches thick. Bedding is commonly wavy, especially in the more thinly bedded parts of the Bunger. The wavy bedding is generally associated with algae, although algae are also common in the flat-bedded parts of the member.

Small fusulinids belonging to the genus *Triticites* are generally found in the upper 1 or 2 feet of the bed but are rare in the lower part and in the algal layers. Crinoid-stem segments and a few brachiopods have been noted on broken and on weathered surfaces.

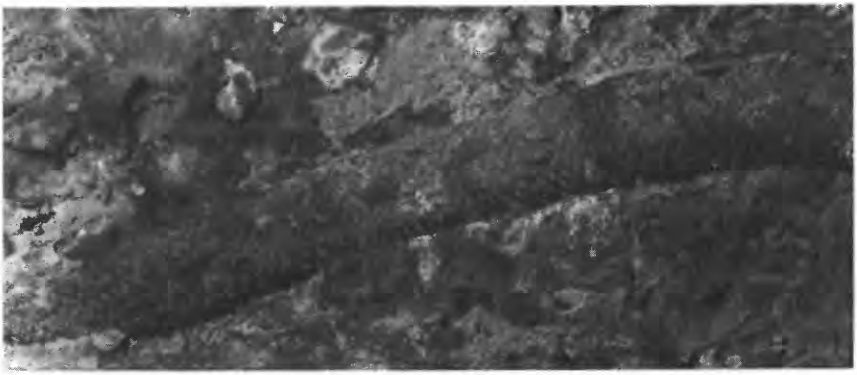
The Bunger crops out almost continuously along the east side of the mapped area, where it commonly caps hills and forms a low ridge.

UNNAMED SHALE MEMBER OVERLYING THE BUNGER LIMESTONE MEMBER

The shale sequence that overlies the Bunger Limestone Member was called the South Bend shale and sandstone by Plummer and Moore (1921, p. 127). Sellards (1932, p. 104) pointed out that the name "South Bend" had already been given to another unit and proposed as a replacement the new name "Necessity Shale," which he credited to Plummer. Sellards did not cite a type area or describe the unit; unfortunately, the references to the Necessity cited by Sellards contain no mention of either Necessity or South Bend. In this report the unit is referred to as an unnamed shale.

FIGURE 2.—Lithologic features in rocks between the Gonzales Limestone and Wayland Shale Members of the Graham Formation. *A*, Crossbedded channel-fill sandstone about 40 feet below the Bunger Limestone Member at M5774. *B*, Cast of tree trunk (*Sigillaria*) in channel-fill sandstone at M5714. Photographed part of trunk is about 20 inches long and has a maximum width of about 3 inches. *C*, Typical weathered surface of algal parts of Gunsight Limestone Member in roadbed at M5711. Algae belong to the genus *Archaeolithophyllum*.

A



B

C

The shale ranges from 15 to 30 feet in thickness and is dominantly siltstone and claystone containing lesser amounts of sandstone in lenticular beds. The siltstone and claystone are gray to light brown. The sandstone is reddish brown to olive gray, consists of fine- to medium-grained quartz, and is in beds as much as 2 feet thick. Some of the sandstone lentils contain impressions of reedlike plants, but many others contain macerated and carbonized plant debris as the only fossils.

Uppermost in the shale sequence is a ¼- to 1½-foot-thick bed of light-olive-gray calcareous sandstone composed of poorly sorted fine-grained quartz. The sandstone has trails and problematic markings on the bedding surfaces. It forms an inconspicuous bench and grades upward into the basal bed of the Gunsight Limestone Member.

GUNSIGHT LIMESTONE MEMBER

The Gunsight Limestone Member was named for the town of Gunsight in southern Stephens County by Plummer and Moore (1921, p. 120). They described the member as

> two thin limestone layers separated by 20 to 25 feet of yellow shale * * *. At the type locality at Gunsight the upper limestone layer is a uniformly thin, light yellowish-gray densely crystalline bed weathering to smooth-surfaced blocks. The lower layer is separated from the upper by 22 feet of soft yellow clay shale and consists of a soft white or light-buff limestone in most places filled with *Campophyllum torquium*, which weather out on exposed slopes so abundantly that in some places they can be scooped up in cart loads.

Plummer and Moore (1921, p. 134) stated: "The upper limestone member occurs in the road at the town of Gunsight, and the lower bed filled with the *Campophyllum* corals forms a low escarpment two miles east of the town." The Gunsight, however, is poorly exposed in this area. The upper limestone bed crops out in the road between Gunsight and U.S. Highway 183 and in the road south from Gunsight. About 6 feet of algal limestone is poorly exposed in a pasture between the road intersection at Gunsight and the cemetery. Fossils, other than algae that resemble *Archaeolithophyllum*, are rare. The lower beds are not exposed at Gunsight but are exposed at other places, including localities M5553 and M5773, northeast of Gunsight.

The lower bed consists of about 2–2½ feet of gray calcareous claystone containing many brachiopods, bryozoans, caninoid corals (*Campophyllum* of earlier workers), and other megafossils. Collections made from this bed are listed in table 2. The unit is overlain by gray calcareous shale ½–1 foot thick which locally becomes light-olive-gray nodular calcarenite. This upper zone contains common to locally abundant large fusulinids, many of which resemble *Triticites secalicus* (Say) 1823. Soil from weathered outcrops of this bed characteris-

tically contains abundant free fusulinids and pebbles and slabs of coquinoid fusulinid limestone. The bed has not been found north of the area of locality M5771, 4 miles north-northwest of Necessity, where it grades into calcareous sandstone. At this locality the sandstone contains fossils similar to those in the calcareous shale.

About 2½ miles southwest of Necessity (loc. M5772, pl. 1), a limestone bed that may be an equivalent of the lower fossiliferous bed crops out in a creek bed about 20 feet below the algal facies of the Gunsight. As seen in thin section, this limestone is bioclastic calcilutite. Hematite and pyrite are disseminated throughout the matrix and are often associated with fragmented fossils. The fragments of fossils, mostly broken and abraded, consist of indeterminate shell fragments, crinoid-stem segments, and a few encrusting Foraminifera(?).

The fossil-bearing beds are overlain by about 25 feet of olive-gray claystone containing minor amounts of siltstone and local bodies of sandstone as much as 7 feet thick that resemble channel-fill deposits. At locality M5575, about 1½ miles northwest of Necessity, a 4-inch-thick bed of yellowish-gray calcarenite composed of comminuted shell debris and a few crinoid-stem segments lies about 13 feet below the upper limestone bed.

The thickness of the upper limestone bed of the Gunsight Member is 1–6 feet, averaging about 3 feet. It is a light-olive-gray to dark-gray fine-grained rock that grades from calcarenite to calcilutite and is often dusky yellow on weathered surfaces. The calcilutite is frequently sublithographic in texture. The lower 2½–3 feet of the bed is algal, containing *Archaeolithophyllum* as identified by Richard Rezak from three localities—M5575, 1½ miles north-northwest of Necessity; M5578, 2½ miles southwest of Necessity; and M5762, three-quarters of a mile north of Eastland-Stephens County line on U.S. Highway 183. At locality M5762 he identified the following algae:

Osagia-Nubecularia (coatings)
Girvanella sp.
Epimastopora sp.
Archaeolithophyllum sp.

The algal part of the bed is the most persistent (fig. 3). It is typically wavy-bedded calcilutite and forms a ledge on which the algae weather in relief, giving the rock a graphic appearance (fig. 2*C*). Fusulinids are not common in the upper bed of the Gunsight Member but, where found, are usually in limestone that overlies the algal part of the bed.

About 4½ miles north-northwest of Necessity, a 3-foot-thick bed of algal limestone is exposed in the bed and banks of Big Bear Creek. It is olive-gray to light-olive-gray brittle calcilutite, locally having a subconchoidal fracture. Except for algae that resemble *Archaeo-*

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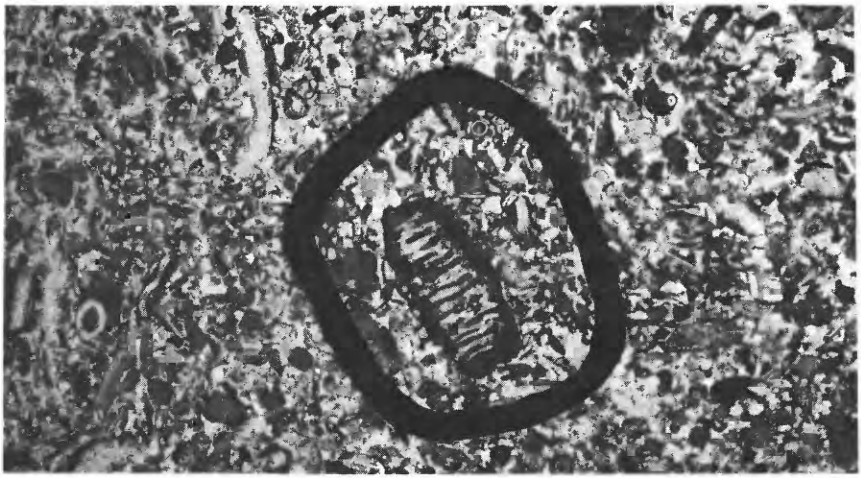

FIGURE 3.—Alga *Epimastopora* (circled) in bioclastic calcarenite of the Gunsight Limestone Member of the Graham Formation. Locality M5762, USNM 641937. × 10.

lithophyllum, fossils are rare. Only sparse crinoid stems and brachiopods were noted on the outcrop. In thin section, the groundmass is very fine grained calcite with agglutinated masses of finer grained calcite. It contains rare subangular to subrounded quartz grains about 0.06 mm in diameter. The algae have been completely recrystallized and resemble veinlets of crystalline calcite. Fossils other than the algae include rare fragments of brachiopod shells, brachiopod spines, and indistinct forms that may be partially recrystallized Foraminifera.

WAYLAND SHALE MEMBER

The Wayland Shale Member was named by Plummer and Moore (1921, p. 130) for exposures in the vicinity of Wayland, although no specific type area was mentioned. The Wayland Shale Member overlies the Gunsight Limestone Member and underlies the Avis Sandstone Member.

Exposures of the Wayland are generally poor. The best exposures can be seen about 1½ miles southeast of Gunsight (locs. M5580, M5581), about 1 mile northwest of Gunsight (loc. M5763), and about 2½ miles northeast of Gunsight (loc. M5773), where the Wayland is light-olive-gray claystone and siltstone interbedded with fine-grained quartz sandstone. Carbonized plant fragments are commonly found in the siltstone and sandstone. Locally, the Wayland includes a bed of light-gray claystone that contains marine fossils, and in some places it contains scattered nodules of limestone. East of the cemetery at Wayland, the member is greenish-gray

siltstone that is sandy near the base of the overlying Avis. The contact between the Avis Member and the Wayland Member, however, is not gradational. The basal few feet of the Wayland Member is concealed by alluvium.

The thickness of the Wayland Member is not uniform. The maximum measured thickness is 86 feet, but in a few localities the Avis Sandstone Member has replaced the Wayland and rests directly upon the Gunsight Limestone Member.

Marine fossils are uncommon in the Wayland but have been found about 9 feet above the base and near the top. They are mostly brachiopods and mollusks (table 1). Fusulinids have been found only about 1½ miles southeast of Gunsight (loc. M5705) in an ant hill near the base of a Wayland outcrop. At this locality, *Dunbarinella* sp., *Triticites* aff. *T. secalicus* (Say) 1823, *Triticites* cf. *T. plummeri* Dunbar and Condra 1927, and *Triticites* cf. *T. beedei* Dunbar and Condra 1927 were collected.

A bioherm exposed about 1¼ miles southeast of Gunsight (loc. M5581) is overlain by siltstone and underlain by siltstone and fine-grained quartz sandstone. Fossils typical of the Wayland have been found about 10 feet above the bioherm (table 1, USGS loc. 16034). The bioherm has an exposed thickness of about 12 feet, is about 150 feet long in a northwesterly direction, and is about 20 feet wide. The exposed surface is grooved with north-trending troughs as much as 2½ feet deep, probably due to solution weathering. The limestone is in part calcarenite composed mostly of comminuted shell debris and in part calcirudite composed of angular fragments of fine calcarenite as much as half an inch in diameter in a matrix of bioclastic calcarenite. In places, especially in the northern and western parts of the bioherm, the deposit is a coquina of brachiopod shells; in other places it is a hash of wave-worked fragments of brachiopod shells, crinoid-stem segments, bryozoan fragments, and indeterminate organic debris (fig. 4).

AVIS SANDSTONE MEMBER

The Avis Sandstone Member was named by Plummer and Moore (1921, p. 154) for exposures near the town of Avis, in Jack County. Plummer and Moore also noted that the unit has a similar expression in Young and Stephens Counties. As exposed in the Wayland quadrangle, the Avis is resistant to weathering and commonly caps hills or forms low escarpments.

The Avis Member was deposited on an eroded surface, probably as channel-fill deposits, and was itself eroded down to an irregular surface upon which younger sediments were deposited. In the Wayland quadrangle the Avis is underlain by the Wayland Member

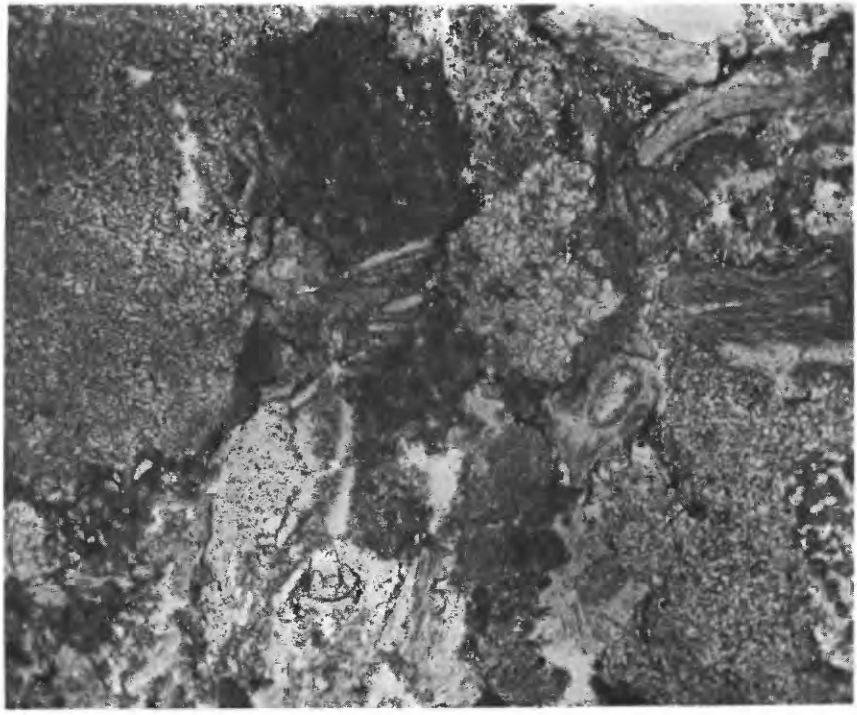

FIGURE 4.—Fragments of limestone from a bioherm in the Wayland Shale Member of the Graham Formation. Note sand-sized rock fragments and fragments of unidentifiable fossils. The irregular contacts of the rock fragments indicate "fitting" by solution shortly after deposition. Locality M5581, USNM 641935. × 50.

or, less commonly, by the Gunsight Member. It is overlain either by an unnamed shale member or by the Ivan Limestone Member. The Avis is typically dusky-yellow to dark-grayish-orange or red medium-grained quartz sandstone; the grains are subangular to subrounded and are moderately well sorted. Many of the quartz grains are iron stained, and, locally, hematite grains are present. Locally, especially near the base of the bed, the Avis is a conglomerate composed of subangular to angular pebbles of chert as much as 1 inch in diameter in a sandstone matrix. The sandstone is crossbedded, and, at locality M5601 (measured sections, p. 55–56), sets of torrential-type crossbeds have been observed. Bedding planes are commonly ripple marked.

The Avis contains interbeds of siltstone and fine sandstone that locally contain nodular hematite, and it grades laterally, presumably along the edges of the channel, into siltstone. Such siltstone was mapped with the underlying or overlying shale units because, in the

absence of the sandstone, the underlying and overlying shales are impossible to distinguish from one another.

The Avis Member ranges in thickness from less than 5 feet to more than 79 feet. The most complete exposure is at locality M5601. A section at this locality is shown on pages 55–56. About 9 miles farther south, at locality M5763, the Avis is 5 feet thick.

Sandstone of the Avis Member from locality M5901, on Farm Road 576 about three-quarters of a mile west of U.S. Highway 183, is composed, as seen in thin section, of angular to subrounded quartz grains having a maximum size of about 0.32 mm and an average size of about 0.20 mm. Minor amounts of biotite and rare fragments of plagioclase showing albite twinning are present. The cementing material is mostly calcite but contains minor amounts of locally clear collophane in amorphous blobs about 0.05 mm in diameter (fig. 5). Spheroidal or botryoidal masses of clear collophane with a rind of dark-brown collophane are also present. A sample analyzed by

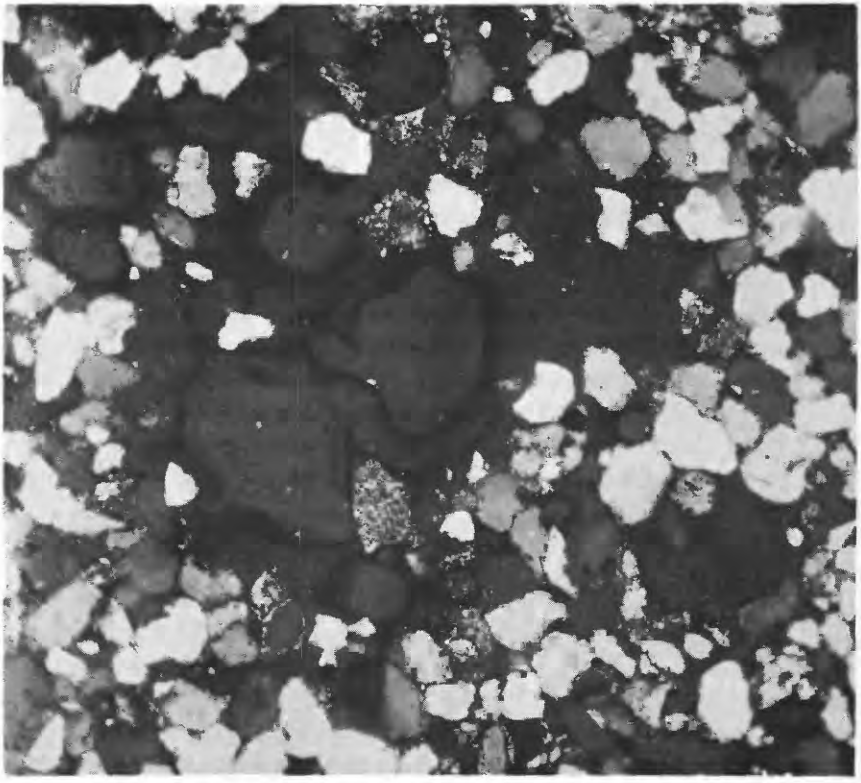

FIGURE 5.—Avis Sandstone Member. Shows amorphous masses of collophane(?), quartz, and chert grains. Locality M5901, USNM 641936. Crossed nicols, × 50.

R. F. Gantnier contained 0.2 percent P_2O_5. Hematite is disseminated throughout the rock.

Sandstone from about 1 mile south-southeast of Gunsight (loc. M5903) is composed of angular to subrounded, mostly subangular, quartz grains, many of which show wavy extinction under polarized light. The maximum grain size is 0.26 mm, and the average is 0.20 mm. The cement is calcite that is finely disseminated and also sparsely distributed in irregular masses as much as 0.25 mm diameter. Minor amounts of collophane, scattered grains of hematite, and a single abraded brachiopod spine were noted.

Fusulinids have been found at the base of the Avis Member about 2¼ miles east-northeast of Gunsight (loc. M5571). Here the Avis replaces the upper part of the Gunsight Limestone Member. Its area of outcrop is, however, too small to be shown at map scale. The fusulinids are probably reworked from the limestone. Other fossils from the Avis consist of unidentifiable carbonized plant debris.

UNNAMED SHALE MEMBER OVERLYING THE AVIS SANDSTONE MEMBER

The shale member between the Avis Sandstone Member and the Ivan Limestone Member consists of as much as 8 feet of nonfossiliferous olive-gray silty claystone or siltstone. Locally the unit is absent and the Ivan rests directly upon the Avis.

IVAN LIMESTONE MEMBER

The Ivan Limestone Member was named by Plummer and Moore (1921, p. 154) for "a rather persistent lentil of limestone which appears in the vicinity of Ivan, Stephens County."

The continuity of the Ivan from its type area southward to the Wayland quadrangle is not certain. In the Wayland quadrangle, a limestone unit at about the stratigraphic position of the Ivan Limestone Member has been mapped as the Ivan although it may be slightly above the position of the true Ivan (Brown, 1960b, p. 13). This unit is 1½–9½ feet thick and generally forms a ledge, especially in the northeastern part of the quadrangle. In the southern part of the quadrangle, the Ivan is generally less than 2 feet thick, and locally the entire bed has been replaced by post-Ivan channel-fill deposits.

The Ivan Limestone Member is divided into two parts. The lower part is a light-olive-gray calcilutite in beds from 1 inch to more than 6 inches thick. The upper, more widespread part is algal limestone in a bed 1–2 feet thick. This bed is well-sorted yellowish-gray bioclastic calcarenite (fig. 6). The lower and upper parts of the member are gradational. The best exposures are 4–4½ miles north-northwest of Necessity (locs. M5771, M5723). Thin sections from locality M5723 show that the lower 1 foot of the member is very arenaceous and grades upward into nonarenaceous limestone that has been

FIGURE 6.—Algae *Osagia* and *Nubecularia* in bioclastic calcarenite of the Ivan Limestone Member of the Graham Formation. The algae coat fragments within the limestone. Locality M5763, USNM 641938. × 10.

leached by solution weathering. The arenaceous bed is bioclastic calcilutite. It contains angular to subrounded, dominantly subangular, etched quartz grains as much as 0.38 mm in diameter and patches of hematite. Some of the quartz grains show wavy extinction in polarized light. The organic debris is mostly smaller Foraminifera, brachiopod spines, crinoid columnals, and brachiopod shell fragments. The upper bed is very fine grained calcilutite. Material that resembles organic remains has been extensively replaced by calcite. The rock contains scattered reticulate masses of hematite. Individual meshes in the hematite network have the shape of calcite rhombs. This bed contains many brachiopods that resemble *Composita*.

Many of the organic fragments in the limestone are algae. Algae in the persistent upper bed have been identified by Richard Rezak as follows:

M5600 (west side of Lake Daniel)
Epimastopora sp.
Osagia-Nubecularia (coatings)
Solenopora sp.
M5601 (2½ miles north-northwest of spillway on Lake Daniel)
Osagia-Nubecularia (coatings)
Epimastopora sp.
M5763B (1 mile northwest of Gunsight)
Osagia-Nubecularia (coatings)
M5765 (U.S. Highway 180, about 1½ miles east of Farm Road 207)
Solenopora sp.

Except for the algae, the Ivan is not notably fossiliferous. Crinoid-stem segments are rather widely distributed; brachiopods, some of which resemble *Composita*, have been noted; and fusulinids have been found at two localities—about 4 miles north-northwest of Necessity (loc. M5771) and about 2¼ miles southwest of Gunsight (loc. M5802). At locality M5771 the fusulinids lie just below the algal limestone; at locality M5802 they have been found in limestone just above the algal beds and in ant hills below the algal beds. The fusulinids are primitive forms of the group of *Triticites ventricosus* (Meek and Hayden) 1858.

UNNAMED SHALE MEMBER OVERLYING THE IVAN LIMESTONE MEMBER

Rocks above the Ivan Limestone Member consist of a sequence of claystone and siltstone about 70 feet thick containing a channel-fill sandstone near the middle.

The shale beneath the channel-fill sandstone ranges from 0 to 39 feet in thickness. This unit is dominantly light-olive-gray to dusky-red siltstone having lesser amounts of light-olive-gray to light-gray claystone. Just south of the mapped area, light-gray calcareous claystone containing nodules of limestone crops out 13 feet above the Ivan Member. This claystone, which has not been found elsewhere, contains very well preserved spiriferoid and productid brachiopods (table 1, USGS locs. 16757, 16763). Because the deposition of this bed apparently is genetically related to that of the Ivan, the collections have been listed under that member in the table.

The channel-fill sandstone that overlies the lower siltstone and claystone unit at places cuts through the underlying beds and into rocks as old as the Avis Sandstone Member. Where the two sandstones merge, they are indistinguishable; hence, an exact maximum thickness for the post-Ivan cannot be stated but is more than 50 feet. The thickest exposure of this bed is about 4½ miles southwest of Gunsight (south of the mapped area), where 14 feet of the sandstone crops out.

The sandstone is calcareous to noncalcareous, grayish orange pink to very pale orange, and generally crossbedded. It consists of subrounded to subangular fine- to medium-grained quartz sand but locally contains lenses of claystone or chert conglomerate. The quartz grains average 0.20 mm in diameter but are as much as 0.40 mm in diameter, and many are in sutured contact. As in most of the sandstone units in the Wayland quadrangle, hematite is disseminated throughout the rock. The cement is in part calcareous and in part siliceous.

Overlying the sandstone is a unit 15–48 feet thick consisting mostly of olive-gray siltstone that is streaked and banded red, yellow, and green. Interbedded with the siltstone are lesser amounts of light-

gray, green, and red claystone and minor amounts of fine-grained quartz sandstone. The variation in thickness of this unit apparently resulted from its having been deposited on an irregular erosion surface.

Thin beds of coal or coaly shale, usually no more than a few inches thick, have been found in the interval between about 4 and 40 feet below the top of the unit. The number of beds of coal and coaly shale is unknown, but probably several lenticular beds occur in two zones. One zone extends from the top of the unit downward about 15 feet, and the other is between 30 and 40 feet below the top.

THRIFTY FORMATION

As restricted by Eargle (1960, p. 71), the Thrifty Formation consists of the following members in the Colorado River drainage basin:

Chaffin Limestone Member
Parks Mountain Sandstone Member
Breckenridge Limestone Member
Speck Mountain Limestone Member

This classification is used in this report except that the Parks Mountain Sandstone Member is not recognized in the Wayland quadrangle and two thin shale and sandstone members are recognized. Thus, the following subdivisions of the Thrifty Formation were mapped in the Wayland quadrangle:

Chaffin Limestone Member
Unnamed shale and sandstone member
Breckenridge Limestone Member
Unnamed shale and sandstone member
Speck Mountain Limestone Member

Note: The Chaffin Limestone Member equals the lower bed of the Crystal Falls Limestone Member of the Harpersville Formation of Lee and others (1938). The Speck Mountain Limestone Member equals the Blach Ranch Limestone Member of the Thrifty Formation of Plummer and Moore (1921), Lee and others (1938), and Brown (1960a).

The Thrifty Formation is approximately 90 feet thick. In the southern half of the Wayland quadrangle, it consists of about 33 percent sandstone and conglomerate, 39 percent shale, and 28 percent limestone; in the northern half it consists of about 25 percent sandstone and conglomerate, 45 percent shale, and 30 percent limestone (pl. 3).

The rocks of the Thrifty Formation were deposited in a cyclic sequence which is a continuation of that noted for the Graham Formation.

Geologic mapping (fig. 7) indicates that the Blach Ranch Lime-

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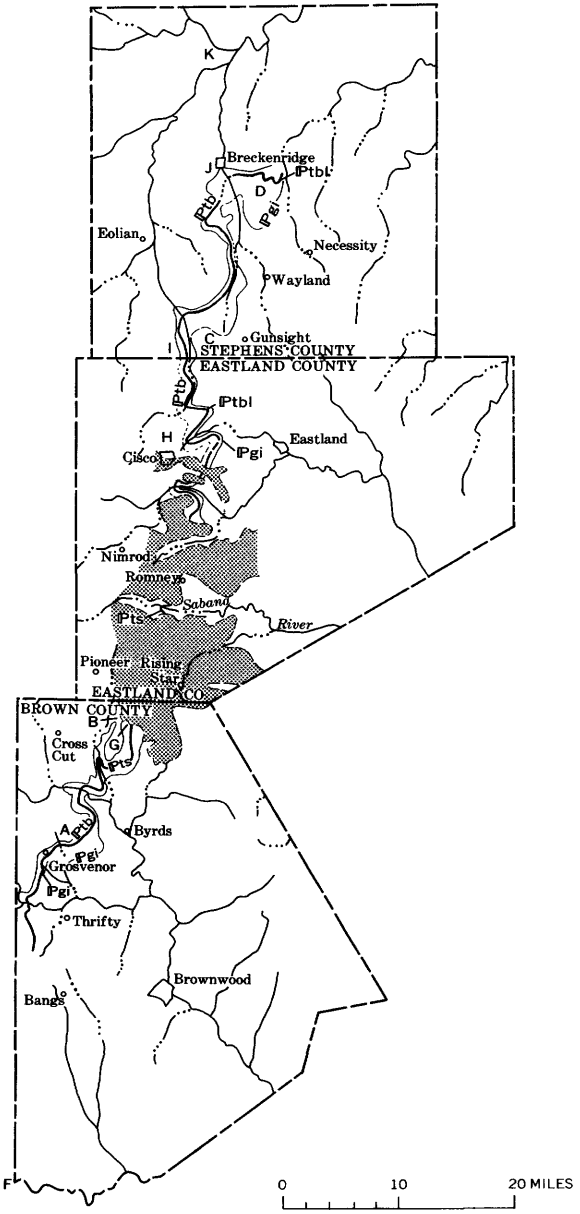

FIGURE 7.—Outcrop pattern of the Breckenridge (Ptb), Speck Mountain (Pts), and Blach Ranch (Ptbl) Limestone Members of the Thrifty Formation and the Ivan Limestone Member (Pgi) of the Graham Formation. Cretaceous rocks (Trinity Group equivalent) indicated by stipple. A–D, location of columnar sections in figure 8; F–K, location of columnar sections in figure 10.

stone Member (Plummer and Moore, 1921; Sellards, 1932; Brown, 1960a, b) in the Brazos River drainage basin is continuous with the Speck Mountain Limestone Member in the Colorado River drainage basin as described by Drake (1893), Eargle (1960), Stafford (1960b), and Terriere (1960). The two members maintain an equivalent stratigraphic position in the rock sequence (fig. 8); they have identical lithologies and outcrop characteristics, similar thicknesses, and the same characteristic fusulinid assemblages (Myers, 1958, pl. 93; 1960b, pls. 22, 24). The units at this position can be traced along almost continuous outcrops for many miles both to the north and to the south of the overlapping Cretaceous rocks on the Callahan Divide. Because the name Speck Mountain has priority, it is used in this report in preference to the name Blach Ranch.

SPECK MOUNTAIN LIMESTONE MEMBER

The Speck Mountain Limestone Member was named by Drake (1893, p. 408) for outcrops on and west of Speck Mountain in eastern Coleman County in the Colorado River drainage basin. Speck Mountain is about 60 miles south-southwest of the Wayland quadrangle.

The Speck Mountain Limestone Member in the Wayland quadrangle and southward to where it is covered by the Cretaceous rocks on the Callahan Divide is composed of two layers of limestone separated by a thin bed of shale. The member is about 40 inches thick. The lower limestone bed is 2 feet thick and is composed of light-olive-gray calcilutite and fine-grained calcarenite. It has conchoidal fracture, weathers brown, and forms a rubble of large polygonal blocks. The lower limestone is separated from the upper one by 4 inches to 1 foot of pale-yellowish-orange to moderate-yellowish-brown nonfossiliferous shale. The upper, light-olive to yellowish-gray limestone is somewhat argillaceous and commonly is poorly exposed, weathering to lenticular slabs and at some places to nodular rubble.

UNNAMED SHALE MEMBER OVERLYING THE SPECK MOUNTAIN LIMESTONE MEMBER

The interval between the Speck Mountain Limestone Member and the Breckenridge Limestone Member contains 45–70 feet of poorly exposed sandstone and shale. Locally beds of yellowish-gray (5*Y* 7/2), grayish-olive (10*Y* 4/2), or light-gray (*N* 7) claystone are exposed. About a mile southwest of Lake Daniel (loc. M5566), *Myalina* fragments and rare gastropods and crinoid stems were found in the claystone 2 feet above the Speck Mountain Member.

The sandstone in this interval occurs as channel-fill deposits or as lenticular beds in claystone. The thickest sandstone unit, generally

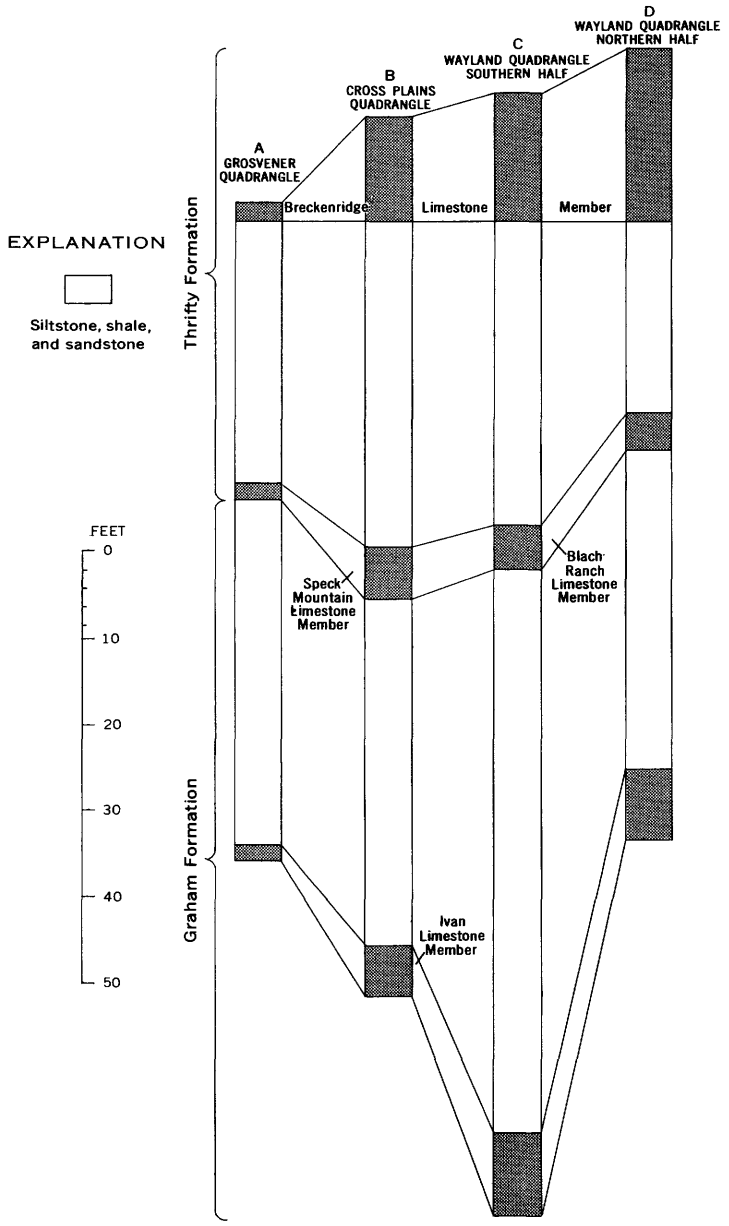

FIGURE 8.—Correlation of Speck Mountain and Blach Ranch Limestone Members of the Thrifty Formation. Datum is the base of the Breckenridge Limestone Member. Location of columnar sections shown in figure 7. Column A generalized from Terriere (1960); B, from Stafford (1960a).

found a few feet below the top of the interval, ranges from zero to more than 25 feet in thickness. The thickest continuous exposure of the sandstone is 4½ miles southwest of Gunsight (loc. M5729, outside mapped area), where there is 12 feet of grayish orange-pink (10*R* 8/2), crossbedded, ripple-marked sandstone. The rock is fairly well to poorly sorted and is composed of subrounded to subangular medium-grained quartz sand. It contains numerous flecks of limonite and (or) hematite. In the same area (loc. M5726, outside mapped area), a channel-fill deposit consists of cherty conglomerate and conglomeratic sandstone at the base and grades upward into sandstone. The conglomeratic phase contains angular to subangular chert pebbles, in a matrix of quartz sandstone, and much disseminated hematite. The chert pebbles appear milky in reflected light and tan to brown in transmitted light. Many show a brown rind or rim caused by alteration. The sandstone phase consists of poorly sorted quartz sand accompanied by abundant angular to rounded chert grains as much as 0.80 mm in diameter. The chert grains are light brown in transmitted light and milky white in reflected light; many have a darker colored alteration rim around a lighter colored center. Hematite and limonite are disseminated in the matrix of the sand.

One and one-half miles northeast of Stephens County Airport (loc. M5759) this sandstone, which is the same as Brown's (1960a) bed "f," lies a few feet above the Speck Mountain Limestone Member. At nearby locality M5760, the channel occupied by the sandstone cuts through the Speck Mountain Member.

BRECKENRIDGE LIMESTONE MEMBER

The Breckenridge Limestone Member was named by Plummer and Moore (1921, p. 155), who stated:

> It forms a prominent escarpment in and about the town of Breckenridge and may be traced easily to the northwest and south. It has an average thickness of 3 or 4 feet and like the other limestones in the Thrifty which have been described, it is gray, massive and resistant. It is 25 to 45 feet above the Blach Ranch member.

No specific type or reference section was designated by Plummer and Moore. Brown (1960a, p. 18–20) redescribed the Breckenridge Limestone Member and designated a type or reference section "on the Harris Veale property, near the south city limits of Breckenridge, west of U.S. Highway 183." This locality is immediately south of the north boundary of the Wayland quadrangle. The member generally forms an easily traced ledge or small escarpment.

The Breckenridge Limestone Member at the type reference section (Brown, 1960a, p. 20) is about 7.4 feet thick. Elsewhere in the Wayland quadrangle it is about 1½–21½ feet thick. Where the member is thickest, it is composed of two beds of limestone separated

by shale. The lower bed of limestone, 1½–2½ feet thick, is yellowish-gray (5*Y* 6/2) fine-grained calcarenite or calcilutite. It weathers to large angular blocks about 1 foot thick. It is not markedly fossiliferous, although fusulinids are locally common.

The upper bed of limestone, which is about 3 feet thick, is yellowish-gray (5*Y* 7/2) nodular calcarenite or calcilutite that weathers to nodular rubble. The bed is locally very fossiliferous, especially in the upper part, where numerous fusulinids, crinoid-stem segments, and scattered brachiopods are found. This bed, which crops out about 5½ miles west-northwest of Gunsight (locs. M5555, M5556) and in the southwestern part of the quadrangle (loc. M5701), was probably deposited originally as a continuous sheet, but over much of the area it has been replaced by channel-fill deposits of sandstone and conglomerate.

The shale sequence between the two limestone beds is rarely exposed. Where seen, it consists of as much as 17 feet of red and gray shale but is predominantly gray shale.

In many places in the Wayland quadrangle, the Breckenridge Limestone Member consists of a single limestone bed, which seems to be the equivalent of the lower of the two limestone beds discussed above. The bed consists typically of 1–5 feet of grayish-yellow (5*Y* 8/4), yellowish-gray (5*Y* 7/2), or light-olive-gray (5*Y* 4/2) limestone. It may be either calcarenite or calcilutite. Fusulinids, of which *Triticites plummeri* Dunbar and Condra is a common species, and crinoid-stem segments are scattered throughout the bed; brachiopods and bryozoans are present in fewer numbers.

UNNAMED SHALE MEMBER OVERLYING THE BRECKENRIDGE LIMESTONE MEMBER

The interval between the Breckenridge Limestone Member and the Chaffin Limestone Member contains three lithologic units: a lower shale bed, an intervening channel-fill deposit of sandstone and conglomerate, and an upper shale bed. The channel-fill deposit is not present everywhere, and where it is absent the upper and lower shale beds are not distinguishable. This interval was assigned to the Quinn Clay by Plummer and others (1949), who ascribed a thickness of 30 feet to the unit in the northern part of the Wayland quadrangle (near loc. M5753, pl. 1). The name is not used in this report because through most of the Wayland quadrangle the rocks of this interval differ from those described by Plummer and others. According to the description, the Quinn Clay is mostly bluish-green clay, having reddish-maroon and brownish-red hues. The lower 10–15 feet of the clay (shale) is locally replaced by a sandstone lentil, and many iron concretions mark the outcrop.

A complete section of the rocks between the Breckenridge Member and the Chaffin Member is exposed near the southwest corner of the quadrangle at locality M5702 (pl. 1), where the sequence is 31 feet thick. The lower 16 feet is light-gray (*N*–7) claystone containing thin bands of spherulitic hematite and siderite. Near the middle of the sequence, the claystone is carbonaceous and contains scattered poorly preserved plant impressions and a one-half-foot-thick bed of coaly and carbonaceous shale. The upper half of the unit is poorly exposed, but in its lower part it is probably gray and red claystone. It contains bands of spherulitic hematite that weather out as slabs as much as 2 inches thick.

Where this member contains a medial channel-sandstone deposit, the shale beneath the sandstone contains reddish-brown hematitic shale or fossiliferous gray calcareous shale having limestone nodules. The calcareous facies may represent the upper bed of the Breckenridge Limestone Member. The maximum measured thickness of calcareous shale is 10 feet about 3¾ miles west-northwest of Gunsight (loc. M5559, pl. 1).

The channel-fill deposits are probably more than 40 feet thick (pl. 3), but the maximum thickness exposed at any one locality is about 12 feet (loc. M5555). The rock is a massive, locally cross-bedded, quartz sandstone that ranges in color from light brown (5*YR* 5/4) to red and orange. The quartz grains are usually coated with iron oxide. Discontinuous bands of angular light-colored chert granules occur locally. In ditches along the edge of the road at locality M5555, the sandstone is in contact with the Breckenridge Limestone Member and contains fragments of the limestone (fig. 9). Thin sections show that the sandstone consists principally of moderately subangular to rounded well-sorted quartz grains that average about 0.30 mm in diameter. Chert grains the same size as the quartz grains compose about 10 percent of the rock. Most quartz grains have a secondary overgrowth of chalcedony which also fills interstices between the grains. Minor amounts of disseminated hematite are also present.

CHAFFIN LIMESTONE MEMBER

The Chaffin Limestone Member (Drake, 1893, p. 410–412) has been mapped continuously from the type area at the Chaffin coal mines in McCulloch County (fig. 1) northward through Coleman and northwestern Brown Counties to the south edges of the Callahan Divide (Stafford, 1960b; Terriere, 1960; Cheney and Eargle, 1951; Hudnall and Pirtle, 1929), except in places where it is cut out by younger channel-fill deposits. North of the Callahan Divide, in Eastland County, the limestone is poorly represented, as it is extensively re-

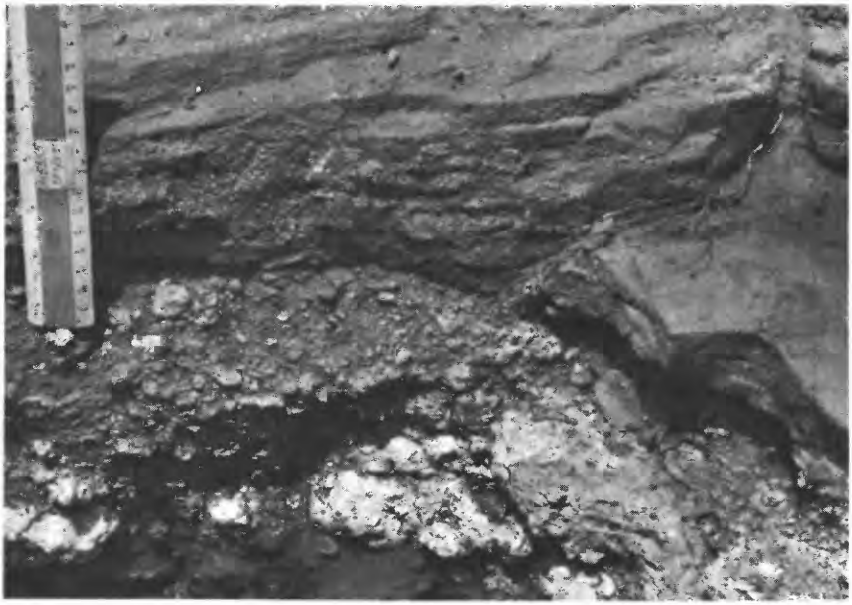

FIGURE 9.—Channel-fill sandstone showing basal conglomerate containing cobbles from the Breckenridge Limestone Member. Ditch on west side of road at locality M5555.

placed by younger channel-fill deposits, but it was traced northward the length of the Wayland quadrangle to the vicinity of Breckenridge, and it was mapped as Crystal Falls Limestone Member from the type area in northern Stephens County to Breckenridge by Brown (1960a).

The Chaffin Limestone Member is correlated with the Crystal Falls Limestone Member on the basis of the similarity of their stratigraphic positions above the Breckenridge Limestone Member (fig. 10) and the similarity of their fusulinid faunas (Myers, 1958, pl. 93). Because the two members are correlative and because the name Chaffin has priority (Drake, 1893) over the name Crystal Falls (Plummer and Moore, 1921), the name Chaffin is used in this report. Hudnall and Pirtle (1929) called the Chaffin Member the "Upper Crystal Falls."

The Chaffin Limestone Member is poorly exposed along most of its outcrop in the Wayland quadrangle but is well exposed in a quarry about 1¼ miles northwest of Harpersville Cemetery in the west-central part of quadrangle (loc. M5758). There the member consists of yellowish-gray (5*Y* 7/2) fine-grained calcarenite about 1.5 feet thick which is blotched very pale purple (5*P* 7/2) and has a delicate violet cast on fresh surfaces. It is underlain by a nodular shaly limestone that contains many fusulinids. In the southwestern part of the quadrangle (loc. M5702), the Chaffin consists of 3.8 feet of light-

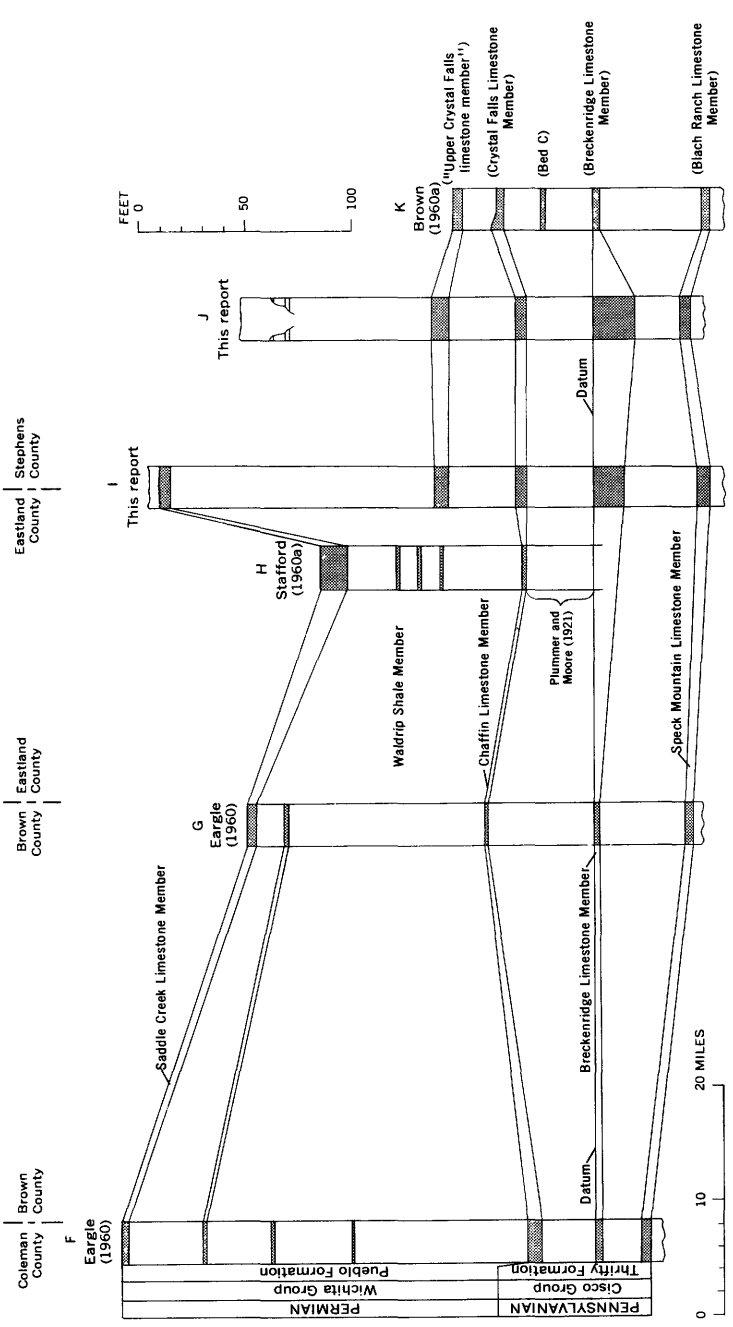

FIGURE 10.—Correlation of limestone beds in the Thrifty Formation and in the lower part of the Pueblo Formation between the Colorado River drainage basin and the Brazos River drainage basin. In section K, beds below the Breckenridge Limestone Member have been projected from the type location of the Black Ranch Limestone Member. Names in parentheses to right of section K represent Brown's (1960a) terminology. Location of columnar sections on figure 7.

olive-gray (5*Y* 5/2) calcarenite containing smaller Foraminifera, fenestrate bryozoans, brachiopods, crinoid-stem segments, and several indistinct calcareous bodies that resemble fragments of organic remains. Elsewhere in the quadrangle the Chaffin is seen in fields as bouldery rubble; in creek beds, where only the upper few inches are exposed; or on a few hilltops, where most of the upper part of the bed has been removed by erosion.

PERMIAN SYSTEM

Rocks of the Permian System in the Wayland quadrangle are represented by the lower part of the Wichita Group of the Wolfcamp Series. The oldest unit is the Waldrip Shale Member of the Pueblo Formation, which lies with apparent conformity on the Chaffin Limestone Member of the Thrifty Formation (pl. 3). The youngest unit is channel-fill sandstone and conglomerate that overlies the Saddle Creek Limestone Member at about the middle of the Pueblo Formation.

As the Chaffin is only 1–3 feet thick, it was mapped with the overlying Pueblo Formation. The Permian-Pennsylvanian boundary, however, may lie within the Waldrip Member of the Pueblo.

The thickness of the exposed Permian rocks is about 167 feet in the southern part of the quadrangle and about 130 feet in the northern part. The rocks in the southern part of the quadrangle are about 84 percent shale, 8 percent sandstone, and 8 percent limestone; those in the northern part are about 63 percent shale, 31 percent sandstone, and 6 percent limestone. Most of the sandstone is in channel-fill deposits (pl. 3).

WICHITA GROUP

The name "Wichita beds" was first applied by Cummins (1890, p. 187–188) to a sequence of "sandstones, sandy shales, clays, and a peculiar conglomerate." After many changes in nomenclature, the Wichita in the Colorado River valley now has group rank and is divided into seven formations (Moore, 1949, sheet 2). These are, in descending order:

Lueders Limestone
Clyde Formation
Belle Plains Formation
Admiral Formation
Putnam Formation
Moran Formation
Pueblo Formation

As classified by Moore, the Wichita Group comprises all the Wolfcamp Series and probably part of the Leonard Series. Eargle (1960, p. 74, 75) defined, for practical purposes, the lower boundary of the Wichita Group as being at the base of the Waldrip Shale Member of

the Pueblo Formation, thus coincident with the base of the Permian System. This definition is used in this report.

In the Wayland quadrangle only that part of the Wichita Group represented by the lower part of the Pueblo Formation is preserved.

PUEBLO FORMATION

The Pueblo Formation was named by Plummer (1919, p. 144–145), who stated:

> The Pueblo Formation is bounded by the Pueblo limestone [Camp Colorado limestone] which is yellow, fossiliferous, and impure. Near the Red Bed line in Stephens County it changes to sand and loses its identity, but just below its horizon is a thin limestone abundant in *Myalina* fossils, which characterize this bed. The series of members in this formation is so variable that no one section is typical.

Later, Moore and Plummer (1922, p. 40) clarified the definition by stating that the Pueblo Formation . . .

> is named from a town on the Missouri, Kansas & Texas Railway in northeastern Callahan County, where the rocks of this division are typically exposed. It lies conformably on the Harpersville Formation and includes the strata to the top of the persistent Camp Colorado Limestone which forms a readily traceable escarpment both in the Colorado and Brazos valleys.

The Harpersville Formation (pl. 2) was defined by Plummer and Moore (1921, p. 160) as including all strata from the top of the Breckenridge Limestone Member of the Thrifty to the top of the Saddle Creek Limestone Member and was named for the no longer extant town of Harpersville in Stephens County.

Cheney (1940, p. 91) abandoned the name "Harpersville Formation" and designated the base of the Pueblo Formation (base of the Permian) as at a vague position beneath the Waldrip limestone No. 3 of Drake (1893). Moore (1949, sheet 2) defined the formation as including "Beds lying between the disconformity at the base of the Waldrip shale and the top of the Camp Colorado Limestone * * *."

This report follows the usage of Moore (1949) and Eargle (1960, p. 74, 75).

The Pueblo Formation in the Wayland quadrangle comprises, in ascending order, the Waldrip Shale Member, the Saddle Creek Limestone Member, and some overlying channel-fill deposits that replace the Camp Creek Shale Member. Younger members of the formation are exposed west of the quadrangle.

WALDRIP SHALE MEMBER

The name Waldrip was first used by Tarr (1890, p. 207) as his "Waldrip coal division." The unit first described, however, by Drake (1893, p. 412–416) as the "Waldrip bed" was a sequence of "blue clays" containing local sandstone beds and three limestone

units, all cropping out in the vicinity of the town of Waldrip in McCulloch County. As defined by Drake, the Waldrip includes all strata between the Chaffin Limestone Member below and the Saddle Creek Limestone Member above. According to Drake (p. 412), the thickness of the Waldrip ranges from 100 to more than 200 feet. The limestone beds, which Drake numbered 1, 2, and 3 (No. 1 at the base), range from 1 to 2 feet in thickness at the type area.

Eargle (1960, p. 76) indicated that the lower two limestone beds of the Waldrip of Drake are not continuous north of the type area. The upper limestone bed, or No. 3 of Drake, has been recognized along the south edge of the Callahan Divide (Terriere, 1960; Stafford, 1960b).

The sequence of strata is about 160 feet thick in the southern part of the quadrangle and about 115 feet thick in the northern part of the quadrangle. It consists of shale and a little sandstone and limestone.

In general, the Waldrip Shale Member contains a basal shale unit followed successively by a limestone bed, a shale unit, a channel-fill sandstone unit, and a shale unit.

The basal shale unit was called the Curry Clay by Plummer and others (1949). In the southwestern part of the quadrangle (loc. M5702, pl. 1), the unit consists of 32 feet of poorly exposed red and gray claystone. In the northern part of the area (Plummer and others, 1949, p. 18–20), its maximum thickness is more than 27 feet.

The limestone bed, which is unnamed in this report, is the "Upper Crystal Falls Limestone" of Plummer and others (1949) and the "Upper Crystal Falls limestone member" of Brown (1960a). This bed, which is 1–3 feet thick, ranges from calcilutite to calcarenite. It is yellowish gray (5*Y*7/2) to light olive gray. At most localities the limestone is bioclastic and contains fusulinids; productid, spiriferoid. and chonetid brachiopods; bryozoans; and crinoid fragments. The fusulinids resemble those found in the Waldrip Nos. 1 and 2 limestones (Drake, 1893) at the type area in McCulloch County.

Thin sections of the limestone (loc. M5752A, southwest of Breckenridge, north of mapped area) show many fragments of ostracodes; *Bradyina*, *Schubertella*, *Triticites*, and smaller Foraminifera that resemble *Climacammina*; bryozoan fragments; crinoid-stem segments; brachiopod shells and spines; and tetracoral fragments. The matrix, which can be seen only under high magnification, appears to be finely crystalline calcite containing angular quartz grains and shell fragments of silt size and smaller. Much disseminated hematite and limonite is also present.

The shale unit that overlies the unnamed limestone bed consists of about 40 feet of poorly exposed red to gray claystone and siltstone and

local beds of nodular and lenticular limestone. It seems to be gradational with the underlying limestone bed. The unit contains crinoid stems and bryozoan fronds that at some localities are stratigraphically as much as 7 feet above the base of the shale. A limestone bed ½–2 feet thick occurs about 24 feet above the base of the shale in the northern part of the area. This bed may be equivalent to the limestone known as the Belknap Limestone Member in the northern part of Stephens County and in Young County. The limestone is olive-gray (5*Y* 4/2) to dusky-yellow-green (5*GY* 5/2) calcarenite or calcilutite containing few fossils, which are mostly crinoid-stem segments and brachiopods. A single specimen of *Aviculopinna*? was noted. A thin section from an outcrop about 5¼ miles west-northwest of the junction of Farm Road 576 with U.S. Highway 183 (loc. M5742) indicates that the rock is bioclastic calcilutite containing much disseminated hematite and limonite and rare angular quartz grains of silt size or smaller. The rock contains sparse *Schubertella*; fragments of ostracodes, brachiopods, and crinoid stems; and many smaller Foraminifera that have been extensively replaced by hematite. Most of the elongate shell fragments are oriented parallel to the bedding.

The top of a channel-fill sandstone deposit lies 45–58 feet above the base of the Waldrip Shale Member. Although the sandstone has a maximum exposed thickness of only 18 feet, it fills a channel that cuts into the basal shale unit of the Waldrip Shale Member; the channel, therefore, is approximately 70 feet deep (pl. 3, col. B). The sandstone generally forms a well-defined topographic bench.

About 5¼ miles west-northwest of the junction of Farm Road 576 with U.S. Highway 183 (loc. M5741, pl. 1), where the channel-fill deposit caps a hill, about 10 feet of thin-bedded sandstone underlain by 8 feet of massive sandstone is exposed. The sandstone is moderate reddish orange (10*R* 6/6) to grayish orange (10*YR* 7/4), fine to medium grained, poorly to moderately well sorted, and crossbedded. Individual quartz sand grains are subangular to subrounded and are coated with hematite. Thin lenses of siltstone and fine-grained quartz sandstone are scattered through the sandstone, and locally the lower part of the unit is calcareous. The sandstone contains a few carbonized plant fragments as much as 2 inches wide and 6 inches long.

The channel-fill sandstone seems to grade laterally into siltstone that is indistinguishable from the typical siltstone and shale of the Waldrip Shale Member.

The unnamed shale sequence that overlies the channel-fill deposits is as much as 105 feet thick and is poorly exposed. In the southern half of the quadrangle, most of the rock is gray claystone containing minor amounts of siltstone and thin beds of sandstone. In the

northern part of the quadrangle, the upper part of the unit has been replaced by a channel-fill sandstone, and the unit has a maximum thickness of only about 37 feet. There, the unit is light-olive-gray silty claystone that contains thin beds of hematitic siltstone near the top and, in some places, a thin bed of carbonaceous or coaly shale. At locality M5748 (pl. 1), a thin bed of light-olive-gray fine-grained calcarenite or calcilutite that weathers grayish red purple has been found a few feet above the coaly shale. It is sparsely fossiliferous although, locally, it is almost a coquina of productid and other brachiopod fragments. The limestone is overlain by about 16 feet of olive-brown claystone and probably some siltstone. Whether the limestone and the overlying claystone and siltstone were once more widespread is not known, as elsewhere the rocks in this interval have been mostly replaced by channel-fill deposits.

SADDLE CREEK LIMESTONE MEMBER

The Saddle Creek Limestone Member was originally described by Drake (1893, p. 416) as the "Saddle Creek bed," named for rocks cropping out 1–2 miles south of the mouth of Saddle Creek in McCulloch County. Drake described the unit as a limestone bed usually 6–7 feet thick but ranging from 5 to 12 feet in thickness and as "the first hard bed rock of any thickness that overlies the thick clays of the Waldrip bed." The member has been traced from the type area northward to the Callahan Divide (Moore, 1949; Eargle, 1960; Terriere, 1960; Stafford, 1960b). North of the Callahan Divide the outcrop of the member was traced by Wender (1929) to the southern edge of Stephens County and by Stafford (1960a) to the Clear Fork Brazos River.

In the southwestern part of the Wayland quadrangle, the Saddle Creek Member is found as outliers, its main outcrop being west of the mapped area. In the outliers the bed consists of 3 feet or more of yellowish-gray (5*Y* 7/2) calcilutite that weathers to large angular blocks. It contains Foraminifera that resemble calcitornellids, rare large ventricose fusulinids belonging to the group of *Triticites ventricosus*, questionable algae, and sparse crinoid-stem segments and bryozoans. Just west of the mapped area, the Saddle Creek is about 5 feet thick and consists of gray calcarenite in wavy beds as much as 6 inches thick. At or near the base is a bioclastic nodular limestone commonly containing large ventricose fusulinids belonging to the group of *Triticites ventricosus* and many algalike bodies.

CHANNEL-FILL SANDSTONE THAT OVERLIES THE SADDLE CREEK LIMESTONE MEMBER

Rocks that overlie the Saddle Creek Limestone Member in the Wayland quadrangle consist of massive channel-fill deposits of sand-

stone that have replaced the Camp Creek Shale Member and, in places, part of the underlying Waldrip Shale Member. This sandstone may be equivalent to the Coon Mountain Sandstone Member of the Pueblo Formation south of the Callahan Divide (Terriere, 1960; Eargle, 1960; Stafford, 1960b), but, because of the discontinuous nature of its outcrops and the various thicknesses of the channel-fill deposits, no correlation is made.

The total thickness of the channel-fill sandstone is not known. In the northern half of the area, the sandstone merges with the underlying channel-fill sandstone of the Waldrip Shale Member and is at least 40 feet thick, having a maximum thickness of possibly more than 100 feet. The sandstone generally caps hills.

The sandstone is typically grayish orange (10*YR* 7/4) to moderate brown (5*YR* 4/4) crossbedded, medium grained, and quartzose. The quartz grains are iron stained and subangular to subrounded. In many places the sandstone contains subangular to subrounded porcelaneous white chert grains of medium-sand size.

In the northwest corner of the quadrangle, a chaotic sequence of superimposed channel-fill sandstone and conglomerate beds overlies the Waldrip Shale Member and occupies the position of the Saddle Creek Limestone Member. Detailed mapping to the north and west is needed before stratigraphic relations of these channel-fill deposits can be clarified.

DISTRIBUTION AND POSSIBLE SOURCE OF CHANNEL-FILL DEPOSITS

The distribution of the channel-fill deposits is economically important because many of the Upper Pennsylvanian and Lower Permian oil- and gas-bearing sandstones in the subsurface in north-central Texas were probably deposited in channels. Most of the sandstone and conglomerate bodies of Pennsylvanian and Permian age in the Wayland quadrangle are channel-fill deposits.

The channel-fill deposits in the Grosvenor quadrangle to the south (fig. 1) were described by Terriere (1960, p. 27–29). Many of the same features are found in the deposits in the Wayland quadrangle; hence, only a general summary of the channel-fill deposits is noted here.

The channels occupied by the sandstones are broad and shallow, most of them being cut only a few tens of feet into the underlying strata but extending hundreds of feet, or even miles, in width. The trend of most of the channels is not known. The contact between the Speck Mountain Limestone Member of the Thrifty Formation and an overlying channel-fill sandstone, as seen at several localities in the north-central part of the quadrangle (pl. 1), suggests a northeastward trend for that channel.

The fact that the channel-fill deposits increase in both number and size north and northeast of the Wayland quadrangle indicates that the source of the sediment, although not known, was likely from those directions (Lee and others, 1938). The similarity of the chert fragments in these conglomerates to the chert found in the Ouachita Mountains of Oklahoma suggests that their source may have been from a part of the Ouachita folded belt that extended through Texas east of the present outcrop of Pennsylvanian and Permian rocks (Bay, 1932, p. 184).

CRETACEOUS SYSTEM; ROCKS OF TRINITY AGE

The rocks assigned to the Cretaceous System in the Wayland quadrangle are all of Trinity age. They are found only in the southern part of the area (pl. 1), where they were deposited on a maturely eroded surface cut on Upper Pennsylvanian and Lower Permian rocks. The relief of the eroded surface is probably about 150 feet (Stafford, 1960b, p. 69).

The Cretaceous rocks consist of quartz sandstone in the southeastern part of the quadrangle and a thin chert conglomerate in the southwestern part. The sandstone weathers to loose sand that effectively masks the contact between it and the underlying rocks; consequently, the thickness of the sandstone could not be accurately measured. Data published by Ross (1921, fig. 5) are suggestive of a thickness between 50 and 80 feet.

The sandstone is generally medium-grained subangular to subrounded quartz and chert grains in a siliceous matrix. The average grain size is about 0.30 mm, the maximum being about 0.6 mm. The contact between many of the quartz grains is sutured. Much disseminated hematite and limonite are present also.

Commonly associated with the quartz sandstone is a pebble conglomerate that consists of angular to subangular pebbles of quartz and brown, gray, and white chert in a coarse sand matrix of poorly sorted angular to subangular quartz and chert grains. The maximum size of the quartz grains is about 1.9 mm, and that of the chert grains, about 2.5 mm. Many of the quartz grains show wavy extinction; some show evidence of etching and have been partially replaced by opaline silica. The cement is siliceous, in places opaline. The sandstone and the pebble conglomerate decompose to reddish-brown sandy soil that contains many chert pebbles.

Siliceous chert conglomerate about 2 feet thick is the basal unit of the rocks of Trinity age in the southern part of the quadrangle. It locally caps the ridge southeast of Gunsight and caps higher hills farther west. It is composed of red, white, black, and dark-gray subangular to subrounded chert and white quartzite pebbles as much as

1 inch in diameter. The pebbles, which have banded rims of opal, are in a siliceous (opaline) matrix; some of the quartz fragments have been partially replaced by opal or related material (fig. 11). The conglomerate was originally very porous, and the cementing material is apparently of recent origin. No vestige exists of the original cement.

Stratigraphic relations between the chert conglomerate and the quartz sandstone are not clear, as there are no continuous outcrops between the two. They both rest upon upper Paleozoic rocks. Except for grain size, the rocks are petrographically similar, and the chert conglomerate is therefore regarded by the author as a coarse facies of the quartz sandstone. In contrast, Ross (1921, p. 305, 306) classed similar chert conglomerate exposed east of the Wayland quadrangle as Tertiary in age. He believed the conglomerate to

FIGURE 11.—Pebble conglomerate from rocks of Trinity age (Cretaceous), showing contact between quartz pebble (light) and chert pebble (dark), both with rims of banded silica. Locality M5775. Crossed nicols, × 50.

have been derived from the rocks of Trinity age and noted that 90 percent of the pebbles more than 1 inch in diameter are dreikanters, which suggests that the beds were deposited in a desert.

QUATERNARY DEPOSITS

Deposits younger than the Trinity Group of Cretaceous age in the Wayland quadrangle include only alluvial valley fill and low terrace deposits along the major streams. These deposits are mostly Recent in age. They have not been studied in detail, and only the larger deposits are shown on the map (pl. 1).

The alluvium and terrace deposits are more than 15 feet thick in some stream valleys where terraces that stand several feet above the stream bottoms remain along the valley sides. These terraces, and abandoned stream channels above present stream level, are evidence of minor rejuvenation of the streams in comparatively recent time.

ECONOMIC GEOLOGY

CLAY DEPOSITS

Clay deposits, some of which contain material suitable for making ceramics, are in the upper part of the Thrifty Formation in the Wayland quadrangle. The clays and their uses were described by Plummer and others (1949).

OIL AND GAS

Oil was first found in commercial amounts in the vicinity of the Wayland quadrangle on October 30, 1916, when the Texas Co. completed a well on the Parks Lease, near Breckenridge (Reeves, 1922, p. 133). According to Reeves, this discovery induced the company to drill a well at Ranger, in Eastland County, and started the greatest exploration, drilling, and leasing activity the country had known. According to Matteson (1919, p. 163), the original Parks well

> found good production at the contact of the "Black Lime" and the Smithwick shale of the Bend series * * * but owing to lack of storage and transportation facilities, it was pinched in to 250 barrels daily, which production it is still maintaining after 20 months.

Development of the Ranger field induced a flurry of exploration and drilling activity in adjacent areas and led to the discovery of several oil fields in Stephens County, some of them in the area of this report.

The Railroad Commission of Texas (1958) listed 132 oil fields and 56 gas fields in Stephens County. Many of these fields have multiple producing zones, and each producing zone is listed as a separate field. Oil production from Stephens County, through January 1,

1958, was 170,210,479 barrels. Natural gas production for the year 1957 was 2,688,444,000 cubic feet, and, in addition, 3,869 barrels of liquid hydrocarbons was produced from the gas wells. About 90 percent of the oil production in the county is listed by the Railroad Commission as being from the Stephens County Regular field, which includes wells that are not in recognized oil fields. The author estimates that the Wayland quadrangle has yielded about 25 percent of the total output of oil and gas from Stephens County.

The deepest production listed by the Railroad Commission for Stephens County is from slightly below 4,400 feet, and the shallowest is from about 1,500 feet. Production is from rocks as young as late Middle Pennsylvanian (Strawn Group) and from rocks as old as Ordovician (Ellenburger Group).

Oil wells are not shown on plate 1 because they are too densely located to be plotted at map scale.

FOSSIL LOCALITIES

The localities of the fossil collections are shown on plate 1. All collections were made by the author. Localities are listed in ascending stratigraphic order rather than in numerical sequence.

USGS collection	*Locality*
16030–PC	Stephens County, Tex. Fossiliferous calcareous shale and nodular limestone that underlie the Gunsight Limestone Member. 3.9 miles S. 65° E. from junction of Farm Road 1032 with U.S. Highway 183; in bank on east side of dirt road.
16031–PC	Stephens County, Tex. Fossiliferous calcareous shale in or below the Gunsight Limestone Member. On east side of hill 115 ft above base of section, a few feet below Avis Sandstone Member. 4.8 miles S. 50° E. from junction Farm Road 1032 with U.S. Highway 183.
16032–PC	Stephens County, Tex. Fossiliferous calcareous shale below the Gunsight Limestone Member in roadcuts where dirt road climbs a hill. 2.5 miles N. 87° E. from junction of road to Gunsight with U.S. Highway 183.
16033–PC	Stephens County, Tex. Fossiliferous calcareous shale below the Gunsight Limestone Member, about 200 yds west of Middle Fork Gonzales Creek. 2 miles S. 69° E. from junction of road to Gunsight with U.S. Highway 183.
16759–PC	Stephens County, Tex. Fossiliferous calcareous shale below the Gunsight Limestone Member. On north bank of ravine, about 4 ft below a sandstone bed that caps the hill; about 100 yds west of pipeline. About 2.5 miles S. 55° E. from schoolhouse at Wayland.

USGS collection	*Locality*
16762–PC	Stephens County, Tex. Gunsight Limestone Member. Poorly exposed outcrop of limestone about 2 ft thick, on slope about 6 ft below crest of hill and about 4 ft below bed of sandstone. Shale overlying the limestone contains brachiopod fauna. 2.5 miles S. 50° E. from schoolhouse at Wayland.
16761–PC	Stephens County, Tex. Wayland Shale Member. 3.6 miles S. 80° E. from junction of Farm Road 1032 with U.S. Highway 183. In cut on east side of road, on curve convex to the west. On west side of sandstone-capped hill.
16034–PC	Stephens County, Tex. Wayland Shale Member. 1.3 miles S. 40° E. from schoolhouse at Gunsight, about 10 ft above a bioherm.
16763–PC	Eastland County, Tex. Fossiliferous calcareous shale about 35 ft below the Speck Mountain Limestone Member, and about 13 ft above the Ivan Limestone Member. Kleiner Estate Ranch, approximately 1.4 miles southwest of the ranchhouse and 0.2 mile south of the Wayland quadrangle.
16757–PC	Eastland County, Tex. Shale and nodular limestone 13 ft above the Ivan Limestone Member. On west side of unnamed lake (earthen dam) on south side of Kleiner Estate Ranch. About 0.6 mile south of the Wayland quadrangle.
16792–PC	Stephens County, Tex. Breckenridge Limestone Member. In ditch on east side of north-trending county road, 100 yds south of right-angle curve to east. 1 mile N. 25° W. from intersection of Farm Road 2231 with U.S. Highway 183.
16760–PC	Stephens County, Tex. (probably on Eastland-Stephens County line). Waldrip Shale Member. Poorly exposed yellowish-gray calcilutite that weathers to nodular white earthy rubble. On west side of unnamed creek 110 ft stratigraphically above creek bed. 7.5 miles S. 35° W. from junction of Farm Road 1032 with U.S. Highway 183.
16789–PC	Stephens County, Tex. Waldrip Shale Member. Collected from washes and gullies east and west of road, where roadbed lies on marly limestone north of Hog Branch. 5.5 miles N. 80° W. of junction of Farm Road 576 and U.S. Highway 183, and 0.65 mile north of Fred Tomlin's ranchhouse.
16790–PC	Stephens County, Tex. Waldrip Shale Member. About 800 ft southeast of farmhouse on Ted Brown Ranch in northwestern part of quadrangle. Brachiopod fauna from limestone that forms low ridges on valley floor. 4.2 miles S. 73° W. from junction of Farm Road 2231 with U.S. Highway 183.
16791–PC	Stephens County, Tex. Pueblo Formation. Bioherm about 2½ ft thick in shale that overlies the Waldrip Shale Member, about 3–5 ft above road level. 0.6 mile N. 30° W. of USGS loc. 16790–PC; about 0.35 mile northwest of farmhouse on Ted Brown Ranch.
16793–PC	Stephens County, Tex. Pueblo Formation. Float from 17–20 ft above bioherm at USGS loc. 16791–PC.

MEASURED STRATIGRAPHIC SECTIONS

Section of Waldrip Shale Member of Pueblo Formation at locality M5748, 5 miles west of Stephens County Airport

Permian System:
Wichita Group:
Pueblo Formation:
Waldrip Shale Member (part):

	Feet
Sandstone, quartz, grayish-orange, medium-grained, subangular to subrounded; contains porcelaneous chert fragments which are the same size as the quartz grains and are subangular to angular; crossbedded; weathers to bouldery rubble; caps hill	2+
Covered, probably claystone	10
Claystone, medium-olive-brown; poorly exposed	6
Limestone, fine calcarenite or calcilutite, light-olive-gray, slightly arenaceous; weathers grayish red purple; sparsely fossiliferous, but locally may be a coquina of productid and other brachiopods	.5
Sandstone, quartz, moderate-yellowish-brown, fine-grained to very fine grained, moderately well sorted; weathers to nodular friable rubble	1.5
Claystone, olive-gray; becomes silty toward top; plastic when damp; contains a few plant fragments	4.3
Sandstone, grayish-brown, very fine grained, carbonaceous; contains macerated plant fragments	.3
Shale, brownish-gray, fissile; contains bands of a yellow mineral resembling copiapite; disintegrates into small flaky chips; contains much macerated plant material and impressions of reedlike plants	1.5
Claystone, olive-gray, plastic; copiapite(?) bands in upper 4 in.; lower foot poorly exposed	2
Sandstone, quartz, moderate-reddish-orange to very pale orange, fine-grained to very fine grained, ferruginous; poorly exposed, weathers to friable rubble; burrows and trails exposed on bedding surfaces	1
Claystone, light-olive-gray; exposed in ravines	14
Limestone, calcarenite, medium-light-gray; weathers brown; in beds about 1 ft thick, with shaly partings between beds; small elliptical bioherm about 50 ft by 150 ft whose long axis trends northwest; contains crinoid stems and echinoid spines and spicules; shaly partings contain plant fragments; northward it passes laterally into fine calcarenite or calcilutite that is light olive gray and weathers to nodules 6 in.–1 ft thick; contains brachiopod fauna, primarily Chonetids, and a few myalinid pelecypods	2.5
Covered, probably claystone	9.5
Sandstone, quartz, pinkish-gray to yellowish-gray, medium-fine-grained, subangular to subrounded, moderately sorted; disseminated hematite(?) grains; weathered surfaces have orange cast; forms cliff; same bed as scarp-forming sandstone near top of section M5747	6
Total Waldrip Shale Member measured	61.1+

Section of Waldrip Shale Member of Pueblo Formation at locality M5747, 5 miles west of Stephens County Airport—Continued

	Feet
Permian System:	
Wichita Group:	
Pueblo Formation:	
Waldrip Shale Member (part):	
Sandstone, quartz, grayish-orange to moderate-brown, medium-grained, subangular to subrounded, moderately well sorted, crossbedded; beds 4 in.–1 ft thick, the thicker beds being at the base; has trails on bedding surfaces	3+
Claystone, light-olive-gray; becomes siltstone near top; hematitic in upper 3–4 in.; weathers to platy chips	8.3
Covered, probably claystone	8
Sandstone, quartz, grayish-yellow, fine- to medium-grained, moderately well sorted; in beds 6–20 in. thick, the thicker beds being near the base; major beds separated by siltstone partings as much as 1 in. thick; cross laminated, with laminae as much as ½ in. thick, swirling suggests eddy currents; texture uniform throughout; forms scarp	4.5
Covered, probably claystone	4
Claystone, purple and yellowish-brown; poorly exposed; in ravines	6
Covered, probably claystone	10
Limestone, calcarenite; weathers to nodular and platy rubble; contains brachiopod fauna	.5
Limestone, calcarenite, light-olive-gray; single bed; bioclastic hash; contains large ventricose fusilinids	2
Limestone, pale-red-purple, arenaceous, platy, poorly exposed; fusulinids common	.5
Claystone, light-olive-gray with purple streaks	1.5
Covered, probably claystone	1.5
Siltstone, or very fine grained sandstone, grayish-olive-green; contains small selenite crystals; weathers to irregular platy fragments as much as ½ in. thick with a few blocks as much as 3 in. thick. Poorly exposed in shallow excavation	.5
Total Waldrip Shale Member measured	50.3+
Base of exposed section.	

Section of rocks of Trinity age, Pueblo Formation, and Thrifty Formation at locality M5702, southwestern part of the Wayland quadrangle

	Feet
Cretaceous System:	
Rocks of Trinity age (part):	
Conglomerate; composed of subangular to subrounded chert pebbles as much as 1 in. diameter; red, white, and black pebbles predominate; siliceous matrix (opaline quartz); forms bouldery rubble; caps hill	2+
Covered, probably sandstone; weathers to sandy soil containing blocks of poorly consolidated sandstone	3
Total rocks of Trinity age	5+

Section of rocks of Trinity age, Pueblo Formation, and Thrifty Formation at locality M5702, southwestern part of the Wayland quadrangle—Continued

	Feet
Permian System:	
Wichita Group:	
Pueblo Formation:	
Saddle Creek Limestone Member:	
Limestone, calcilutite, yellowish-gray; beds in lower 20 in. and upper 10 in. from 1 to 6 in. thick; middle part massive; weathers to large blocks; contains calcitornellidlike Foraminifera, and algae; upper bed contains rare large ventricose fusulinids, rare crinoid stems, and rare bryozoans	3
Total Saddle Creek Limestone Member	3
Waldrip Shale Member:	
Covered, probably shale; much limestone float; upper 8 ft has dense brush cover	19.5
Claystone, red and gray, poorly exposed	22
Covered, probably red and gray claystone; much sandstone, limestone, and conglomerate float	58
Claystone, light-gray and purple	5.8
Sandstone, quartz, light-olive-gray, fine-grained, subrounded to subangular, poorly to moderately well sorted; hematite grains disseminated throughout matrix; in two 6-in. beds separated by 1 ft of siltstone or very fine grained yellowish-brown sandstone; weathers to angular blocks; forms conspicuous bench	2
Claystone, light-gray, with beds grayish-red-purple as much as 1 ft thick throughout section, and yellowish-orange bands as much as 2 in. thick	15
Limestone, calcilutite, yellowish-gray; weathers to white earthy nodular rubble; poorly exposed; the limestone and overlying 2–3 ft of shale contain a brachiopod fauna as well as echinoid spines, crinoid stems and calyx plates, and bryozoans	.5
Shale, red and gray, poorly exposed	9.3
Covered, probably red and gray shale	23
Total Waldrip Shale Member	155.1
Total measured Pueblo Formation	158.1
Pennsylvanian System:	
Cisco Group (part):	
Thrifty Formation (part):	
Chaffin Limestone Member:	
Limestone, calcarenite, light-olive-gray; indistinct bodies in matrix appear organic and are fragmental; lower bed 1.8 ft thick, upper beds 2–4 in thick; weathered surfaces have ferruginous splotches; joints in limestone have been healed with limonitic material in bands as much as 3 in. wide; smaller Foraminifera resembling *Textularia* and calcitornellids are common; fenestrate bryozoans, crinoid stems, and brachiopods are rare	3.8
Total Chaffin Limestone Member	3.8

Section of rocks of Trinity age, Pueblo Formation, and Thrifty Formation at locality M5702, southwestern part of the Wayland quadrangle—Continued

	Feet
Pennsylvanian System—Continued	
Cisco Group (part)—Continued	
Thrifty Formation (part)—Continued	
Unnamed shale member:	
Shale, lower 6 ft probably red and gray claystone, poorly exposed	15
Shale, brown, papery; bands of yellow earthy mineral resembling copiapite; plant impressions which resemble bull rushes	.5
Claystone, yellowish-orange, nonbedded	.4
Shale, grayish-brown to black, carbonaceous and coaly; interspersed bands copiapite(?); carbonaceous shale beds as much as 2 in. thick	.5
Claystone, grayish-yellow to yellowish-gray, with streaks of moderate-yellow earthy mineral resembling copiapite; scattered poorly preserved plant impressions	.5
Claystone, light-gray; jointed in reticulate system; joints healed with hematitic or sideritic material which weathers out and litters the ground with flakes; matchstick-shaped bryozoans, rare crinoid stems and rare ventricose fusulinids noted on slopes and in ant hills	2.5
Shale, poorly exposed in creek bank	1
Claystone, light-gray, nonbedded; disseminated silt-sized particles; contains bands spherulitic hematite, much of which has altered to limonite; weathers to rounded clayey slopes	5.8
Covered	6
Total unnamed shale member	32.2
Breckenridge Limestone Member (part):	
Limestone, weathers to nodular rubble. Same as uppermost bed at locality M5701	2
Total measured Thrifty Formation	38.0
Base of exposures.	

Section of the Breckenridge Limestone Member and an unnamed shale member at locality M5701, southwestern part of the Wayland quadrangle

	Feet
Pennsylvanian System:	
Cisco group (part):	
Thrifty Formation (part):	
Breckenridge Limestone Member:	
Limestone, calcilutite, yellowish-gray, nodular weathering, poorly exposed; contains very few fossils. Basal bed of M5702	3
Covered, probably shale	9
Limestone, calcilutite, yellowish-gray; weathers dark-yellowish-orange; weathers to angular blocks as much as 13 in. thick; common to very common large ventricose fusulinids in pockets, fusulinids rare elsewhere; echinoid spines and crinoid stems common, spiriferoid and other brachiopods noted	2.5
Total Breckenridge Limestone Member	14.5

Section of Breckenridge Limestone Member and an unnamed shale member at locality M5701, southwestern part of the Wayland quadrangle—Continued

	Feet
Pennsylvanian System—Continued	
Cisco Group (part)—Continued	
Thrifty Formation (part)—Continued	
Unnamed shale member (part):	
Covered; shale and platy 1- to 3-in.-thick sandstone beds exposed in gullies	7
Sandstone, quartz, yellowish-gray, fine-grained, calcareous; exposed surfaces pitted and etched by solution weathering	3
Siltstone, yellowish-gray, fine; contains 2- to 3-in.-thick beds of fine-grained sandstone like that of underlying bed; grades upward into sandstone; makes light-colored soil	3.3
Sandstone, quartz, yellowish-gray, medium-fine-grained, well-rounded, well-sorted, calcareous; 10-in.-thick lower bed that in some places resembles an arenaceous limestone; 2- to 3-in.-thick upper beds that are less calcareous	1.5
Covered; lower 2–4 ft alluvium; remainder probably shale	8
Total unnamed shale member	22.8
Total Thrifty Formation measured	37.3
Base of exposures.	

Section of the Thrifty and Graham Formations at locality M5566, about 1½ miles southwest of Lake Daniel

	Feet
Pennsylvanian System:	
Cisco Group (part):	
Thrifty Formation (part):	
Breckenridge Limestone Member (part):	
Limestone, calcarenite, olive-gray, fine; ferruginous stain on weathered surface; lenticular bedding; large ventricose fusulinids common in zone 1 ft above base, rare elsewhere; scattered crinoid stems, rare brachiopods	2+
Total exposed Breckenridge Limestone Member	2+
Unnamed shale member:	
Claystone, light-olive-gray, with ¼- to 1-in. beds of orange claystone; calcareous; upper 3 ft has limestone nodules as large as ¼ in. diameter. Lower 7 ft poorly exposed	10
Sandstone, quartz, grayish-yellow-green, medium-grained, subangular to subrounded; moderately well consolidated, calcareous cement; moderately well bedded in beds as much as 2 in. thick	1
Claystone, yellowish-gray, with small amounts of red claystone in upper 5 ft; zone containing *Myalina* and rare crinoid stems 2 ft above base	21
Total unnamed shale member	32

Section of the Thrifty and Graham Formations at locality M5566, about 1½ miles southwest of Lake Daniel—Continued

	Feet
Pennsylvanian System—Continued	
Cisco Group (part)—Continued	
Thrifty Formation (part)—Continued	
Speck Mountain Limestone Member:	
Limestone, calcarenite, light-olive-gray; weathers to large angular blocks; scattered fusulinids, sparse to rare crinoid stems, rare brachiopods resembling *Hustedia*, scattered shell(?) fragments showing prismatic structure in cross section	1
Covered, probably siltstone	1
Limestone, dusky-yellow, silty, earthy; scattered crinoid stems, a few brachiopods, much comminuted fossil debris	.7
Total Speck Mountain Limestone Member	2.7
Total Thrifty Formation measured	36.7+
Graham Formation (part):	
Unnamed shale member (part):	
Siltstone, light-olive-gray, poorly exposed	5
Siltstone, medium-light-gray, red and orange siltstone bands and very fine-grained sandstone beds as much as 6 in. thick but averaging 2 in. in thickness; forms steep bluff in roadcut; contains flecks carbonized plant material	6
Siltstone, light-olive-gray, fine; scattered discontinuous sandstone beds (channel-fill) as much as 3 in. thick; poorly developed fissility	10
Sandstone, quartz, grayish-orange, fine-grained, subrounded to subangular, moderately well sorted, crossbedded	2
Covered, probably shale	5
Total unnamed shale member	28
Total Graham Formation measured	28
Base of exposures.	

Section of the Thrifty and Graham Formations at locality M5567, about 2½ miles south of Lake Daniel

	Feet
Pennsylvanian System:	
Cisco Group (part):	
Thrifty Formation (part):	
Unnamed shale member (part):	
Sandstone, quartz; grayish orange, fine grained, subrounded to subangular, moderately well to well sorted in lower bed; moderate brown to very dusky red purple, medium grained, subangular to subrounded, fairly well sorted in upper bed; contains bands as much as ¼ in. thick of white angular chert fragments in upper bed; lower bed about 3 ft thick; upper bed, which is less resistant, caps hill and weathers to a ferruginous rubble	6+
Covered, probably shale	18
Total unnamed shale member	24+

Section of the Thrifty and Graham Formations at locality M5567, about 2½ miles south of Lake Daniel—Continued

	Feet
Pennsylvanian System—Continued	
Cisco Group (part)—Continued	
Thrifty Formation (part)—Continued	
Breckenridge Limestone Member:	
Limestone, calcarenite to calcilutite, brownish-gray to light-olive-gray, fine; beds 2–3 in. thick; large ventricose fusulinids common near base, rare toward the top; crinoid columnals and brachiopods noted	3
Total Breckenridge Limestone Member	3
Unnamed shale member:	
Covered, probably shale	23
Speck Mountain Limestone Member:	
Limestone, calcarenite, light-olive-gray, fine, in two beds; 12-in.-thick lower bed weathers to large angular blocks; 12-in.-thick upper bed, separated from the lower by about 12 in. of siltstone, is exposed as a nodular rubble. Fusulinids locally common, rare elsewhere; contains a few bands of bioclastic hash; crinoid stems locally common, brachiopods scattered to rare	3
Total Speck Mountain Limestone Member	3
Total Thrifty Formation measured	53+
Graham Formation (part):	
Unnamed shale member:	
Covered, much limestone float	5.7
Siltstone, light-gray; has yellow bands which are somewhat more resistant to weathering and which indicate bedding	6
Sandstone, pink, fine-grained	.5
Siltstone, yellow and gray, poorly exposed	8
Siltstone, as below	6
Sandstone, quartz, pale-greenish-yellow, fine-grained, subrounded to subangular, well-sorted, calcareous; poorly exposed except in ravines	2
Siltstone; lower 2 ft. is light olive gray; overlying 20 ft is red, green, purple, and gray siltstone; remainder is light gray. Bedding obscure	39
Covered	4
Total unnamed shale member	71.2
Ivan Limestone Member (part):	
Limestone, calcarenite, yellowish-gray; bioclastic hash; lower 1 ft nodular, upper 6 in. a single bed forming a barely discernible escarpment; upper bed jointed into polygonal blocks; composed almost entirely of comminuted indeterminate fossil debris; paves creek bed	1.5
Total Graham Formation measured	72.7

Section of the lower part of the Thrifty Formation and upper part of the Graham Formation at locality M5568, about 3 miles south of Lake Daniel

	Feet
Pennsylvanian System:	
Cisco Group (part):	
Thrifty Formation (part):	
Unnamed shale member (part):	
Sandstone, quartz, very dark red, medium grained subangular to subrounded, moderately well sorted, crossbedded; angular chert grains somewhat larger than quartz grains; one or more 2- to 3-in.-thick chert-conglomerate beds near base; medium-grained quartz sand matrix containing angular to subangular chert pebbles as much as ½ in. diameter; weathers to irregular boulders as much as 1 ft thick	3+
Claystone, light-olive-gray, with ½-in.-thick beds medium-yellowish-brown claystone which are somewhat better consolidated and weather out as ½-in.-thick chips	19
Total unnamed shale member measured	22+
Speck Mountain Limestone Member:	
Limestone; two 18-in.-thick beds separated by thin siltstone parting. Lower bed, light-olive-gray fine calcarenite containing many fragments of shells and crinoid stems in lower 4 in.; fossils rare elsewhere. Upper bed, olive-gray brittle fine calcarenite containing rare fusulinids and common brachiopods resembling *Marginifera*. Lower bed weathers to blocks as much as 6 ft across	3
Total Speck Mountain Limestone Member	3
Total Thrifty Formation measured	25+
Graham Formation (part):	
Unnamed shale member:	
Claystone, light-gray; has yellow and orange claystone bands as much as ¼ in. thick and flecks of carbonized plant fragments	10
Shale, dark-yellowish-brown, papery, carbonaceous, coaly; many plant impressions	.3
Siltstone, light-gray, very fine; contains carbonized plant fragments near top	6
Sandstone, quartz, yellowish-gray, fine-grained, subangular to subrounded; in beds as much as ½ in. thick	.5
Siltstone, light-olive-gray; becomes lighter gray 20 ft above base; has scattered light-olive-gray fine-grained sandstone lenses and red-claystone streaks	31
Sandstone, quartz grayish-orange-pink, very fine grained, slightly calcareous; interbeds of claystone as much as 8 in. thick	5
Claystone and siltstone, olive-gray; weathers to light olive gray; very poor bedding	13
Siltstone, dusky-red; grades into overlying claystone and siltstone; no apparent bedding	10
Covered, probably siltstone	14
Total unnamed shale member	89.8

Section of the lower part of the Thrifty Formation and upper part of the Graham Formation at locality M5568, about 3 miles south of Lake Daniel—Continued

	Feet
Pennsylvanian System—Continued	
Cisco Group (part)—Continued	
Graham Formation (part)—Continued	
Ivan Limestone Member:	
Limestone, calcarenite, light-olive-gray; upper 6 in. nodular, argillaceous, bioclastic; lower 1 ft argillaceous in basal 2 in.; remainder in two slabby beds; in places paves creek bed; locally a coquina of fragmented shell debris	1.5
Total Ivan Limestone Member	1.5
Unnamed shale member (part):	
Siltstone, greenish-gray; contains several 2-in. beds of pale-olive very fine grained quartz sandstone; poorly exposed	4
Total unnamed shale member	4
Total Graham Formation measured	95.3

Section of the Graham Formation at locality M5601, 2½ miles north-northwest of Lake Daniel

	Feet
Pennsylvanian System:	
Cisco Group (part):	
Graham Formation (part):	
Ivan Limestone Member (part):	
Limestone, calcarenite, yellowish-grav; bioclastic hash; contains numerous rodlike bodies having opaque rims and clear cores, a few round to oval bodies that may be oolites, a few elongate to rounded limonitic bodies ¼–½ in. in diam.; weathers to polygonal blocks as much as 8 in. thick that have rounded corners; surfaces show effect of solution weathering; a few crinoid stems and shell fragments noted; rare productid brachiopods on weathered surfaces	2+
Total Ivan Limestone Member measured	2+
Unnamed shale member:	
Claystone, light-olive-gray, plastic; clayey soil	2.5
Total unnamed shale member	2.5
Avis Sandstone Member (part):	
Sandstone, quartz, pale-yellowish-orange, medium- to fine-grained, poorly sorted, subrounded to subangular, crossbedded; interbedded siltstone; crossbeds strike east and dip as much as 15° S., flattening in dip at top	4
Sandstone, quartz, pale-yellowish-orange, medium-grained, poorly sorted, friable, crossbedded; 8- to 10-in.-thick beds; crossbeds strike east and dip as much as 15° N. flattening in dip at top	7
Covered; chert pebbles and cobbles in soil; a few sandstone exposures	8
Covered; sandy soil	5
Sandstone; same as underlying bed but having less apparent crossbedding; hematite nodules weather free and litter slopes	5.7

Section of the Graham Formation at locality M5601, 2½ miles north-northwest of Lake Daniel—Continued

Pennsylvanian System—Continued
Cisco Group (part)—Continued
Graham Formation (part)—Continued
Avis Sandstone Member (part)—Continued

	Feet
Sandstone, quartz, yellowish-gray, medium-grained, subrounded, well-sorted; scattered hematite grains same size as quartz grains; lower 5 ft calcareous, well cemented; remainder friable; grain size increases somewhat toward top of unit; upper 3–4 ft well bedded in 2- to 3-in-thick beds, changes to pale yellowish orange where bed is no longer calcareous; lower 10–11 ft crossbedded (torrential bedding?); crossbeds dip as much as 25° E., but bedding becomes flat at top of each crossbed	14
Sandstone, quartz, dusky-yellow, medium- to fine-grained, subrounded, ripple-marked; somewhat better sorted than underlying bed; has streaks of hematitic granules that attain a thickness of ¼ in.; ripple marks 3 ft above base strike N. 60° W. (magnetic) and dip most steeply to the southeast; symmetrical ripple marks 8 ft above base of unit strike N. 60° W. (magnetic); poorly developed cross lamination	13
Sandstone, quartz, dusky-yellow, medium-grained, subangular to subrounded, poorly sorted; in 2- to 6-in.-thick beds; oscillation ripples on bedding planes; weathers to rectangular blocks; locally, upper 1–2 in. of each bed disintegrates into plates about ⅛ in. thick; three covered intervals, each about 1 ft thick, are probably siltstone	5
Covered, probably siltstone or very fine grained sandstone	12
Covered, sandy soil; sandstone boulders common on upper 3 ft of surface	5.8
Total Avis Sandstone Member	79.5
Total Graham Formation measured	84.0+

Section of the Graham Formation at locality M5771, 4 miles north-northwest of Necessity

Pennsylvanian System:
Cisco Group (part):
Graham Formation (part):
Ivan Limestone Member (part):

	Feet
Limestone, calcilutite, light-olive-gray; bioclastic in lower 3 ft; grades upward into calcarenite and bioclastic hash; lower 4 ft contains irregular beds about 1–6 in. thick and forms scarp; upper beds weather but cap hill; has fusulinids 4 ft above base, sparse to very common crinoid stems, a few brachiopods	7+
Total Ivan Limestone Member measured	7+
Unnamed shale member:	
Covered	8
Total unnamed shale member	8

Section of the Graham Formation at locality M5771, 4 miles north-northwest of Necessity—Continued

	Feet
Pennsylvanian System—Continued	
Cisco Group (part)—Continued	
Graham Formation (part)—Continued	
Avis Sandstone Member:	
Sandstone quartz, grayish-yellow, fine- to medium-grained, moderately well to poorly sorted, subrounded to subangular, thin-bedded to massive; massive part seen as boulders at base of hill; ferruginous flecks scattered throughout	6
Total Avis Sandstone Member	6
Wayland Shale Member:	
Claystone and siltstone, of which claystone predominates; poorly exposed; much sandstone and limestone float in upper 45 ft	77
Covered	5.5
Total Wayland Shale Member	82.5
Gunsight Limestone Member:	
Limestone, calcilutite, light-olive-gray, sublithographic, wavy-bedded; weathers to large blocks, ferruginous on weathered surfaces; contains algae which resemble *Archaeolithophyllum*, occasional to common fusilinids near top of bed, occasional brachiopods	3
Total Gunsight Limestone Member	3
Unnamed shale member (part):	
Covered	14
Sandstone, quartz, light-olive-brown, fine- to medium-grained, subangular to subrounded, moderately well sorted to well-sorted, thin bedded	3
Total unnamed shale member	17
Total Graham Formation measured	123.5+

Section of the Graham Formation at locality M5553, 3¼ miles northeast of Gunsight

	Feet
Pennsylvanian System:	
Cisco Group:	
Graham Formation:	
Avis Sandstone Member (part):	
Sandstone, platy; 1-ft-thick beds; texture and color same as basal bed	8
Sandstone, platy; 4-in.-thick beds; texture and color same as basal bed	20
Sandstone, quartz, grayish-dusky-yellow to moderate brown, medium-grained, subrounded to subangular, well-sorted, massive; weathers into large blocks	2.5
Total Avis Sandstone Member measured	30.5

Section of the Graham Formation at locality M5553, 3¼ miles northeast of Gunsight—Continued

	Feet
Pennsylvanian System—Continued	
Cisco Group (part)—Continued	
Graham Formation—Continued	
Wayland Shale Member:	
Covered, sandstone talus	83
Total Wayland Shale Member	83
Gunsight Limestone Member:	
Covered; composed of limestone plates, light-olive-gray calcarenite, and bioclastic hash having hackly fracture	3
Limestone, calcarenite, light-olive-gray; grades upward into calcilutite having subconchoidal fracture; surfaces pitted and etched by solution weathering	1.5
Total Gunsight Limestone Member	4.5
Unnamed shale member (part):	
Covered	3
Sandstone, poorly exposed	7.2
Covered	8.6
Sandstone, quartz, grayish-yellow, medium-grained, subrounded to subangular, well-sorted; may be slump	1.3
Claystone, olive-gray; weathers light olive gray; poorly exposed; fusulinids locally in great abundance	7.2
Limestone, calcarenite, light-olive-gray, nodular, lenticular; grades laterally into calcareous shale that is almost a coquina of large ventricose fusulinids; zone on hill slopes away from good exposure marked by many loose fusulinids in soil	.5
Shale, gray, calcareous; very fossiliferous in upper part; many well-preserved brachiopods, bryozoans, fusulinids, and a few gastropods	2
Sandstone, light-olive-gray, calcareous	.3
Shale, light-olive-gray	2.5
Total unnamed shale member	32.6
Total Graham Formation measured	150.6

Section of the Graham Formation at locality M5571, about 2¼ miles east-northeast of Gunsight

	Feet
Pennsylvanian System:	
Cisco Group (part):	
Graham Formation (part):	
Avis Sandstone Member (part):	
Sandstone, quartz, grayish-orange, fine- to medium-grained, subrounded to subangular, well-sorted; contains grains and scattered patches of hematitic material; calcareous cement; about 3 ft above base is a fossiliferous 1-in.-thick bed of calcareous sandstone containing many fusulinids, many crinoid stems, and a few *Caninia;* rocks below this bed are poorly exposed and may be float	5+
Total Avis Sandstone Member measured	5+

Section of the Graham Formation at locality M5571, about 2¼ miles east-northeast of Gunsight—Continued

	Feet
Pennsylvanian System—Continued	
Cisco Group (part)—Continued	
Graham Formation (part)—Continued	
Gunsight Limestone Member:	
Limestone, calcarenite, yellowish-gray, fine, somewhat argillaceous; basal bed, 2 in. thick and poorly exposed, grades upward into 18-in.-thick bed of nodular limestone and shale(?), which is overlain by a 6-in.-thick bed of earthy limestone containing many *Caninia*, some of which are in position of growth; remainder is nodular limestone containing many *Caninia*, which weather free and locally pave the ground; rare fusulinids, crinoid stems, bryozoans, and brachiopods noted	3
Total Gunsight Limestone Member	3
Unnamed shale member:	
Siltstone, poorly exposed; fusulinids free in soil	4
Sandstone, quartz, light-olive-gray, fine-grained, calcareous; in beds as much as 1½-in.-thick; contains brachiopods and rare reedlike plant fragments	2
Covered, probably gray shale	32
Sandstone, quartz, poorly exposed, moderate-reddish-orange to dusky-red, medium-grained, subrounded, well-sorted; found as tabular cobbles as much as 4 in. in diameter and 1½ in. thick	1
Covered, limestone float	8
Total unnamed shale member	47
Bunger Limestone Member:	
Limestone, calcarenite, dusky-yellow, ferruginous, earthy; forms bench; crinoid stems common	1.2
Limestone, calcarenite, light-olive-gray; 4- to 8-in.-thick beds; weathers to well-rounded boulders; large ventricose fusulinids common; also contains scattered crinoid stems and a few brachiopods	1
Limestone, calcarenite or calcilutite, light-olive-gray; ferruginous on weathered surface; wavy bedding in lower 1 ft; contains laminated ferruginous bands which may be algal; lower beds average 2 in. thick; scattered brachiopods and crinoid stems, rare fusulinids, rare ostracodes(?)	5.7
Total Bunger Limestone Member	5.7
Unnamed shale member (part):	
Covered, probably siltstone with sandstone interbeds; much limestone and sandstone float	32
Siltstone, light-olive-gray, poorly exposed	5
Siltstone, light-gray; fragments of orange siltstone weather out; a few flakes of muscovite as much as 1 mm in diameter; flecks of carbonized plant material	3

Section of the Graham Formation at locality M5571, about 2¼ miles east-northeast of Gunsight —Continued

Pennsylvanian System—Continued
Cisco Group (part)—Continued
Graham Formation (part)—Continued
Unnamed shale member (part)—Continued

	Feet
Covered	9
Claystone, gray, plastic, poorly exposed	5
Covered	2
Sandstone, quartz, yellowish-gray, fine-grained; 2- to 3-in.-thick beds; breaks into polygonal slabs; locally exposed as pavement in bed of stream, but mostly covered by stream gravels	.5+
Total unnamed shale member	56.5+
Total Graham Formation measured	119.4+

Section of the Graham Formation along the East Fork of Gonzales Creek, locality M5713, southeastern part of the Wayland quadrangle

Pennsylvanian System:
Cisco Group (part):
Graham Formation (part):
Bunger Limestone Member (part):

	Feet
Limestone, olive-gray, with orange ferruginous streaks and bands of calcarenite; fusulinids common to very common; algae, scattered to rare; caps hill	1
Limestone, calcilutite, light-olive-gray; beds 3–4 in. thick in lower half, 2–3 in. thick in upper half; weathers to nodular slabs and boulders; bedding wavy; algal; algae most numerous in upper 2 ft; crinoid stems and spines common, brachiopods occasional to rare; fossils other than algae are most common in lower half	4
Limestone, calcilutite, gray, thin-bedded, platy; beds as much as 2 in. thick	.75
Total Bunger Limestone Member measured	5.75

Unnamed shale member:

Covered, probably claystone	2
Claystone, olive-gray	2.5
Claystone, carbonaceous, and coal; much macerated plant debris; plastic when wet; claystone laminae as much as 1/16 in. thick	.3
Claystone, olive-gray; contains interbeds of dark-yellowish-orange claystone; beds as much as 1 in. thick	1
Claystone, light-olive-gray, poorly exposed; in ravines	9
Covered, probably shale	11.5
Sandstone, quartz, yellowish-gray, fine-grained, poorly sorted; calcareous cement; poorly preserved plant fragments resembling rushes; bedding surfaces contain trails; forms bench; poorly exposed	2
Covered; lower 3 ft probably sandstone; upper 7 ft probably siltstone	10

Section of the Graham Formation along the East Fork of Gonzales Creek, locality M5713, southeastern part of the Wayland quadrangle—Continued

	Feet
Pennsylvanian System—Continued	
Cisco Group (part)—Continued	
Graham Formation (part)—Continued	
Unnamed shale member—Continued	
Sandstone, quartz, dark-yellowish-orange to yellowish-orange, medium-grained, subrounded to subangular, moderately well sorted; contains angular white chert fragments, iron-stained quartz grains; in beds as much as 40 in. thick; crossbedded; forms sequence of benches about 3–5 ft apart; weathers to rounded rubble including boulders as much as 40 in. thick and 6–8 ft across	24
Covered, probably sandstone	5
Covered, probably shale	17
Total unnamed shale member measured	84.3
Total Graham Formation measured	90.05

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