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STATIGRAPHIC AND PALEONTOLOGIC STUDIES OF THE PENNSYLVANIAN AND PERMIAN ROCKS IN NORTH-CENTRAL TEXAS

By

WALLACE LEE, C. O. NICKELL, JAMES S. WILLIAMS, AND LLOYD G. HENBEST

Bureau of Economic Geology
E. H. Sellards, Director

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of Democracy, and while guided and controlled by virtue, the noblest attribute of man. It is the only dictator that freemen acknowledge, and the only security which freemen desire.

Mirabeau B. Lamar

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PREFACE

The investigations in north-central Texas the results of which are recorded in this report were carried on by the United States Geological Survey with funds allocated to the Survey under the Public Works Administration. The project included stratigraphic studies in Brown and Coleman counties on the Canyon and Cisco (restricted) groups of the Pennsylvanian by Clarence O. Nickell assisted by Fred F. Yockstick; stratigraphic studies of the Cisco group (restricted) in Young, Stephens, and Throckmorton counties by Wallace Lee assisted by Ivan J. Fenn; subsurface studies of the Bunger and associated oil pools in southeastern Young County, by Lloyd E. Wells, and of the Cross Cut-Blake oil pools in northwestern Brown County by Edgar D. Klinger assisted by R. B. Cheney. The results of the subsurface work on the Bunger and Cross Cut-Blake districts to which occasional reference is made in this report are to be published elsewhere. The areas in which the stratigraphic work was done are shown on the accompanying guide map (fig. 1).

Fossil collections in the areas of field work were made by James Steele Williams whose report on the invertebrate fossils except fusulinids is included in the report. Lloyd G. Henbest has reported on the fusulinids collected by the field parties. Both the paleontologic reports added materially to the results of the field work.

Pennsylvanian system, Permian system, Cisco group restricted, and Wichita group redefined, as herein used, correspond to the Pennsylvanian series, Permian series, Cisco group, and Wichita group as now accepted by the United States Geological Survey. This usage has been followed to accord with the present classification of the Texas Bureau of Economic Geology. The Permian-Pennsylvanian boundary in this region is, however, still a debated subject.

The writers of these reports are greatly indebted to many firms and individuals who gave freely of their facilities and information, and without whose aid only a part of the work could have been accomplished in the time available. Among the firms who helped materially by supplying maps, logs, and altitudes are The Continental Oil Company, The Texas Company, Atlantic Oil Company,

Shell Petroleum Corporation, Stanolind Oil Company, Sinclair-Prairie Oil Company, Humble Oil & Refining Company, Gulf Oil Corporation, Laughlin & Simmons, Hudnall & Pirtle, Hightower Oil & Refining Company, Carter Oil Company, and Mid-Continent Oil & Gas Company.

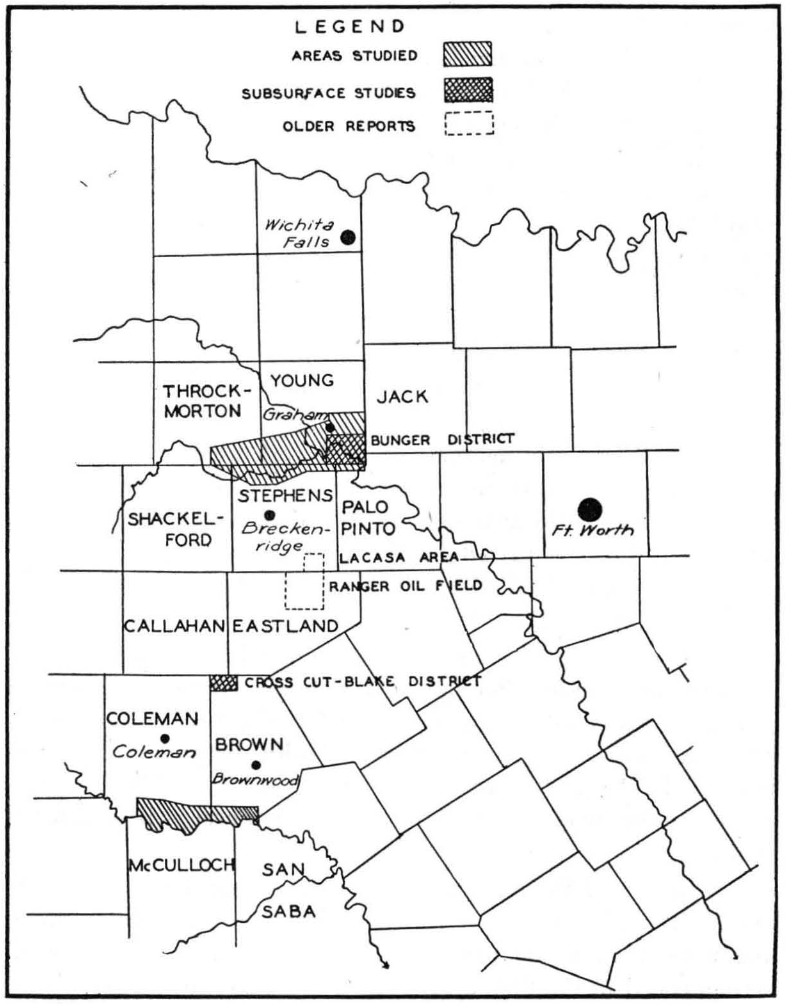

Fig. 1. Key map of north-central Texas showing areas studied.

Among the many individuals to whom the geologists contributing to this report are indebted are R. T. Hill, Dallas, Texas; M. G. Cheney, Coleman, Texas; Ben H. Ramsey, Graham, Texas; T. F. Petty and John F. Bricker, Cisco, Texas; W. D. Kelley, J. J. Maucini, Ralph S. Powell, Virgil Pettigrew, Everett C. Parker, Frank Parsons, John A. Kay, and M. M. Garrett, Wichita Falls, Texas; R. E. Graves and C. D. Anderson, Brownwood, Texas; H. B. Fuqua, J. B. Lovejoy, H. S. Clark, and J. M. Armstrong, Fort Worth, Texas; and A. L. Beekley and A. F. Truex, Tulsa, Oklahoma. Many others assisted from time to time and no one from whom information or help was asked failed to coöperate.

The various projects were undertaken after consultation with the director of the Texas Bureau of Economic Geology and the officers of the North Texas Geological Society, the Fort Worth Geological Society, and others interested in the economic development of north-central Texas. Work was commenced on April 2, 1934, and the field work was completed by the several parties at various dates in September, 1934. The manuscripts of the various reports were completed in the fall of 1935.

The stratigraphic work laid special emphasis on the details of the sections with a view not only to determine the intervals between key beds useful in the determination of structure for the development of oil and gas, but also to determine the variations that occur in the character and thickness of the beds in different areas. Considerable information was procured in regard to unconformities within various formations which should be useful in oil development.

During the editing of the various papers included in this report, it became necessary to abandon the term Merriman limestone member originally applied to a specific bed in the Ranger district which has subsequently been rather loosely used. A new and more inclusive term, the Winchell member, has been introduced for the reasons explained in the paper on the "Stratigraphy of the Canyon and Cisco Groups on Colorado River in Brown and Coleman Counties." The term Winchell member has been inserted also in the other parts of this report although the older term was used by the several authors in the original manuscripts.

WALLACE LEE.

August 15, 1935.

STRATIGRAPHY OF THE CISCO GROUP OF THE BRAZOS BASIN

WALLACE LEE

INTRODUCTION

The study of the stratigraphy of the Cisco group along the Brazos River was begun on April 2 and completed on September 30, 1934. Much work had already been done on the stratigraphy of the region as a whole, but no local study of so detailed a character has heretofore been made. Earlier work had been concentrated on the limestones of the section as the most direct approach to the study of the structure of the area for oil development, and the sandstones and conglomerates of the section had received less attention than their importance has now been found to justify. The relation of the discontinuous limestone beds to the sandstones and to the many unconformities had not previously been recognized. A number of facts of considerable significance for working out the structure and also concerning the character of the sand bodies in which oil accumulation takes place down the dip have been learned. On account of the numerous unconformities the work proved difficult and slow, and the determination of the complicated relations of the various outcrops to one another resembled in many respects the solving of a jigsaw puzzle. For this reason the description of the different formations and their thin and interrupted component members is necessarily detailed. The areal geology is shown in Plates V and VI.

PENNSYLVANIAN SYSTEM

CISCO GROUP RESTRICTED

The Graham, Thrifty, Harpersville, and Pueblo formations constitute the Cisco group, the highest division of the Pennsylvanian, as here limited. Formerly the Moran and Putnam formations were also included in the Pennsylvanian, but the Texas Bureau of

Issued July, 1938.

Economic Geology[1] now places these formations in the Permian, thus restricting the earlier definition of the Cisco group.

The formations of the Cisco group are composed chiefly of shale, sandy shale, and sandstone, with a considerable number of thin limestone beds, many of which are discontinuous.

The formations, particularly in the area along Brazos River, contain a great many unconformities, and those in the lower formations of the group are particularly conspicuous.

GRAHAM FORMATION

DIVISIONS

The Graham formation, not including the filled channel at its base, is at least 590 feet thick, the uncertainty being due to the fact that the formation is bounded both at the top and bottom by unconformities. In the Brazos River region it is conveniently divided into the following units, for discussion:

	Thickness *Feet*
Wayland shale member	110
Shale, with numerous channels and unconformities	174
Bunger limestone member	6
Shale and sandstone	168
Gonzales limestone member	18
Shale and sandstone	113
Salem School limestone member	1
Channel deposit	
	590

To this must be added a thickness of at least 150 feet for the channel deposit below the Salem School limestone. As the formation is bounded both above and below by unconformities, no definite thickness for it can be set. Measurable and convenient limits for a partial thickness of the formation, however, are from the base of the Salem School limestone member up to a limestone bed at the base of the Wayland shale member, an interval of 480 feet.

BASE OF THE GRAHAM FORMATION (KISINGER CHANNEL)

The lowest division of the Cisco group is the Graham formation. At its very base an unconformity is manifested in a deep channel in the southeast corner of Young County, on the southern margin

[1]Sellards, E. H., Adkins, W. S., and Plummer, F. B., The Geology of Texas, Vol. I, Stratigraphy: Univ. Texas Bull. 3232, pp. 140-144, 1932 [1933].

of which is the Kisinger oil pool. This channel (Pl. I) was eroded through the Home Creek limestone member at the top of the Caddo Creek formation and an undetermined amount into but not through the Ranger limestone member at the top of the underlying Brad formation. The following composite section shows the sequence of beds immediately below the Graham formation. It was measured on the southern margin of the channel, where it is believed that not much erosion has taken place, though there is no way of determining locally how much of the Home Creek limestone may have been removed.

	Thickness *Feet*
Home Creek limestone member	38+
Shale	2
Sandstone (lenticular and variable)	2–18
Talus (probably shale)	107–91
Ranger limestone member (base not exposed)	15+

This report is not concerned with strata below the Cisco group, but it is worth mentioning that the sandstone below the Home Creek differs so much in thickness from place to place that the presence of an unconformity within the Caddo Creek formation is suggested. This sandstone is 2 feet below the base of the Home Creek on the bluff southeast of the mouth of Connor Creek, where it is 2 feet thick, but 2 miles distant, on the bluff half a mile northeast of Ming Bend School, it is 18 feet thick. No extensive study of this sandstone, however, was made.

As the channel at the base of the Graham formation has been cut completely through the Caddo Creek formation and into the Ranger limestone, it was at least 149 feet deep and probably not less than 160 feet deep. The channel was therefore commensurate in depth with the present valley of Brazos River, though in this locality it did not attain the maturity of erosion of the present cycle.

The lower part of the channel is filled with quartz sandstone and chert conglomerate. Most but not all of the pebbles are subangular and 1 inch or less in diameter, but a few 3 inches or more in diameter were noted. The pebbles are very irregularly distributed in the sandstone, occurring in interrupted bands and masses with cross-bedded and swirling lines of deposition at all levels. They are chiefly gray and white chert, though there is a considerable variety of other pebbles, including black and banded chert and some greenish material that may be novaculite, but there are no quartz pebbles. All the material, so far as known, could have been derived from a southwestward extension of the Ouachita Mountains, which were being raised at this time. Earlier studies of the Pennsylvanian conglomerates of the Brazos Valley have indicated that the material came from this source.[2] The greatest thickness of sandstone and conglomerate measured at any point is 55 feet, though the deposit is undoubtedly thicker.

The upper part of the material filling the channel is sandy shale and laminated shaly sandstone containing quantities of macerated plant fragments. In many places the laminae are almost coaly, and at one point 2 inches of impure coal was seen. This sandy shale member is 22 to 30 feet thick near the margin, but toward the center of the channel in some places it is thicker. On the west side of Connor Creek about a mile above its junction with Brazos River, fossil leaves were collected from ferruginous shale concretions in channel deposits between the Salem School limestone member and the top of the conglomeratic sandstone. These specimens were examined by Charles B. Read, of the United States Geological Survey, who reports the following species:

Mariopteris sillimani (Brongniart) White
Neuropteris ovata Hoffman
Asterophyllites equisetiformis (Schlotheim) Brongniart
Annularia stellata (Schlotheim) Wood
Sphenophyllum sp.
Dicranophyllum sp.
Cordaites sp.
Sigillaria sp.

As might be supposed, the sides of the channel vary considerably in the angle of slope. Where it is steep there is no difficulty in determining the contact of the channel deposit with the channel wall. Where, however, the slopes were low the trace of the old surface on the present topography is irregular and is not everywhere easy to follow or map.

At most places where erosion has exposed the contact of the channel deposits with the old surface, these deposits contain large and small boulders and pebbles of Home Creek limestone incorporated in the contact conglomerate. In many places huge masses of

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[2]Bay, Harry, A study of certain Pennsylvanian conglomerates of Texas: Univ. Texas Bull. 3201, pp. 149–188, 1933.

Home Creek limestone dislodged from the ancient rim rock occur at various levels in the contact deposits, as shown on the southeastern margin of the channel in the accompanying sketch (Pl. I). These pebbles and boulders do not differ in appearance from similar debris from the present outcrops of Home Creek limestone and suggest that the Home Creek limestone was already consolidated at the time of its first exposure and erosion.

The sketch (Pl. I) shows the areal extension of the channel as indicated by the edge of the eroded Home Creek limestone in the outcrops. Lloyd E. Wells, who was working on the subsurface of the Bunger oil pool, which lies immediately to the west, was able to trace certain areas in which the Home Creek limestone is absent in the well logs in that area. These are also shown in Plate I. It is evident that as 38 or more feet of erosion must have taken place to remove the Home Creek limestone completely, only the deeper parts of the subsurface channel in general can be definitely recognized in this way, and the actual width of the channel in the subsurface area is greater than that shown. Certain areas in the surface exposures where the Home Creek limestone was not entirely removed show limestone conglomerate at the top of the limestone, and some well logs show only partial sections of the Home Creek. However, the accuracy of many of the well logs is questionable. In some logs the conglomeratic sandstone has either been logged as limestone or not mentioned at all, to the confusion of the subsurface investigation of the channel deposits.

The deeper part of the channel along Connor Creek, where the Home Creek limestone is entirely removed on the outcrop, is about 2 miles wide toward the northeast and tapers southwestward to a width of less than 1 mile on Herron Bend. No subsurface extension of the deep, broad channel of the surface outcrops could be detected in the logs, which, in the Bunger pool, suggest a branching tributary channel.

The channel exposed at the surface tapers toward the southwest in this area and its course in consequence appears to have been toward the northeast. As the source of the pebbles in the conglomerate, however, appears to have been to the northeast, it seems probable that the channel as here defined was tributary to a basin somewhere to the east, where the Home Creek limestone is erratic in its distribution, and that the filling of the channel was coincidental with the filling of the basin.

This channel deposit is here considered the basal deposit of the Graham formation; the Salem School limestone, which immediately overlies it, is therefore the first marine member of the Graham formation.

SALEM SCHOOL LIMESTONE MEMBER

The bed which is here named the Salem School limestone member of the Graham formation is a yellowish earthy limestone crowded with marine fossils. It is in few places more than 8 inches thick, but over the central part of the channel on Connor Creek it is nearly 2 feet thick. This bed is particularly interesting because it overlies both the channel deposits and the older Home Creek limestone. Half a mile southeast of Salem School, where it is well exposed, it is 5 feet above the Home Creek limestone. On the south side of the channel, a short distance south of Ming Bend School, it is 17 feet above the Home Creek. As the Home Creek limestone was exposed to erosion prior to the deposition of the Salem School limestone, the variations in the interval between them may be attributed to erosion of the surface of the Home Creek limestone. However, near Salem School there is no evidence of unconformity, although during the interval represented by the 5 feet of shale separating these beds, a channel more than 150 feet deep was eroded and filled.

The regional extension of the Salem School limestone is not now known, but it was recognized above the Home Creek north of Finis, at least 1 mile from the margin of the channel. Where the Home Creek limestone is absent this limestone has previously been mapped as Home Creek. This has probably not involved any serious error in the determination of structural relations, though there is reason to believe that there is a lowering of the Salem School limestone over the central part of the channel. Probably less error is involved in using this bed as a datum plane than in using the eroded surface of the Home Creek itself.

SALEM SCHOOL LIMESTONE MEMBER TO GONZALES LIMESTONE MEMBER

The interval from the top of the Salem School limestone, on the margin of the channel which it overrides, to the top of the Gonzales limestone was found at two places on the northwest side of the channel to be 130 feet and 134 feet. Over the channel no intervals so small as these were measured, the interval ranging from 140 to 148 feet. It appears likely that either through compacting or incomplete filling of the channel, the Salem School is lower over the center of the channel than elsewhere.

The following section is representative of the beds from the Salem School limestone to the Gonzales limestone:

Section from Salem School limestone to Gonzales limestone half a mile southeast of Salem School, southeastern Young County.

		Thickness *Feet*
12.	Gonzales limestone member, only partly exposed (estimated)	16
11.	Not fully exposed, probably shale with some sandstone beds	36
10.	Sandstone, massive	2
9.	Not exposed, probably shale	5
8.	Sandstone	1
7.	Shale, dark, weathering buff, with thin partings of yellow clay ironstone	10
6.	Sandstone	2
5.	Sandy shale, platy, with macerated plant fragments	10
4.	Shale, gray	15
3.	Shale, gray, clay ironstone concretions and many fossils, particularly gastropods, in lower 5 feet	17
2.	Shale, black, fissile, nonfossiliferous; on weathering forms abundant gypsum crystals	15
1.	Salem School limestone member, hard, earthy; weathers yellowish; fossiliferous	1
		130

The black fissile shale (bed 2 of the section) is present both above the channel deposits and outside the channel area but is seldom reported in well logs. The abundant gypsum crystals of the exposures are a conspicuous and unique feature. The 56 feet of beds 6 to 11, immediately below the Gonzales limestone, contains bands of sandstone and many irregularities of sedimentation, but nothing suggesting channeling was seen. In the outcrops on Brushy Mound, a hill south of the Graham-Finis road and east of Connor Creek, a thin fossiliferous limestone appears about 45 feet below the top of the Gonzales limestone. This horizon lies within the interval of alternating sandstones in the above section, and the absence of the limestone near Salem School may be an indication of its erosion and replacement by a sandstone bed. This change would be quite in line with the usual sequence of events, but this bed is only a few inches thick and could not be followed, as its horizon is nearly everywhere covered by talus.

GONZALES LIMESTONE MEMBER

The Gonzales limestone is well exposed on a high, nearly inaccessible westward-facing bluff on the south side of Brazos River opposite and southeast of Salem Bend, where it is 18 feet thick. This is the only place where a complete and unweathered section of the Gonzales limestone was seen.

Section of Gonzales limestone member and associated beds on bluff opposite Salem Bend, southeastern Young County.

	Thickness Feet	Inches
5. Conglomeratic sandstone	7	
4. Shale, gray, sandy	6	
3. Sandstone, fine grained, dense, thick bedded, light gray; bedding irregular, in part limy	9	
Unconformity		
2. Gonzales limestone member (18 feet):		
Limestone, hard, resistant, fossiliferous; top bed crowded with crinoid stems, weathers yellow to buff	4	
Limestone beds alternating with thin shale partings containing fusulinids	2	
Limestone composed almost entirely of broken brachiopods		3
Limestone beds alternating with shale; shale beds increasing in thickness	1	9
Shale, limy, very fossiliferous, crowded particularly with fusulinids, though fusulinids are common in all the shale partings	2	
Limestone, irregularly bedded, nodular, dark gray, not particularly fossiliferous	3	
Limestone, sandy, crowded with fusulinids	1	
Limestone, sandy, or limy sandstone; no fossils	4	
1. Sandstone with fucoidal webs	4	
	44	

As the top of the Gonzales limestone is in contact with sandstone unconformably above it, the entire original section of the Gonzales may not be represented even here, though this section is thicker than any other in the area. Most of the limestone beds of the Gonzales are either very thin bedded or earthy or sandy. This condition reduces their resistance to weathering, so that few outcrops show the whole section, and the beds are commonly so much altered as to be difficult of recognition. Earthy limestones may alter to flaky masses; sandy limestones are leached to soft sandstone; and the thinner beds break down and become covered by the talus from the resistant sandstone beds above. The beds are rarely seen except on well-drained areas high on hill slopes. In weathering by moisture the beds are so completely leached that they disintegrate.

In some places only the upper parts of the section are well exposed, whereas in others only the basal beds are seen. In the saddle south of Brushy Mound the greater part of the topmost limestone is conspicuous in a bench. The lower beds, however, which contain very abundant fusulinids, are inconspicuous, being represented only by small fragments in the talus. On the other hand, along the road from Graham to Henry's Chapel, west of Connor Creek, on a hillside north of the road, only a few weathered fragments of the upper members are recognizable in the talus about the outcrop. The basal limy sandstone member is conspicuous, but the member containing the fusulinids is seen in but few places. As this member is followed along the hillside toward the west it slopes to a lower altitude and the leaching becomes progressively more nearly complete. The bed passes first into blocks leached along the surface and bedding planes. Farther on the leaching attacks the joints, leaving only a central kernel of unaltered sandy limestone. Finally all semblance to the original rock is lost, and the once limy sandstone with fusulinids becomes indistinguishable except by its porosity from the overlying blocks of sandstone in the talus. Contrary to appearances, the beds of the Gonzales do not change radically in character within short distances along the outcrop. It is the phases of weathering which materially affect the appearance of different outcrops of the same bed from point to point. By a careful study of the characteristics and fossil content of the different beds it is possible to identify them with a considerable degree of accuracy over considerable areas.

GONZALES LIMESTONE MEMBER TO BUNGER LIMESTONE MEMBER

The following section showing the interval from the Gonzales limestone to the Bunger limestone was measured on the south slope of Brushy Mound, an isolated hill south of the Graham-Finis road about half a mile east of Connor Creek:

Section showing interval from Gonzales limestone to Bunger limestone on Brushy Mound, southeastern Young County.

	Thickness Feet	Inches
10. Conglomerate, base not exposed	15	
9. Talus, probably shale	50	
8. Bunger limestone member	1	
7. Talus, probably shale	15	6
6. Sandstone		6
5. Talus, chiefly shale	67	
4. Sandstone, massive and bedded, not all exposed	67	
3. Sandstone, limy, massive, dark and pitted	2	
2. Talus	16	
1. Gonzales limestone member	10	
	244	

The interval from the top of the Gonzales limestone member to the base of the Bunger limestone member is 168 feet, to which must be added a thickness of 6 feet for the Bunger limestone, here only partly exposed, making the interval to the top of the Bunger 174 feet.

The thick sandstone deposit, beds 3 and 4, which overlies the Gonzales limestone member is in many places extremely conglomeratic. It rests unconformably on the underlying beds (fig. 2). On Brushy Mound, as shown in the section, there is an interval of 16 feet between this sandstone and the Gonzales. On the river bluff already mentioned, opposite Salem Bend, sandstone and conglomerate rest directly on Gonzales limestone. On the hillside north of the road from Graham to Henry's Chapel, three-fourths of a mile northwest of Connor Creek, the conglomeratic sandstone at its base contains pebbles of clay ironstone and limestone, which suggests that the top of the Gonzales has been eroded, though the contact was not seen.

Ross,[3] in describing the Gonzales limestone at its type locality, in the Lacasa area of the Ranger district, 30 miles to the south, says:

> The top of the Gonzales limestone is marked by a slight unconformity. In most of the area it is overlain by only a few inches of shale, above which lies a very massive bed, the base of which is an intraformational conglomerate containing ferruginous clay pebbles. This grades into a conglomerate composed of light-colored chert pebbles with quartz sand filling the interstices, and this conglomerate in turn grades into a normal sandstone.

[3]Ross, C. S., The Lacasa area, Ranger district, north-central Texas: U.S. Geol. Survey Bull. 726, pp. 307–308, 1921.

He notes that the Gonzales limestone thins or is absent in the northern part of the Lacasa area and that the interval above the Home Creek limestone is "about 100 feet." *Campophyllum torquium* is reported to be abundant in the Lacasa area, but none was seen in the Gonzales on Brazos River.

It seems likely that a somewhat greater unconformity exists at the base of this sandstone overlying the Gonzales on Brazos River than was observed by Ross in the Ranger district. The Gonzales limestone seems to be cut out by unconformity south and west of Salem Bend, and it is probably missing in other areas farther south.

The conglomeratic sandstone deposit is less regular on Brazos River than would appear from the description of the bed in the Lacasa area. The vertical distribution of the conglomerate also is less regular, the thickness greater, and the top less well defined. It passes into the shale of the upper part of the section by a series of beds of alternating sandstone and shale, and no sharp line can be drawn at its top.

The sandstone deposit, although showing unconformable relations at its base, shows no sign of having been deposited in channels in any of the places seen along the outcrop. It contains poorly preserved trunks and fragments of plants in some places, but these are sporadic and rare. The pebbles are similar to those in the Kisinger channel.

The following section, measured on the river bluff at the west end of Haynes Mountain, 2 miles north of Bunger on the east (left) side of Brazos River, shows the sedimentation above the thick sandstone.

Section below Bunger limestone north of Bunger, southern Young County.

	Thickness *Feet*
9. Conglomerate; unconformable on bed 8	17
8. Bunger limestone member	1
7. Shale	20
6. Limestone, thin bedded, earthy, sandy, fossiliferous	2
5. Shale and talus	42
4. Sandy limestone, with 2-inch crinoidal limestone layer at top (North Leon limestone member?)	2
3. Sandstone and shale alternating, poorly exposel	29
2. Not exposed	22
1. Sandstone, platy at top, massive below	9
	144

Bed 1 probably lies at the top of the thick sandstone sheet above the Gonzales limestone member. The sandy limestone (bed 4) at 62 feet below the Bunger occurs near the horizon of the North Leon limestone member of the Lacasa area and, though thin and erratic, may be a northern representative of the marine invasion recorded by that member. It was not observed in place elsewhere, but float of similar character at about the same horizon is present in a small drain that discharges westward into Brazos River west of the highway from Graham to Bunger, 1½ miles north of Bunger.

Bed 6, though earthy and thin bedded, is usually present where the horizon comes to the surface, but in some places it is cut out by channeling, as described below. In a small saddle north of the road from Graham to Henry's Chapel, a quarter of a mile southeast of Flat Rock Creek, 4 miles from Graham, several very fossiliferous beds 2 to 3 inches thick occur in the 20-foot interval below the Bunger limestone, but they were not noted elsewhere.

The following section was measured on the hill west of Bunger at the type locality:

Section of beds below Bunger limestone near Bunger, southern Young County.

	Thickness *Feet*
5. Bunger limestone member	2
4. Shale, weathered, yellowish	20
3. Limestone, earthy, sandy, fossiliferous, thin bedded, at top a very fossiliferous plate 2 inches thick, red in color	2
2. Shale, not well exposed	31
1. Sandstone, massive	5
	60

BUNGER LIMESTONE MEMBER

The Bunger limestone was named for its outcrop near the town of Bunger, 5 miles south of Graham, though much better and more complete exposures of it occur at other points, as on the west side of Brier Bend, at the base of Bass Mountain, and on Brazos River north of South Bend.

It consists of a dense, hard, yellowish-gray, very fossiliferous limestone weathering to hard ringing slabs. On fresh surface it is dark and crystalline and shows many fusulinids. In general there are two separate benches in the outcrops, each about 1 foot thick, weathering smoothish with rounded corners. In the best exposures, however, these resistant beds are joined to and underlain by 4 feet or

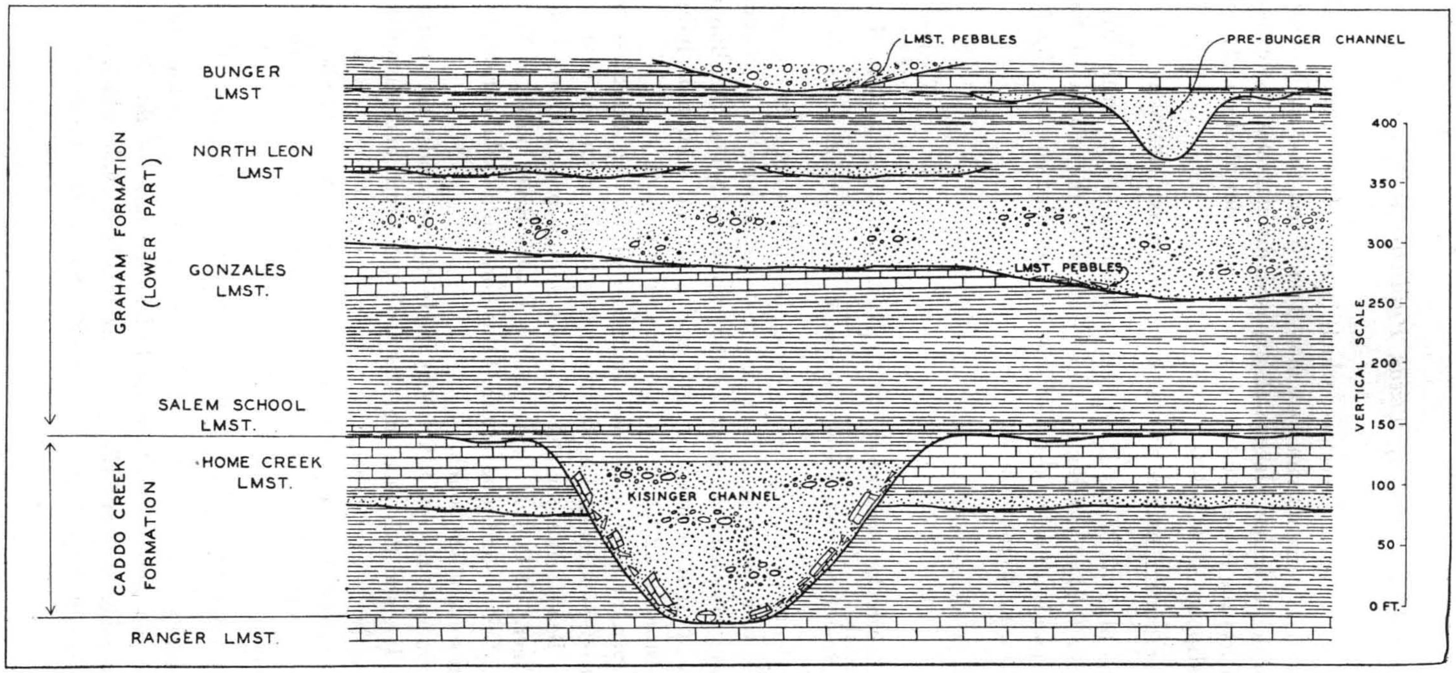

Fig. 2. Diagrammatic cross section of Caddo Creek formation and lower part of Graham formation, southeastern Young County, Texas. Geology by Wallace Lee.

more of less massive limestone, which in such places forms with it a striking and resistant rim rock more than 6 feet thick. The lower 4 feet, which is in few places well exposed, disintegrates in weathering and lets the more resistant members settle downhill on the soft yellow slippery shale below.

CHANNEL BELOW THE BUNGER LIMESTONE MEMBER

On the bluff of Brazos River just west of the bridge on the highway from Graham to Bunger, upstream from the mouth of Salt Creek, there is a fine exposure of a deep sand-filled channel (fig. 2). The following section was measured:

Section in channel deposit below Bunger limestone.

	Thickness *Feet*
3. Bunger limestone member	4
2. Shale	6
1. Sandstone (exposed down to edge of river alluvium)	56

This channel from rim to rim along the bluff is not over a quarter of a mile wide, but it is at least 56 feet deep, the base of the channel not being exposed. At most of the exposures below the Bunger there is no sign of unconformity, and a normal section including the limestone at 22 feet below the Bunger is present.

However, at some localities sandstone of varying thickness but without obvious channeling occurs at this horizon. On the west side of Brier Bend, sandstone at least 8 feet thick is present 6 feet below the Bunger. At the old bridge across Brazos River north of South Bend 13 feet of sandstone occurs at this horizon, and thinner deposits occur at some other points.

The channel, though filled with fairly coarse sandstone, contains no pebbles, and this fact, together with the depth and narrowness of the valley suggests that it may have been a tributary to a more extensive drainage system. Such inequalities as were produced by the erosion were effectively filled before the deposition of the Bunger limestone.

BUNGER LIMESTONE MEMBER TO TOP OF WAYLAND SHALE MEMBER

The interval from the top of the Bunger limestone to the top of the thin but persistent limestone bed at the base of the Wayland shale member is about 175 feet. The Wayland shale which is followed by an important unconformity has a maximum observed thickness of 110 feet, thus giving the post-Bunger deposits of the Graham formation a known thickness of 285 feet. No less than nine unconformities, several of them involving general erosion and others deep channeling, were observed in this interval (Pl. II). As some of these erosion surfaces intersect others and as in most of them the inequalities of the erosion surface are leveled off, with the deposition of sandstone or conglomerate, it would be quite impossible to differentiate between them if it were not for the fact that most of the sandstone deposits were followed by marine invasions during which thin deposits of fossiliferous limestone were laid down.

The following sections show the normal sequence of deposits immediately above the Bunger limestone:

Section on the road a quarter of a mile north of the cemetery in Brier Bend.

	Thickness *Feet*
5. Slabs and plates of light-colored limestone, weathering smooth and pitted and yellowish gray; contains fusulinids and other fossils	1
4. Shale, limy and sandy	14
3. Limestone, hard, light-colored; has a few fossils	1
2. Shale	5
1. Bunger limestone member	1
	22

Section on the south side of Bass Mountain, half a mile southeast of bridge on highway from Graham to South Bend, southern Young County.

	Thickness *Feet*	*Inches*
No. 5 post-Bunger cycle:		
9. Sandstone, no conglomerate, yellowish to gray, cross-bedded and ripple-marked, in part with macerated plant remains	23	
Normal post-Bunger sequence:		
8. Shale, dark gray, slabby	20	
7. Shale, with fossils	1	
6. Clay shale	46	
5. Shale, with ammonoids, gastropods, and other fossils	5	
4. Shale, black, fissile	2	
3. Clay shale, gray	26	
2. Shale, with a few fossils		6
1. Bunger limestone member	7	6
	131	

Section on west side of Duff Branch, half a mile north of Stephens-Young County line.

	Thickness *Feet*
No. 3 post-Bunger cycle:	
Unconformity.	
6. Limestone, gray, weathering bluish, or in places to lumpy white mortar-like masses	2
5. Limestone, sandy, weathering to yellowish spotted sandstone, fusulinids in base	4
Probable unconformity.	
Normal post-Bunger sequence:	
4. Clay shale, dark, sparsely fossiliferous throughout	52
3. Shale, not well exposed	25
2. Clay shale, weathering yellowish	16
1. Outwash not well exposed, probably shale	10
Bunger limestone member.	
	109

The limestone (bed 5) 20 feet above the Bunger in the first section given above is present rather generally in the area northwest of Bunger, but at Bass Mountain and south of Brazos River it seems to be represented only by a highly fossiliferous shale. At least 103 feet of marine shale, as shown by the section measured on Duff Branch, followed the deposition of the Bunger limestone before erosion set in.

North of Brazos River along the outcrop, the thick marine shale deposits above the Bunger have been generally removed by subsequent erosion. In some places, notably on Salt Creek south of Graham, erosion during the same period also removed the Bunger limestone.

The series of unconformities in the Graham formation after the deposition of the Bunger limestone member are referred to numerically for convenience of reference and the various deposits of each cycle are mentioned in the same way, for none of the beds are widely enough distributed to warrant giving them place names. That is, reference to No. 1 limestone and No. 2 conglomerate indicates respectively a limestone deposited after the first erosion period and a conglomerate after the second. Where more than one limestone occurs in a cycle the first will be referred to, for example, as No. 9 limestone and the second and third as No. 9a limestone and No. 9b limestone respectively.

NO. 1 POST-BUNGER CYCLE

At the end of this period of erosion the surface of the marine shale overlying the Bunger limestone had a measurable relief of

103 feet. As thicker sections of the shale must have existed in some places prior to the erosion, and as the Bunger limestone has been cut out at the base, the relief may have been considerably in excess of this figure. The first sediments deposited on this eroded surface were conglomeratic sandstones, which reached to a height of 40 feet above the Bunger. An estimate of their maximum thickness must be increased by the unknown amount of erosion below the Bunger limestone. The relations of this deposit are best seen on the hill west of the mouth of Salt Creek, where the top of the conglomeratic sandstone overlaps the shale above the Bunger and forms a bench at 40 feet above it on the river bluff. Half a mile northwest of the crest of this hill, on a secondary road near the railroad, the base of the conglomeratic sandstone is in contact with the Bunger and contains pebbles of Bunger limestone. On the northwest slope of the same hill at the top of the sandstone there is a thin sandy limestone containing crinoid stems, indicating clearly the return to marine conditions at this horizon. This marine bed is referred to as No. 1 limestone. The conglomeratic sandstone is followed by sandy shale, which is common south of Brazos River, where it overlaps the original marine shale at varying intervals above the Bunger without any intervening sandstone.

The sandy shales above the conglomerate are followed by a limestone 6 inches to 1 foot thick, gray, sandy, and fossiliferous, which was seen in an isolated area near Thedford Tank, where it forms the cap of a small butte.

Section at butte 200 yards south of Thedford Tank, one and one-half miles west of mouth of Salt Creek, southern Young County.

	Thickness *Feet*
No. 5? post-Bunger cycle:	
Sandstone.	
Unconformity.	
No. 1 post-Bunger cycle:	
4. Limestone 1a, gray, fossiliferous, sandy	1
3. Sandy shale and thin streaks of sandstone with broken plant remains	36
Normal post-Bunger sequence:	
2. Shale, marine, fossiliferous	10
1. Shale; reported in log of Jacobs-Thedford well 1	35
Bunger limestone member.	
	82

The interval from the Bunger to limestone 1a is 82 feet, as determined in the Jacobs-Thedford well 1, nearby, the lower 35 feet of the section being taken from the log of this well. No conglomerate of this cycle is present in this well or in the area to the southwest, and the sandy shale deposit overlaps on the marine shale surface, so that limestone 1a evidently represents a second return of marine conditions.

No other remnant of this bed is known to occur north of Brazos River, but a very similar limestone is present at almost exactly the same horizon on the west side of the strong ridge between Duff Branch and Clear Fork of Colorado River, where the following section was measured with the aid of the Cox well, half a mile west of the Graham-Breckenridge highway, a quarter of a mile north of the Stephens County line, and 3½ miles southwest of South Bend.

Section of beds in part of No. 1 post-Bunger cycle three and one-half miles southwest of South Bend, southern Young County.

	Thickness Feet	Inches
No. 1 post-Bunger cycle:		
4. Limestone 1a, fossiliferous, earthy and sandy		6
3. Sandy shale with streaks of thin sandstone	45	
Normal post-Bunger sequence:		
2. Shale, marine, fossiliferous	10	
1. Shale (from log of Cox well)	25	
Bunger limestone member.		
	80	6

The No. 1a limestone, at the top of this section, crops out for about a mile to the north, where it is cut out by the unconformity at the base of a younger sandstone, to be mentioned later. The fact that this limestone is at essentially the same horizon as the limestone bed at Thedford Tank and that it is underlain by 45 feet of similar shale resting on fossiliferous marine shale and is not underlain by the No. 2 conglomerate seems to warrant the correlation of the two beds in spite of the intervening distance.

NO. 2 POST-BUNGER CYCLE

The sandy shales and the limestone bed (No. 1a) were in part cut out by renewed erosion, and when sedimentation was resumed remnants of bed 1a were left in isolated areas and a new basin was cut through the No. 1 sandy shales and into the No. 1

conglomeratic sandstone. The first deposit of the No. 2 cycle was a conglomeratic sandstone in the area about the mouth of Salt Creek and to the east, where the two conglomeratic beds are in contact. These deposits can be distinguished from each other only where the No. 2 sandstone overlaps the No. 1 shale. Southwest of Salt Creek the No. 2 conglomerate does not overlap very far on the older deposits, but toward the east it overlaps a considerable distance. The deeper parts of both basins, however, lie in the same general area.

On Salt Creek 1¾ miles south of Graham courthouse the combined thickness of the two superimposed conglomeratic sandstones is 65 feet, the bottom not being exposed. The following section was measured here.

Section on west side of Salt Creek, one and three-quarter miles south of Graham courthouse.

	Thickness *Feet*
No. 9 cycle:	
6. Earthy limestone bed at base of Wayland shale member of Graham formation (No. 9 limestone)	1
5. Not exposed	33
No. 7 cycle?:	
4. Sandstone, forming bench	20
Relations indeterminate:	
3. Talus and shale, not well exposed, in part No. 2 cycle	57
No. 2 cycle:	
2. Sandstone	9
1. Conglomeratic sandstone (No. 1 and No. 2 cycles)	56
	176

The base of bed 1 of the above section is not exposed. It is approximately at the horizon of the Bunger limestone, which is absent by erosion in this area. Both the No. 1 and No. 2 conglomerates may be represented in the 56 feet of conglomeratic sandstone of bed 1.

The base of the No. 2 conglomeratic bed toward the east is progressively higher and apparently overlaps on an older surface of shale. On Brushy Mound, 7½ miles east of Salt Creek, the top of the bench formed by the No. 2 conglomerate, which is here only 15 feet thick, is 64 feet above the Bunger, and the lower No. 1 conglomerate is absent. At the east end of Haynes Mountain, 5 miles east of Salt Creek, the eroded top of the No. 2 conglomerate is 56 feet above the Bunger. On an outlier south of Haynes Mountain just east of the road from Graham to Henry's Chapel, 3½ miles east of Salt Creek, the interval is 65 feet. Here the thickness of the No. 2 conglomeratic sandstone is only 20 feet and the presence of the No. 1 sandstone is doubtful, although both are distinguishable half a mile farther north. These measurements and other observations seem to indicate (1) that the basin in which these conglomerates were deposited had a northwest trend, (2) that it was filled to an altitude of 65 feet above the Bunger limestone by deposits of conglomeratic sandstone, and (3) that its width was at least 8 miles. No sandstone of either the No. 1 or No. 2 cycle, so far as known, was deposited south of the present Brazos River.

The logs of wells furnish very little information concerning the subsurface development of these conglomeratic sandstones, as in the upper 200 or 300 feet the logs are usually very sketchy and seldom make note of conglomerate, even when the well starts on the outcrop. These conglomerates differ in no respect from the earlier conglomerates of the Graham formation and like them contain erratically rare and poorly preserved trunks of fossil trees.

The following section, measured in a railroad cut on the west side of Salt Creek 2.2 miles south of Graham courthouse, shows the sequence of beds immediately following the No. 2 conglomeratic sandstone:

Section of beds of No. 2 post-Bunger cycle on Salt Creek.

	Thickness *Feet*
Clay shale	15
Sandy shale	15
Conglomeratic sandstone	15+
	45+

The top of this well-exposed section is about 95 feet above the Bunger limestone, so that the No. 1a limestone is clearly absent.

The absence of this limestone in the sequence following the No. 2 conglomerate in the section shown above supports the conclusion that the No. 1a limestone represents a second return of marine conditions in the No. 1 cycle.

NO. 3 POST-BUNGER CYCLE

After the No. 2 cycle the surface was again eroded, and in the Duff Branch area whatever deposits had been laid down above the marine section were removed and the shales again exposed. So far as seen, the erosion beginning the No. 3 cycle produced no local channels of any great depth, though channel erosion may well have taken place. The greatest relief south of Brazos River expressed by the irregularities at the base of the deposits of the No. 3 cycle, is 25 feet. The first deposit of this cycle is sandstone, which contains no pebbles south of the river. It seems definitely to have covered any outlying topographic highs that may have survived to this time. In the Duff Branch area, where this sandstone (the No. 3 sandstone) rests on marine shale, and also at a locality west of the Graham-Breckenridge highway, where it rests on sandy shale and interrupts the No. 1a limestone, it is unconformable but shows no evidence of channeling. On the Seddon farm, east of the Graham-Breckenridge highway, on South Tonk Creek, and also on the crest of the ridge northeast of Thedford Tank, a bed that seems to be the No. 3 sandstone lies on a more deeply eroded surface and carries varying amounts of chert.

The No. 3 sandstone was followed immediately by fossiliferous limestone, which is best exposed on the west side of Duff Branch north of the Young-Stephens County line. This limestone is interstratified with shale and ordinarily only the lower member, not more than 2 or 3 feet thick, has survived subsequent erosion. At one point, however, north of Duff Branch, a quarter of a mile north of the county line, more than 16 feet of limestone was measured. The lower bed of this limestone is sandy, dense, gray, and fossiliferous, and it rests in some places directly on the underlying sandstone. Subsequent erosion, however, has left little of it, and north of Brazos River the only area in which a remnant of this limestone has survived is on the Seddon farm at the locality previously described. Here a small area only a few yards in diameter shows fossiliferous sandy limestone at the eroded top of an incompletely exposed body of sandstone. The fortunate propinquity of an abandoned oil test (Cosden-Smith No. 1) made possible the determination of the base of the limestone at 102 feet above the Bunger. In both areas the limestone rests on sandstone, and in both the top of the bed shows erosion and is followed by unconformable sandstone.

The limestone exposed where the county-line road crosses Peveler Creek, 3 miles east of the Graham-Breckenridge highway, is believed to be the No. 3 limestone. At this point it carries such quantities of corals of the genera *Campophyllum* and *Syringopora* that they can be handled with a shovel. Specimens of *Campophyllum* are also present, though fewer, on the road in the Duff Branch area.

NO. 4 POST-BUNGER CYCLE

In Duff Branch, on the road east from the Graham-Breckenridge highway on the Stephens County line, and farther to the south on the west side of Duff Branch, red clay beds and thin sandstones carrying plant fossils rest unconformably on the No. 3 limestone and are followed unconformably by the No. 5 sandstone. This cycle was not recognized farther north, but south toward Ivan, in Duff Branch, it has a considerable development and is recognizable by the plant fossils, which are well preserved at several localities.

The following section shows the relation of the deposits of the No. 4 cycle to those above and below:

Section of beds of No. 4 post-Bunger cycle on the west side of Duff Branch on county-line road between Young and Stephens counties.

	Thickness	
	Feet	*Inches*
No. 5 cycle:		
12. Sandstone, light-colored, in part limy and thin bedded	5	
Unconformity.		
No. 4 cycle:		
11. Limy sandstone, fine grained, thin bedded	1	
10. Clay shale, yellowish and reddish	3	
9. Sandstone, fine grained, laminated, lenticular	1	
8. Sandy shale, with plant remains	3	
7. Sandstone, soft, yellowish, fine grained	1	
6. Clay shale, yellowish	1	
5. Clay shale, greenish, upper part red	4	
4. Sandy shale, laminated	1	6
3. Limy sandstone, gray, laminated, with plant remains	1	6
2. Clay shale, gray-green	5	
Unconformity.		
No. 3 cycle:		
1. Limestone, dark, very sandy, 1 to 3 feet thick	3	
	30	

Half a mile farther south the No. 3 limestone is cut out by the overlying beds of the No. 4 cycle.

NO. 5 POST-BUNGER CYCLE

The nonmarine deposits of the No. 4 cycle are unconformably overlain by a sandstone deposit, which has a very general development south of Brazos River but whose presence north of the river is less certain because there it is in contact with the No. 3 sandstone. In the locality of the above section on Duff Branch the base of the No. 5 sandstone is 22 feet above the No. 3 limestone, but half a mile to the north it rests on the No. 3 limestone; and a quarter of a mile still farther north erosion has cut completely through it, and the base of the sandstone includes many large and small fragments of this limestone in the basal conglomerate. In this area, the maximum observed thickness of the No. 5 sandstone is 30 feet. Like the No. 3 sandstone, from which it is separated by remnants of No. 3 limestone, it contains no chert conglomerate south of Brazos River and is more sheet-like than channel-like in its distribution. Where the No. 5 sandstone is in contact with the No. 3 sandstone, as it seems to be north of Brazos River, the two are indistinguishable. It caps the bluffs at South Bend and at Bass Mountain and seems to be represented on Sidney Mountain, where it is thin, by the second sandstone from the top of the hill. It appears unconformably above the limestone remnant on the Seddon farm, where it is conglomeratic, and still farther north it is probably in many places in contact with the No. 3 sandstone. Its presence near Graham is problematic, as it is indistinguishable from the No. 3 sandstone. Where the No. 3 and No. 5 sandstone deposits are in contact, as in the territory north of Thedford Tank, they have a measured thickness of 53 feet. The following section shows the relations of the No. 5 cycle to the adjacent cycles:

Section showing beds of No. 5 post-Bunger cycle on Sidney Mountain, three miles northeast of South Bend, southern Young County.

	Thickness Feet	Inches
No. 7 cycle:		
11. Sandstone, with fine chert grains, reddish	3	
No. 5 cycle:		
10. Shale	3	
9. Limestone, platy, impure, sparsely fossiliferous	2	

	Thickness Feet	Inches
8. Sandstone, limy; no fossils	4	
7. Shale, crowded with fusulinids (the so-called fusulinid bed)		6
6. Shale	3	6
5. Sandstone, slabby	2	
4. Sandstone, massive	5	
Unconformity.		
Undetermined age:		
3. Sandy shale, with macerated plant remains	46	
2. Clay shale, gritty (from nearby well cuttings)	71	
Bunger limestone member:		
1. Limestone	6	
	146	

The top of the No. 5 sandstone is 124 feet above the Bunger limestone.

These beds, particularly the fusulinid-bearing shale, can be followed westward for a mile or more along the outcrop. Measured on the surface the fusulinid bed is 128 feet above the Bunger. Measured in the Wadley-Fluty No. 1 well the interval is 131 feet. The measurement in the well is probably more nearly correct.

NO. 6 POST-BUNGER CYCLE

In the general area of the junction of Clear Fork and Salt Fork of Brazos River at essentially the same horizon above the Bunger as the No. 5 sandstone there is an excellent example of channeling. The channel is abrupt and well defined, and its south margin is exposed at three points at intervals of a mile. The most westerly of these points is north of the Stovall hot-water well; the next to the northeast is on the west side of the ridge north of the forks of Brazos River; and the third is in the head of Kickapoo Creek. These three points indicate that the margin of the channel trends N. 45° E. The thickness of the sandstone that fills the channel increases abruptly toward the northwest from nothing to 56 feet within half a mile, the contact dipping below the flood plain of Salt Fork. The northwestern margin of the channel is not exposed, for reasons mentioned below, but the width of the channel was probably about 1¾ miles. At each of the three points at which the margin of the channel is best exposed the sandstone wedges out rather abruptly, and the limestone that immediately overlies the sandstone continues only a few hundred yards until it apparently overlaps the shale slopes of the channel. At each locality where the sandstone begins to thin, the limestone becomes a mass of *Campophyllum* corals, beneath which, north of the Stovall hot-water well, there is a layer 2 or 3 inches thick of *Syringopora* corals. These corals apparently found the margin of the basin a favorable locality for growth. At the west angle of the ridge just north of the forks of Brazos River they are so numerous that they could be carried away in truck loads.

The No. 6 sandstone has very little conglomeratic material except toward the center of the channel, where small chert pebbles become fairly abundant but not to the extent of the other deposits of conglomeratic sandstone previously mentioned.

The sandstone deposit of this channel was immediately followed by the deposition of limestone, and in the central part of the channel the limestone takes on more the character of a limy fossiliferous sandstone than of a limestone. Toward the margin the limestone thickens to 3 feet and becomes less sandy. It is gray, bedded, and dense and here contains a greater variety of fossils. In the central portion fusulinids are particularly abundant, but on the margin, as has been mentioned, the fossils are preponderantly corals. Two hundred yards beyond the margin of the sandstone there is neither limestone nor any visible break to suggest interruption of sedimentation.

The ridge north of the Stovall oil pool follows in part the margin of the channel deposit and presents the rather surprising phenomenon of a ridge whose east face above Salt Fork is a solid bluff of sandstone, in contrast to the south face, which is practically all shale.

The interval from the No. 6 limestone to the Bunger limestone was determined from the logs of two wells starting on or near the outcrop. In the Miami-McKeen well, 1½ miles north of the forks of Brazos River, the interval is 131 feet. In the Phillips-Laquey well, three-quarters of a mile farther north, the same interval measures 132 feet. The top of the No. 6 limestone therefore occurs at essentially the same horizon as the fusulinid bed of the No. 5 cycle. The No. 6 limestone, however, is closely related to and rests immediately upon the No. 6 channel sandstone, whereas the No. 5 limestone lies 4 feet above the fusulinid shale and 8 feet above the

No. 5 sandstone, not distinguished by channeling. These considerations, together with the fact that the beds of one cycle cannot be traced into those of the other and the fact that the beds of the No. 6 cycle as here considered have an entirely different habit of deposition from those of the No. 5 cycle, lead to the conclusion that the deposits represent separate erosion cycles in spite of the approximate equivalence in the horizons of their respective limestones. No great error, however, results to structural work if these limestones are correlated as one, for they occur at essentially the same distance above the Bunger.

The following section shows the relation of the beds above the No. 6 limestone on the road to the upland area north of the Stovall hot-water well.

Section showing relation of beds of No. 6 and No. 7 post-Bunger cycles north of Stovall hot-water well, southern Young County.

	Thickness Feet	Thickness Inches
Pleistocene gravel:		
No. 7 cycle:		
8. Sandstone, massive	3	
7. Sandstone, thin bedded	4	
6. Sandstone, massive	2	
5. Sandstone, thin bedded	6	
4. Sandstone, yellowish	1	
Unconformity.		
No. 6 cycle:		
3. Clay shale, ironstone partings, a few thin sandy sheets in upper 10 feet, with plant remains	24	
2. Limestone, platy, with *Campophyllum* and crinoid stems (No. 6 cycle)	1	3
1. Shale, with *Syringopora*	1	
	42	3

The upper 16 feet (beds 4 to 8) represents unconformable deposits of the No. 7 cycle, by which the northwestern margin of the No. 6 channel was dissected. The top of the above section is 171 feet above the Bunger, but the sandstone elsewhere extends indeterminately higher.

The following section measured on the west side of Kickapoo Creek also shows the sequence of beds conformably above the No. 6 limestone.

Section of beds of No. 6 post-Bunger cycle, west side of Kickapoo Creek, southern Young County.

	Thickness Feet	Inches
10. Limy sandstone, sparsely fossiliferous	1	6
9. Shale	3	
8. Sandstone	1	
7. Shale, not well exposed	8	
6. Limestone, with fusulinids, sparsely fossiliferous	1	
5. Sandstone	1	
4. Shale	6	
3. Sandstone, lenticular	2	
2. Shale	22	
1. Limestone, composed chiefly of *Campophyllum* coral (No. 6 limestone)	1	
	46	6

The upper limestone of this section is 176½ feet above the Bunger, and the section is believed to represent the normal sequence of deposits of the upper part of the No. 6 cycle. These limestones are present as float on the west end of the flat top of Sidney Mountain, which they probably overlap, and a similar deposit of sparsely fossiliferous impure limestone occurs at the mouth of a small ravine half a mile east of the Medlin ranch house, where it crops out in the bed of the drain and on the ridge half a mile to the southeast.

NO. 7 POST-BUNGER CYCLE

The erosion that began the No. 7 cycle was rather general in extent and seems to have resulted in a maturely eroded surface, though it was not without deep, sharp channels. The basal deposits, if they may all be attributed to the same period, vary in different parts of the area from sandy shale and cross-bedded, sheeted, and massive sandstone to conglomeratic sandstone.

In the area west and northwest of the Stovall hot-water well, which is half a mile west of the forks of Brazos River, the sandstones are massive and irregularly bedded and in many places show initial dips and interbedded sandy shale. In the vicinity of Graham and southwest toward North Tonk Creek the sandstones that seem to correspond in age are in general highly conglomeratic. In these areas the base of the beds is nowhere well exposed, but north of the Stovall hot-water well there is a deep, narrow channel filled with cross-bedded sandstone. The highest sandstone seen in this channel is 171 feet above the Bunger. The base is not exposed, but 55 feet of sandstone was measured, and although the channel was only 300 yards wide, its thickness, to judge by the angles of deposition and the slope of the basal contact, must have reached at least 70 feet. On the northwestern margin of the No. 6 channel the erosion beginning the No. 7 cycle cut to an undetermined depth and removed the marginal deposits.

On account of the absence of continuous exposures and of well logs in this area, the only evidence as to the maximum thickness and top of the No. 7 sandstone deposit is in the narrow channel north of the Stovall hot-water well. If the conclusions are correct as to the relations of the deposits in the various areas, there are probably localities as yet undiscovered or not exposed where this sandstone is of even greater thickness. The precise interval to the top of the sandstone deposit above the Bunger also is somewhat in doubt, but it is not less than 171 feet.

The sandstone and conglomerate of this cycle were followed, as usual, by the deposition of limestone. This limestone is, however, discontinuous in outcrop and of varying thickness, by reason of the severe erosion that followed the No. 7 cycle. The No. 7 limestone was deposited in several beds separated by shale and is in general gray, crystalline, and very fossiliferous, but as most outcrops are rather dense, fossils do not weather out freely from the matrix. The outcrops, however, vary considerably in their characteristics, some being sandy and others earthy or semicrystalline. The beds exposed on the crest of the high hill 2 miles southwest of South Bend are rather sandy and semicrystalline, as they are also in some places west of the Stovall oil pool and 1 mile above the mouth of Medlin Branch. At all these localities there are large numbers of fusulinids, particularly in the interbedded limy shale beds. The exact horizon of the base of the No. 7 limestone is not accurately determinable, but as the No. 7 sandstone extends upward to at least 171 feet above the base of the Bunger, the No. 7 limestone is certainly not less than 175 feet and probably more than 180 feet above it.

In the area east of Graham a gray crystalline fossiliferous limestone bed crops out on the Graham-Jacksboro highway 2 miles west of the Jack County line. This bed is the lowest of a group of limestone beds, one or more of which is generally exposed in that area. The Root and Root-Shanafelt No. 1 well, south of the highway and a mile west of the Jack County line, starts on the lowest of these beds, whose base is thus known to be 190 feet above the Bunger.

On the highway this limestone bed is underlain by 17 feet of shale, which rests in apparent conformity on a thick conglomeratic sandstone that is thought to be the basal deposit of the No. 7 cycle. This group of limestone beds is considered to belong to the No. 7 cycle, although its interval above the Bunger is somewhat greater than estimated near the Stovall hot-water well, 15 miles distant. The group is unconformably overlain by reddish sandstone, which cuts out the higher limestone beds of the group. This sandstone may represent the Avis sandstone, but more probably it is the basal deposit of the younger (No. 8) cycle.

At the Holmac-Logan well, on the J. Poitevent survey A-288, 8½ miles northeast of Graham, the base of the lowest of these No. 7 limestone beds crops out just above the top of the well and is underlain by sandstone 8 feet lower.

NO. 8 POST-BUNGER CYCLE

Sandstone.—Along Brazos River the outcrops of the No. 7 cycle are unconformably overlain by Wayland shale, which is in turn overlain unconformably by Avis sandstone. In the area about Graham the No. 7 limestone has been completely removed by pre-Wayland erosion.

In the area east and north of Graham a series of beds not present above the beds of No. 7 cycle in the Brazos River area intervenes below the Wayland shale and the Avis sandstone. At the Root and Root-Shanafelt well and in the area between it and the Holmac-Logan well, sandstone at the base of the beds of the No. 8 cycle is present at varying intervals above the No. 7 limestone; west of Dakin switch the sandstone cuts out the No. 7 limestone. Where present, the No. 7 limestone is followed unconformably in places by as much as 50 feet of conglomeratic sandstone, though it is in most places thinner. This sandstone resembles the Avis sandstone, and where the two come together, as they seem to do north of Dakin switch, they cannot be distinguished. This sandstone is in some places overlain by a group of limestone beds at least 30 feet thick, whose base, as nearly as can be determined, is 252 feet above the Bunger limestone and which extends upward in places to 283 feet or more above the Bunger.

Rocky Mound limestone member.—The group of limestones of the No. 8 post-Bunger cycle is herein named the Rocky Mound limestone member. It crops out conspicuously on the southwest slope of Rocky Mound, where it is erratically overlain by Avis sandstone. The sandstone lies in pockets on the limestone but appears to be interbedded with it. In the ravines between Rocky Mound and the Loving highway, a mile to the northwest, the limestone is well exposed at several points where thicknesses of 33 feet and 35 feet were measured. Good exposures also occur a quarter of a mile west of the Loving highway, where it is overlain unconformably by Avis sandstone. One of the beds of this member crops out conspicuously on the Loving highway half a mile farther north, where it forms a dip slope in the road ditch. Some part of the Rocky Mound limestone is also exposed in Flint Creek, still farther north. Other outcrops of the Rocky Mound occur in the drain below the Slick-Robertson well 2 miles north of Rocky Mound, though it is not recorded in the log of the well. The Cheney et al.-Harrison well started on one of these beds. There are many outcrops of these beds around the north end of Eddleman Lake, 3 miles north of Graham, where it is not overlain by Avis sandstone. At the southeast corner of the lake limestone beds underlying the Avis sandstone at one place contribute to its basal conglomerate and may belong to this member.

The Rocky Mound limestone beds are in general gray, crystalline, and fossiliferous and contain a good many fusulinids. They do not resemble lithologically the older limestone beds of Graham age. They are not unlike some phases of the limestone of the No. 7 post-Bunger cycle whose outcrops in the northern area contain fewer fusulinids. The only place in which a continuous section could be examined in detail is 4 miles west of the Jack County line, 2 miles north of the railway, and half a mile west of the Holmac-Logan well, on the J. Poitevent survey, where the following composite section was measured:

Section of beds of No. 7 and No. 8 post-Bunger cycles near Holmac-Logan well, eastern Young County.

	Thickness Feet	Inches
No. 8 post-Bunger cycle:		
Rocky Mound limestone member (29 ft. 9 in.):		
17. Limestone, light-colored, crystalline, fossiliferous; weathers light gray	3	

	Thickness Feet	Inches
16. Not exposed, probably shale	8	
15. Limestone, dark, earthy, fossiliferous, many fusulinids; weathers dark brownish	1	6
14. Limy sandstone		3
13. Shale, yellowish	4	
12. Limestone, dull gray, finely crystalline, many broken fossils; weathers dark dove-gray	2	
11. Limy shale and thin beds of light-colored limestone	8	
10. Limestone, dull gray, earthy, fossiliferous, some fusulinids mottled with limonite; weathers light gray	2	
9. Limestone, dark, coarsely crystalline, fossiliferous, especially crinoids; weathers yellowish and limonitic	1	
8. Sandstone and conglomerate, yellow to brownish at top, in part shaly at base	50	
Unconformity.		
No. 7 post-Bunger cycle:		
7. Limestone, gray, weathering light in upper bed and dark in lower bed, finely crystalline; carries fossils	2	
6. Shale, red	3	
5. Not exposed	1	
4. Top of Holmac-Logan log.		
3. Not reported	8	
2. Sandstone	22	
1. Limestone of log (probably conglomerate)	13	
Interval to top of Bunger limestone member in log	157	
	285	9
Bunger limestone member	5	

Owing to the steep dips and the distance of the exposures from the Holmac-Logan well, the relation of the section measured on the surface to that taken from the well log is not exact but is essentially as shown.

The Smor-Robertson well was drilled on the crest of Rocky Mound a quarter of a mile southeast of the road. It started near the base of the Avis sandstone, where it rests unconformably on or near the base of the Rocky Mound limestone. The log is not a good log, but it shows the position of the Bunger limestone and so indicates 250 feet as a close approximation of the interval from the base of the Rocky Mound limestone to that datum. This interval is approximately confirmed by other logs in the area, though, as no careful records seem to have been kept of the first 100 feet in any of the logs, the data are not entirely satisfactory.

The following list of wells shows the interval from the base of the lowest Rocky Mound limestone bed in or near the indicated wells to the Bunger limestone:

	Thickness *Feet*
Holmac-Logan well, 7½ miles northeast of Graham (accuracy of surface interval in question)	256
Cheney et al.-Harrison well, 5 miles northeast of Graham (may not be lowest bed of group)	278
Smor-Robertson well, 4 miles northeast of Graham on Rocky Mound (from surface to Bunger limestone)	255
United Royalties-Wallace well, 4½ miles northeast of Graham	268
Casey, Mercier-Jeffery well, 4 miles northwest of Graham, north of Eddleman Lake	282

On account of its nearness to the outcrop, the best estimate of the interval seems to be furnished by the Smor-Robertson well, and it is believed that the base of the Rocky Mound limestone member is not less than 250 feet above the Bunger limestone. The thickness of the Rocky Mound member is at least 35 feet. How much thicker this member may once have been, or what higher beds may originally have been deposited above it, cannot now be determined in this area. It was no doubt originally overlapped by the Wayland shale, but this was very generally removed from the crests by the succeeding pre-Avis erosion, and in most of the outcrops it is now overlain unconformably by Avis sandstone.

The sequence of sandstones and limestones from the No. 7 limestone to the top of the Rocky Mound limestone member is seldom exposed. About all that is known concerning the beds of this interval is that the No. 7 limestone deposit is overlain unconformably by conglomeratic sandstone in some places and by sandy shale in others, and that these deposits are followed by the Rocky Mound limestone member extending from about 250 to 285 feet above the Bunger. Massive sandstones occur below the outcrops of the Rocky Mound limestone on the northeast side of Lake Eddleman and half a mile west of the Holmac-Logan well.

On Rocky Mound the surface relations of these beds, as shown in figure 3, is complicated by the presence of a strong southwest dip and by a fault or series of faults along the northeast side of the ridge. The fault, which has a strike of N. 40° W. and a displacement of 35 feet downward on the northeast side, brings conglomeratic sandstone of uncertain age to the bed of the creek at the roadside.

This sandstone crops out along the northeast side of Dry Creek and may be followed to a point above the railroad track where it rests unconformably upon the Wayland shale. It is possible that some of the confusion in the identity of this bed results from the contact of the Avis sandstone with pre-Rocky Mound conglomeratic sandstone.

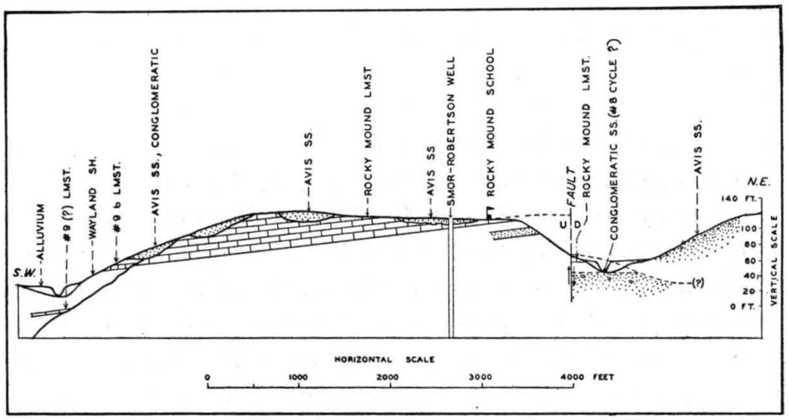

Fig. 3. Diagrammatic cross section through Rocky Mound, 3 miles northeast of Graham, Young County, Texas. By Wallace Lee.

On the southwest side of Dry Creek the basal bed of the Rocky Mound limestone is underlain by shale containing several superposed lenticular bodies of sandstone in sandy shale. Near the road these sandstone bodies are thick, but toward the southeast end of Rocky Mound they finger out, and the Rocky Mound limestone is underlain by sandy shale.

NO. 9 POST-BUNGER CYCLE

Channel Deposits

After the deposition of the Rocky Mound limestone, the region was subjected to deep and long-continued erosion, for beds from No. 7 cycle up to the Rocky Mound limestone were very generally removed throughout southern Young County and northern Stephens County. The erosion cut deep just west of Graham, where a sharp, deep channel was cut to a depth within 62 feet of the Bunger limestone, a horizon which is 225 feet below the crests of the buried hills capped with Rocky Mound limestone. This relief is greater than that in the same region today and apparently reached a state of topographic maturity, leaving the Rocky Mound limestone capping a ridge or series of buttes.

The channel west of Graham is filled with well-laminated sandy shale to a depth of 98 feet below the base of the Wayland shale member. This channel filling is followed conformably by a limestone bed at the base of the Wayland. The channel deposit, whose base is exposed for 100 yards between the creek bank and the railroad track near the southwest corner of Graham, begins with 2 feet of conglomerate that contains chiefly chert pebbles but also a great many pebbles of gray fossiliferous limestone. The chert pebbles have probably been derived from the earlier conglomeratic sandstones that were exposed nearby on the bottom and sides of the channel. The limestone pebbles are gray, dense, and fossiliferous and contain fusulinids. The beds are unlike any other limestone beds of the Graham formation except those of the Rocky Mound limestone member, whose base is stratigraphically 190 feet higher.

The channel deposits of No. 9 cycle are well exposed on the bluffs west of Graham and in the ravine followed by the Graham-Breckenridge highway. Unlike the earlier channels of the Graham formation this channel is filled with finely laminated sandy shale containing varying amounts of comminuted plant material. In some places it contains beds of laminated fine-grained sandstone 3 to 6 feet thick, but these deposits form only a small part of the total thickness. On the margin of the channel near the forks of the road west of Graham the sandy shale a few feet below the limestone contains thin sheets of coal in the shale partings.

The thickest observed section of the No. 9 channel deposits occurs on the bluff west of Salt Creek, opposite the southwest corner of Graham, though the best exposures are farther north, near Graham Dam. The following composite section was measured on the bluff west of the basal limestone conglomerate; the details have been filled in from outcrops farther north:

Section of deposits of No. 9 post-Bunger cycle west of Graham, Young County.

	Thickness *Feet*
No. 9 post-Bunger cycle:	
8. Limestone, basal bed of the Wayland shale member, No. 9 limestone	1
7. Shale, sandy, laminated; plant remains	13
6. Sandstone, fine, laminated	4
5. Shale, sandy, laminated; plant remains	41
4. Sandstone, medium grained, laminated	6
3. Shale, sandy, laminated; plant remains; not all exposed	31
2. Conglomerate, with chert and limestone pebbles	2
Unconformity.	
	98
No. 2 cycle (?):	
1. Conglomeratic sandstone	15+

The fact that this shale-filled channel might not have been observed had the exposures in the neighborhood of Graham not been so good, suggests the possibility that shale-filled channels may exist elsewhere and that they may be more common than their infrequent discovery would indicate.

The material filling the channel and overlapping its margin is followed conformably by a yellowish earthy fossiliferous limestone 6 to 12 inches thick, which at this place forms the base of the Wayland shale member. Attention was first called to the unconformable relations of these deposits by the presence at the forks of the road 1¼ miles west of Graham of worn knobs of conglomeratic sandstone sticking up through the enveloping laminated shale. At the point south of the road a mass of conglomeratic sandstone reaches within 10 feet of the horizon of the overlying limestone. On the other side of the road, only 200 feet distant and 20 feet lower, the unconformable surface is still below the road ditch. Several other knobs of conglomeratic sandstone are well exposed in the same vicinity.

Wayland Shale Member

Lithology.—The Wayland shale, the upper part of the deposits of the No. 9 post-Bunger cycle, consists primarily of a series of clay shales with some thin partings of earthy limestone. The shales, contrary to the current descriptions of the Wayland shale, are for the most part not fossiliferous, but the member contains bands of very highly fossiliferous shale, generally but not invariably in close association with thin beds of earthy limestone. The shale contains a few thin lenticular layers of sandy shale, and north of Dakin switch and on the southwest side of Rocky Mound there are thin deposits of leaf-bearing black fissile shale not seen elsewhere.

The limestones of the Wayland shale, of which three are recognized, are similiar in lithologic character. They are all thin; the greatest thickness of any bed seen is less than 2 feet, though on Rocky Mound one of the beds is split locally by a 3-foot bed of fossiliferous shale. They are all earthy and weather yellowish. Where conditions are favorable they weather to smoothish plates and slabs, but where the drainage is poor the beds break down into flakes. The limestone beds are all extremely fossiliferous, and many outcrops contain considerable numbers of fusilinids. The shales adjacent to the limestone beds are in general also highly fossiliferous, and the slopes below the outcrops are usually littered with a great variety of well-preserved fossils. The only discernible difference between the beds lies in the assemblages of fusilinids.

Although the limestone beds of the Wayland shale member are well exposed and easily followed in surface outcrops, they are almost never recorded in the well logs. This omission is in part due to the fact that they are thin and in part to the fact that until they are weathered they do not take on the appearance of limestones. This is clearly indicated by a fresh outcrop in Clear Fork of Brazos River below the bridge at Eliasville. Here the limestone exposed in a recently caved bank just above the bed of the stream is black and, though limy and fossiliferous, has much more the appearance of a black shale than of a limestone. It is in this condition where it is penetrated by the drill. Farther downstream, where the exposure is higher on the bank, the limestone has the typical yellowish earthy appearance.

No. 9 limestone.—The lowest of the three limestone beds in the Wayland is referred to on the maps and sections as No. 9 limestone. It is the first limestone observed above the filling of the No. 9 channel near Graham and has been referred to by some authors as the Gunsight limestone, but it seems to have little in common with the Gunsight save its presence at the base of the Wayland shale member.

The No. 9 limestone is, in most places, less than 1 foot thick. It is traceable almost continuously from Graham to the head of Kickapoo Creek, where it overlaps the eroded surface of the deposits of the No. 6 cycle. It is present on the hills in the town site of Graham and to the north. East of Graham it is believed to be represented by outcrops on the hill east of the Morrison oil pool and at the base of the hill west of the Graham-Loving road, where it is thin. It may be represented in a thin bed at the base on the southwestern side of Rocky Mound, about half a mile from the highway, but the fusulinid assemblage at this point is not entirely diagnostic.

In the immediate vicinity of Graham, according to somewhat unsatisfactory well logs, the No. 9 limestone appears to be only about 160 feet above the Bunger limestone, but toward the southwest the interval is thicker—179 feet at the Texas-Killion well, 3½ miles southwest of Graham, and 175 feet at the Kouri-Seddon well, near the head of Kickapoo Creek. On the ridge east of the Morrison oil pool, east of Graham, the interval as shown in well logs appears to be about 195 feet to the Bunger, and where the Wayland overlaps the Rocky Mound buried ridge, if the identification is correct, the interval is even greater. The variations in the interval are probably to be attributed to the unconformity at its base, greater compaction of the basal deposits of the No. 9 cycle having occurred over channel deposits than over buried hills. However, the two occurrences east of Graham may represent limestone lentils in the Wayland shale above the horizon of the No. 9 limestone. The assemblage of fossils distinguishing the No. 9 limestone was not observed southwest of Kickapoo Creek except at a point 1½ miles southeast of Eliasville. This limestone is probably the one that crops out in the bed of Clear Fork at Eliasville, for, though no fusulinids were collected at this place, the interval from this bed to the Ivan limestone is normal.

No. 9a limestone.—Limestone No. 9a was first encountered north of Clear Fork of Brazos River, on the butte north of Graham Lake. It is in nearly all respects similar to the No. 9 limestone but differs by having a different assemblage of fusulinids, by its occurrence at that point at an interval considerably higher above the Bunger, and by the difference in the character of the associated shales. In the northern area the No. 9 limestone is overlain by 10 to 12 feet of fossiliferous shale, whereas the No. 9a limestone has practically no fossiliferous shale above it. The number of fusulinids in the No. 9a limestone is in many places considerably less than in the No. 9 limestone, and in some outcrops they are scarce. The locality at the butte north of Graham Lake is an exception in this respect.

Lloyd G. Henbest, in reporting on the two groups of fusulinid collections, one from areas shown on the map as No. 9 limestone and the other from localities shown as No. 9a limestone, says:

> Sufficient differences in the faunas of these horizons exist to warrant the supposition that they are slightly different in age. . . . [The collections from the southern area (the No. 9a limestone)] contain *Triticites beedei*, *T. secalicus?*, *Triticites?* (cf. "sp. N" on chart, a peculiar, distinct new form); *Triticites* sp. (cf. "sp. J" on chart); and *T. plummeri* var.? (the inflated fusiform type of this species). *T. beedei* is the most abundant of the lot. [In the horizon represented by the collections in the northern area (the No. 9 limestone)] a typical *Triticites plummeri* association was found. *T. plummeri* (spherical form) and *T. plummeri* var.? are prominent though not always numerous members of the fauna. Large numbers of typical *T. moorei* and very few *T. beedei*; *T.* n. sp. aff. *T. secalicus*; and *Triticites* n. sp.? compose this assemblage.

The fusulinid collections west and south of the forks of Brazos River to a point 3 miles north of Ivan, in northern Stephens County (a distance of 7 miles), indicate that all the limestones of the Wayland outcropping in this area are those of the No. 9a limestone except one at the point on the county line 1½ miles southeast of Eliasville, already mentioned, which contains the fusulinid assemblage of the No. 9 limestone.

The absence of No. 9 limestone in the area above mentioned is attributed to the overlap of the Wayland shale on an eroded surface, although the detailed relations toward the south were not studied. Unfortunately no section could be found in which these two beds were both exposed. As the No. 9a limestone is definitely absent in the excellent exposures west of Tonk Valley School, it appears to be lenticular.

On the hill 1 mile north of Graham and also northwest of the Texas-Killion well, 1½ miles southwest of Graham, float limestone of the type found in the Wayland shale member occurs in the talus of the Avis sandstone above the outcrop of the No. 9 limestone. Though not seen in place, the float is thought to indicate the presence of the No. 9a limestone (or another lenticular bed) in those places or its incorporation in the basal deposits of the Avis, from which pieces are released by weathering.

No. 9b limestone.—On a high bluff 1½ miles due west of Tonk Valley School, there is a limestone bed in the Wayland shale 76 feet above the No. 9 limestone and 251 feet above the Bunger. This bed is similar in appearance to the earlier limestones of the Wayland shale. It crops out around the southern and western sides of a ridge, at whose extremities it is cut out by the unconformity at the base of the Avis sandstone. This bed is distinguished by an assemblage of fusulinids unlike those contained in No. 9 or No. 9a limestones. Mr. Henbest reports that

> the fusulinids in 9b and 9a limestones have several species in common, but in the collections that I have seen the more abundant species of one are rare or inconspicuous in the other. For instance, *Triticites beedei* shares prominence equally with *T. moorei* and *T. plummeri* in the No. 9 limestone. In the No. 9a limestone it greatly outnumbers all other species combined. In No. 9b it is rare or sometimes absent. *T. plummeri* is rare in No. 9b limestone. The very large, more elongated form of *T. plummeri* and the large species of *Triticites* (cf. "sp. J" on chart) are the most prominent members of the 9b assemblage. The peculiar *Triticites?* ("sp. N" on the chart) is common in the No. 9a limestone, but only one specimen has been found in the 9b (cf. collection 675).

The No. 9b limestone is definitely absent from the thick Wayland section exposed at Eliasville, but fusulinids collected from a limestone bed outcropping on the south side of Rocky Mound at the same distance above the Bunger as the outcrop west of Tonk Valley School were examined by Mr. Henbest, who finds that the limestones should be correlated. Most of the outcrops west of Tonk Valley School contain considerable numbers of *Campophyllum torquium*, but these are not present on Rocky Mound.

The following section of Wayland shale was measured on the southwest side of Rocky Mound, southeast of the highway, 3 miles from Graham:

Section of Wayland shale member on southwest side of Rocky Mound, 3 miles northeast of Graham, Young County.

	Thickness Feet	Inches
No. 9 post-Bunger cycle:		
10. Shale, gray, not fossiliferous	5	
9. Limestone, earthy, light brown to yellowish; breaks down in places to flaky chips; fossiliferous, many fusulinids; No. 9b limestone (upper part)	1	
8. Shale, yellowish, fossiliferous	3	
7. Limestone, similar to above but less resistant; No. 9b limestone (lower part)	1	
6. Shale, sandy and gritty, with thin sandstone partings, in places very fossiliferous	16	
5. Clay shale, typical Wayland type, with clay ironstone partings	9	
4. Fissile shale, black, with good leaf impressions		3
3. Clay shale with clay-ironstone partings, fossiliferous	14	
2. Limestone, earthy, with many fusulinids and other fossils, broken down in weathering; possibly representing No. 9 limestone		3
1. Clay shale	5	
Outwash deposits and alluvium.		
	54	6

The exact stratigraphic position of this section of the Wayland shale above the Bunger limestone was determined by the fact that beds 7 and 9 of the above section overlap the Rocky Mound limestone member at or near its base. Bed 9 of the section (determined by Mr. Henbest to be the No. 9b limestone) is therefore thought to be about 250 feet above the Bunger. This corresponds closely with the horizon of the No. 9b limestone on the bluff west of Tonk Valley School. The fusulinids from bed 2 of the section do not identify it unqualifiedly with the No. 9 limestone, and its position only 39 feet below the No. 9b limestone suggests that it may possibly represent the No. 9a limestone or, as it is thin, a local and lenticular bed not present farther south.

On Rocky Mound, west of the bend in the road half a mile southwest of the school, beds 7 and 9 of the above section are closely overlain unconformably by Avis sandstone, which cuts them out within 300 yards along the outcrop.

The limestone bed in the Wayland shale north of Dakin switch, 5 miles east of Graham, although a single bed, was considered in the field to be the equivalent of the higher limestones (beds 7, 8, and 9) of the Wayland shale of the Rocky Mound section because both beds are about the same distance above a black, leaf-bearing fissile shale bed. The fusulinid assemblages, however, seem to indicate that the bed at Dakin switch should be correlated with bed 2 of the Rocky Mound section, which was described by Mr. Henbest as resembling limestone No. 9 but which may be a local limestone lens slightly higher in the section.

The greatest thickness of the Wayland shale was measured on the ridge on the head of Choate Creek, which flows west 2 miles west of Tonk Valley School, where 33 feet of shale was measured above the No. 9b limestone bed, so that in this locality 110 feet of Wayland shale, including the No. 9 limestone, is present, reaching at least 284 feet above the Bunger. It is overlain here by Avis sandstone.

Except where it overlies the channel deposit near Graham, the Wayland shale is unconformable on the underlying beds. In the head of Kickapoo Creek, where the interval down to the Bunger is 175 feet, the No. 9 limestone overlaps on the eroded surface of deposits of the No. 6 cycle. The following two sections, less than 100 yards apart, measured above the same bed a short distance north of the road crossing the head of Kickapoo Creek, show the occurrence of overlap at that point.

Sections of beds at horizon of the No. 9 limestone at head of Kickapoo Creek.

	Thickness *Feet*
No. 9 post-Bunger cycle:	
Limestone (No. 9 limestone)	1
Gray shale	4
Red and green shale	4
No. 6 post-Bunger cycle:	
Limestone (No. 6a limestone)	1
	10

	Thickness *Feet*
No. 6 post-Bunger cycle:	
Sandstone and shale	4
Sandstone	3
Shale, gray	3
Limestone (No. 6a limestone)	1
	11

At Rocky Mound the Wayland shale overlaps on the buried ridge already described. North and east of Dakin switch no outcrops of Wayland shale were found, and in this area they apparently overlapped the buried ridge capped by the Rocky Mound limestone and where deposited along the contact were later eroded. Unconformity at the base of the Wayland shale is also shown in the following section, measured on a butte half a mile north of Graham Lake and 1½ miles west of the Stovall hot-water well.

Section half a mile north of Graham Lake, Young County.

	Thickness Feet	Inches
Thrifty formation:		
Avis sandstone member:		
19. Sandstone, not conglomerate	16	
Graham formation:		
No. 9 post-Bunger cycle:		
Wayland shale member:		
18. Not exposed	4	
17. Talus, in part clay shale	21	
16. Clay shale with clay-ironstone partings, part not exposed, no fossils noted	34	
15. Limestone, earthy, yellowish to brownish, very fossiliferous, many fusulinids, breaks down in flakes (No. 9a limestone)		6
Pre-Wayland deposits of No. 9 cycle:		
14. Shale, gray	2	
13. Sandstone, gray, cross-bedded; base unconformable	3	
12. Sandstone, fine grained, and sandy shale, laminated; has plant remains	4	
11. Shale, red and green streaked and spotted	11	
10. Shale, red and purple; clay-ironstone concretions with plant fossils	8	
No. 7 post-Bunger cycle:		
9. Limestone, gray, sandy; base very fossiliferous; crowded throughout with fusulinids, some Foraminifera; weathers to hard bluish bed or leaches to soft brownish sandstone (No. 7 limestone)	2	
8. Limestone, lumpy and earthy, not fossiliferous, in part crystalline; weathers reddish and sandy	1	
7. Covered, partly olive-green clay shale	4	6
6. Sandstone, soft, gray, with sandy shale partings	7	6
5. Shale, olive-green, and sandstone, dirty gray	3	
4. Shale, olive-green; weathering gray	5	
3. Shale, purple	1	
2. Shale, olive-green, gritty		6
1. Sandstone, white, ripple-marked; plant remains		3
	128	3

Bed 9 of the above section is the No. 7 limestone. Bed 15 is the No. 9a limestone of the Wayland shale member and lies 28 feet higher. The No. 7 limestone is at least 171 feet and may be 180 feet or more above the Bunger, so that the No. 9a limestone is about 30 feet above the normal horizon of the No. 9 limestone, which is absent.

The following fossil plants were collected from bed 10 of the above section and identified by C. B. Read, of the United States Geological Survey:

Pecopteris cf. P. arborescens (Schlotheim) Brongniart
Pecopteris lamurensis Heer
Pecopteris unita Brongniart
Pecopteris feminaeformis (Schlotheim) Sterzel
Pecopteris hemetelioides Brongniart
Pecopteris polymorpha Brongniart
Pecopteris sp.
Pecopteris oreopteridia (Schlotheim) Sternberg
Annularia stellata (Schlotheim) Wood
Artisia sp.
Cordaites sp.
Cardaicarpon sp.

This collection is very high in the Graham formation and was reported on at the same time as the collection from below the Salem School limestone, at the base of the Graham. Referring to both collections, Mr. Read reports:

> The collections are clearly late Pennsylvanian. There is not enough material to define carefully the horizon in terms of the Appalachian section. I do not believe, however, that these plants represent highest Pennsylvanian. The horizon is more likely middle Monongahela. Certainly there is little in the collections that is suggestive of close proximity to the Permian.

GUNSIGHT LIMESTONE MEMBER

The Gunsight limestone, named for its exposure at Gunsight post office, in southern Stephens County, has not been identified in southern Young County. At the type locality and farther south it occurs in two beds separated by shale. Both the beds are gray, dense, and fossiliferous, and the lower bed particularly is well known for its abundant *Campophyllum* corals, though they are not conspicuous at the type locality.

At the type locality[4] the Gunsight is overlain by the Wayland shale, at whose base occurs a bed of yellowish earthy highly fossiliferous limestone typical of the thin limestones of that member. Toward the north, to the east of Breckenridge, the Gunsight is cut out by an unconformity at the base of the Avis sandstone, and northeast of Breckenridge it is generally absent and cannot be traced on the surface into northern Stephens County. In this area and in southern Young County the earthy limestone bed of the Gunsight area or a similar one in the base of the Wayland has

[4]Plummer, F. B., and Moore, R. C., Stratigraphy of the Pennsylvanian formations of north-central Texas: Univ. Texas Bull. 2132, p. 135, 1921.

been correlated with the Gunsight, though it has nothing in common with that member except its position at the base of the Wayland. This bed is strikingly different lithologically from the Gunsight, and its fossils are those of the Wayland shale.

It has not been possible to identify the Gunsight limestone with any of the many limestone beds of southern Young County. The No. 3 limestone exposed in Duff Branch at 105 feet above the Bunger appears to be the most plausible correlative from its stratigraphic relations, but the fusulinids from the Gunsight outcrops in the Colorado River area 120 miles distant, examined by Mr. Henbest, are insufficient for close correlation. Lithologically the Rocky Mound limestone most closely resembles the Gunsight, but there are strong objections to correlating them.

THRIFTY FORMATION

The Thrifty formation begins with the Avis sandstone member, a thick deposit of sandstone, which, in many places, is extremely conglomeratic. This sandstone has an unconformity at both top and base (Pl. III). The remainder of the Thrifty formation consists chiefly of shale and thin lenticular sandstones. It contains, in the upper part, several beds of limestone, including the Ivan and Blach Ranch members and at the top the Breckenridge limestone member. The Thrifty contains some coaly streaks near the top. After the erosion of the top of the Avis sandstone there was little major interruption to sedimentation. As the formation is bounded below by an unconformity, the thickness is variable, ranging from 117 feet near Rocky Mound to 215 feet near Graham. The top of the Breckenridge is 402 feet above the top of the Bunger.

Avis sandstone member.—The deposition of Wayland shale, the top member of the Graham formation, was followed by a period of prolonged erosion, during which the Wayland shale was widely and deeply dissected, and the ridge underlain by the Rocky Mound limestone was again exposed. At Eliasville the surface on which the Avis sandstone member was deposited was 250 feet above the Bunger limestone. On the ridge west of Tonk Valley School its surface was at one point 281 feet above the same datum, but at Graham, on the bluff above the dam, the Wayland was eroded to a depth of 187 feet above the Bunger, and in places near the south end of Lake

Eddleman, 2 miles north of Graham, it seems probable that the pre-Avis surface may have been even lower. The relief of the pre-Avis surface in southern Young County was therefore at least 94 feet.

The Avis sandstone member, which was deposited on this surface, consists essentially of sandstone containing in many localities and at different horizons great quantities of chert pebbles entirely similar to those deposited in many of the sandstones of the Graham formation. The Avis, though composed chiefly of sandstone and conglomerate, shows breaks of sandy shale and a little gritty clay shale in several localities, notably north of Eliasville. At a few places, as at the south end of Lake Eddleman, near Graham, unconformities can be seen between different parts of the Avis itself. It is not unlikely that the period of aggradation was interrupted, at least once, by erosion, but the tendency of the Avis to form talus slopes seldom permits a sufficiently detailed examination of the outcrops to determine the internal history of the member.

The top of the Avis also is irregular, and it appears that after deposition the sandstone was subjected to deep erosion, for the interval between its top and the Blach Ranch limestone member differs greatly from place to place. On the west side of Salt Fork, at McCann Bridge, the top of the Avis is only 12 feet below the top of the Blach Ranch limestone, whereas 2 miles west of Graham it is 125 feet below the same datum, its upper surface thus having a relief of at least 113 feet. A mile northwest of Eliasville the Avis deposit consists of only 10 feet of sandy shale at 75 feet below the Blach Ranch limestone. This thin section of Avis is overlain by the thickest section of post-Avis deposits observed in the Eliasville area. Similar relations also occur near Graham, where the Avis is relatively thin but is followed by a thick post-Avis section. North of Lake Eddleman and northwest of Rocky Mound, erosion has stripped the Avis from parts of the area.

The irregular surface at the top of the Avis is shown in Plate III. The Avis was no doubt built up of coarse materials deposited by streams, but this origin is inadequate to account for its irregular upper surface. It is concluded, therefore, that after the inequalities of the pre-Avis surface were smoothed by deposition, the region was again subjected to widespread and deep erosion, at the end of which the relief must have been as great as in parts of the same region today. The post-Avis erosion resulted in the removal of vast amounts of sand and gravel and should be represented seaward by offshore sandstone deposits conformable with the sediments of the time.

Avis sandstone member to Blach Ranch limestone member.—On the irregular surface of the Avis was laid down a series of shale, thin sandstone, and thin limestone beds, and in this respect the unconformity differs from most of the previous ones, which were followed by sandstone. The surface was low west and south of Eliasville and also near Graham, but between these low areas there seems to have been a ridge. To the north of the Graham Basin also there was a ridge capped by Rocky Mound limestone and Avis sandstone, and still farther northeast probably another basin, as yet undefined.

Marine conditions from time to time returned to the area about Eliasville as the estuaries or basins were filled. The lowest marine deposit seen in the Eliasville area is 80 feet below the Blach Ranch limestone member. This deposit occurs 1½ miles northwest of Eliasville in a side road leading to the upland area north of Gage Creek. It is a limestone bed 28 feet below the base of the Ivan limestone member, 6 inches thick, fossiliferous, earthy, and sandy, and carries no fusulinids. Another outcrop of limestone below the Ivan occurs at about the same interval below it, but the interval could not be measured. The outcrop is in the bank of Gage Creek downstream from the Ivan outcrop. In spite of the facts that it is about 3 feet thick, is more earthy than the other outcrop, and carries fusulinids as well as other fossils, it occurs at so nearly the same horizon that it is probably the same bed modified by the erratic accumulation of clastic material in what must have been a near-shore deposit. In the northern basin in Flint Creek, 2 miles northeast of Eddleman Lake, near the bridge, a 2-foot bed of limestone overlies the Avis sandstone at 92 feet below the Blach Ranch member, but it does not seem to have a very wide distribution. There are several other limestones in the Eddleman Lake area at about this distance below the Blach Ranch member, but these appear to be overlain by Avis sandstone and therefore to be of Graham age. Plummer and Moore report a limestone southeast of Breckenridge at 60 feet below the Ivan limestone, which may well be contemporaneous with those mentioned above, the discrepancy of interval not being significant in a partly filled basin or in what may have been different estuaries of the same basin.

Ivan limestone member.—A limestone bed exposed in the Eliasville area, particularly in the basin of Gage Creek, has been traced by others through intermittent outcrops to the Ivan limestone near Ivan. This bed west of Eliasville is 45 feet below the Blach Ranch limestone. It is dense, gray, and crystalline, and contains relatively few fossils. Where examined on Gage Creek the top is rough with *Syringopora* corals. The maximum thickness noted is on Gage Creek, where it is 9 feet thick. It is underlain by a thin sandstone containing plant fragments. About 2 miles north of Eliasville, the Ivan limestone overlaps the Avis sandstone (Pl. III), and farther north it is missing. No outcrops identifiable with the Ivan were seen in the area about Graham, which seems to have been separated from the Eliasville area by a sandstone ridge.

Although the fluctuations of sea level reached their climax for a time in the disturbances that resulted in the deposition and erosion of the Avis, deposition did not proceed without interruption during the filling of the post-Avis estuaries, though in this region the interruptions seem to have been of a distinctly minor character. Below the Blach Ranch limestone there are deposits of clay, shale, red shale, black shale, and some thin streaks of coaly material, and also lenticular deposits of gray sandstone. These sandy deposits may have been in part derived from Avis deposits still exposed on the divides between the estuaries. The lenticular cross section of some of the sandstones shows that they were deposited in channels, and although they may for the most part represent contemporaneous deposition, at least one, north of Flint Creek and west of the Loving highway, has a thickness of 25 feet, though it is only a few hundred feet wide and apparently indicates exposure and channeling.

East of the Simms-Willis No. 1 well, at the foot of the north end of the first butte capped by Blach Ranch limestone, east of the Loving road, an 18-inch silicified tree trunk occurs in place in a bed 38 feet below the top of the Blach Ranch, indicating that in this locality at least subaerial conditions prevailed at this horizon and giving ground for belief that at least some of the lenticular sand bodies in the upper part of the Thrifty represent the filling of subaerially eroded channels.

The following sections were measured below the Blach Ranch limestone member:

Section of the lower part of the Thrifty formation in Gage Creek, two miles west of Eliasville.

	Thickness Feet	Inches
12. Blach Ranch limestone member	2	
11. Shale, gray	20	
10. Clay shale, red	5	
9. Clay shale, gray	7	
8. Shale, coaly	1	
7. Shale, gray to white		6
6. Limestone, not fossiliferous		3
5. Shale, limy, in part purplish	7	
4. Sandstone, gray, fine grained, with plant fragments, lenticular, overlapping bed below	1	
3. Shale, black, banded with *Syringopora* corals	4	
2. Ivan limestone member:		
Limestone, gray, massive, sparsely fossiliferous, top rough with *Syringopora;* weathers in ragged boulders	4	
Limestone, gray, weathering bluish, platy, with thin clay and shaly lime partings; sparsely fossiliferous	5	
Limestone, gray, fine-textured, nonfossiliferous		3
1. Sandstone, limy, with plant fragments	2	
	59	

Section of lower part of the Thrifty formation one mile northeast of Rocky Mound School.

	Thickness Feet
10. Blach Ranch limestone member	2
9. Shale	4
8. Sandstone, gray, soft, massive	14
7. Clay shale	22
6. Sandstone, gray, platy	6
5. Talus, probably shale	9
4. Sandstone, gray, massive	16
3. Shale	33
2. Not exposed, plowed field; no residual rocks	44
1. Conglomeratic sandstone (Avis sandstone member?)	
	150

Within a mile of the above section the buried Rocky Mound ridge, capped by late Graham limestone and by a thin deposit of Avis sandstone, rises to a horizon within 60 feet of the Blach Ranch member.

Blach Ranch limestone member.—The Blach Ranch limestone is the first reliable datum above the Avis. In the southern part of Young County, where most of the field work for this report was done, it consists of two limestones separated by 2 to 3 feet of bluish clay shale. The following sections at two points 10 miles apart indicate its essential uniformity:

Section showing details of Blach Ranch limestone member half a mile west of McCann Bridge over Brazos River, on the highway seven and one-half miles west of Graham.

	Thickness Feet	Inches
Blach Ranch limestone member:		
7. Limestone, dark, earthy, and finely crystalline, weathers in angular slabs, light brown to yellowish in color, fossiliferous, with fusulinids in top	1	4
6. Shale, yellow, limy, and fossiliferous		3
5. Clay shale, bluish; contains scattered fossils	2	6
4. Limestone, like upper member but somewhat less earthy	1	6
3. Shale, gritty, carbonaceous		3
2. Coal, dirty		6
1. Clay shale, gray	2	
	8	4

Section showing details of Blach Ranch limestone member in bed of creek one and one-half miles west of Eliasville, half a mile south of highway.

	Thickness Feet	Inches
Blach Ranch limestone member:		
8. Limestone, earthy, dark, densely crystalline, weathering yellowish and hackly, in slivers and rough masses		8
7. Shale	2	
6. Limestone, dark to bluish, dense, finely crystalline, weathering gray to light brown, massive and angular blocks, fossiliferous	2	
5. Limy shale, fossiliferous	2	
4. Sandstone, platy, with shale partings	3	
3. Clay shale, slightly gritty, bluish	2	6
2. Clay, shale, black and coaly; contains macerated fossil leaves		6
1. Shale, yellowish	1	
	13	8

Where the exposures are not complete it is generally the upper bed that crops out. The double character of this member continues northeastward toward the Jack County line.

The beds immediately below the lower limestone bed of the Blach Ranch are seldom seen, but the presence of a coaly layer at widely separated points suggests that it was widely deposited and that the inequalities of the surface had been filled at this time. This is believed to be the horizon of the Chaffin coal of the Colorado River Basin. In general, the Blach Ranch outcrops are distinguished by their dark color on fresh surfaces and by the habit of the bed to weather in good-sized only slightly rounded blocks and slabs.

Lack of convergence below Blach Ranch limestone member.—In view of the violent fluctuations of sea level attending the final phase of the Graham formation and the beginning of the Thrifty formation it is a little surprising to find within the area examined so little evidence of convergence. The interval from the Blach Ranch limestone to the limestone at the base of the Wayland member was measured at Eliasville and also south of Medlin Chapel and found to be essentially the same—178 feet and 173 feet respectively. If errors of measurement and local variations in sedimentation are disregarded, this indicates a thinning of only 5 feet in 9 miles—much less than might be expected. Unfortunately, the Wayland limestones are almost never reported in the well logs, and these measurements could not be checked by subsurface data.

The following measurements were taken from carefully kept logs to indicate the interval at various points between the Blach Ranch limestone and the Bunger limestone, both of which are usually identifiable in the logs even though the position is seldom recorded with the accuracy desirable for detailed studies.

Interval between Blach Ranch limestone and Bunger limestone, as indicated in well logs.

	Thickness *Feet*
Core-drill hole, Graham ranch, T. E. & L. survey No. 2904, 14 miles west of Graham	375
Nash & Windfohr, Graham No. 1, 13 miles west of Graham	361
Pitzer & West, 5½ miles east of Newcastle	380
Christie Bros.-Jeffery No. 1, 4 miles north of Graham	361
Casey, Mercier-Jeffery No. 1, 4 miles north of Graham	371
Clarco-Morgan No. 1, 4 miles north of Graham	380

These logs, which represent a spread of 16 miles from east to west, indicate that no great amount of convergence resulted in this interval in this area. The last three wells in the list essentially offset one another, and the variation in interval may represent convergence, though it is thought to be due to inaccuracies in the logs.

The Clarco-Morgan log, which shows discrepancies on other beds, is especially open to question.

Blach Ranch limestone member to Breckenridge limestone member.—No great variation occurs in the interval between the top of the Blach Ranch limestone and the top of the Breckenridge limestone. Intervals measured from south to north from Clear Fork to McCann Bridge at about 2-mile intervals show 55 feet, 52 feet, 58 feet, and 50 feet. In the core-drill log on the Graham ranch, T. E. & L. survey No. 2906, 6 miles west of the outcrop, this interval is recorded as 56 feet. It seems probable that only slight variations occur, those noted being attributable more to weathering in the outcrops or fluctuations of deposition than to convergence.

This interval was not without its depositional interruption (Pl. III). Immediately below the Breckenridge occurs a bed of red shale from 9 feet thick south of the highway west from Eliasville to 6 feet thick west of the McCann Bridge. Just below this red shale, at the first locality, there is 7 feet of sandstone, unconformable at the base and sun-cracked at the top; 2 miles northwest of Eliasville this sandstone bed is 25 feet thick; on Fish Creek, 3 miles farther north, the sandstone is 18 feet thick; and at the McCann Bridge outcrop it is 13 feet thick. This sandstone is in places coarse and irregularly bedded but not massive and contains some interbedded sandy shale. Though it may represent contemporaneous deposition, it was probably deposited in a broad, low basin, the sun cracks indicating subaerial exposure at the end of the epoch. The section from the Blach Ranch limestone to this sandstone lens consists of thin-bedded nonfossiliferous clay shale with a few clay-ironstone partings showing no stratigraphic break.

Breckenridge limestone member.—The Breckenridge limestone is dove-gray and finely crystalline and weathers to hard, rough, irregularly cracked slabs and small boulders. It is sparsely fossiliferous, containing crinoid stems and especially near the top a good many fusulinids. It ranges in thickness from 5 feet near Crystal Falls to 1½ feet near McCann Bridge but is uniform in character.

HARPERSVILLE FORMATION

The Harpersville formation extends from the top of the Breckenridge limestone member to the top of the Saddle Creek limestone member, an interval of 233 feet. It is part of a chaotic series of thin

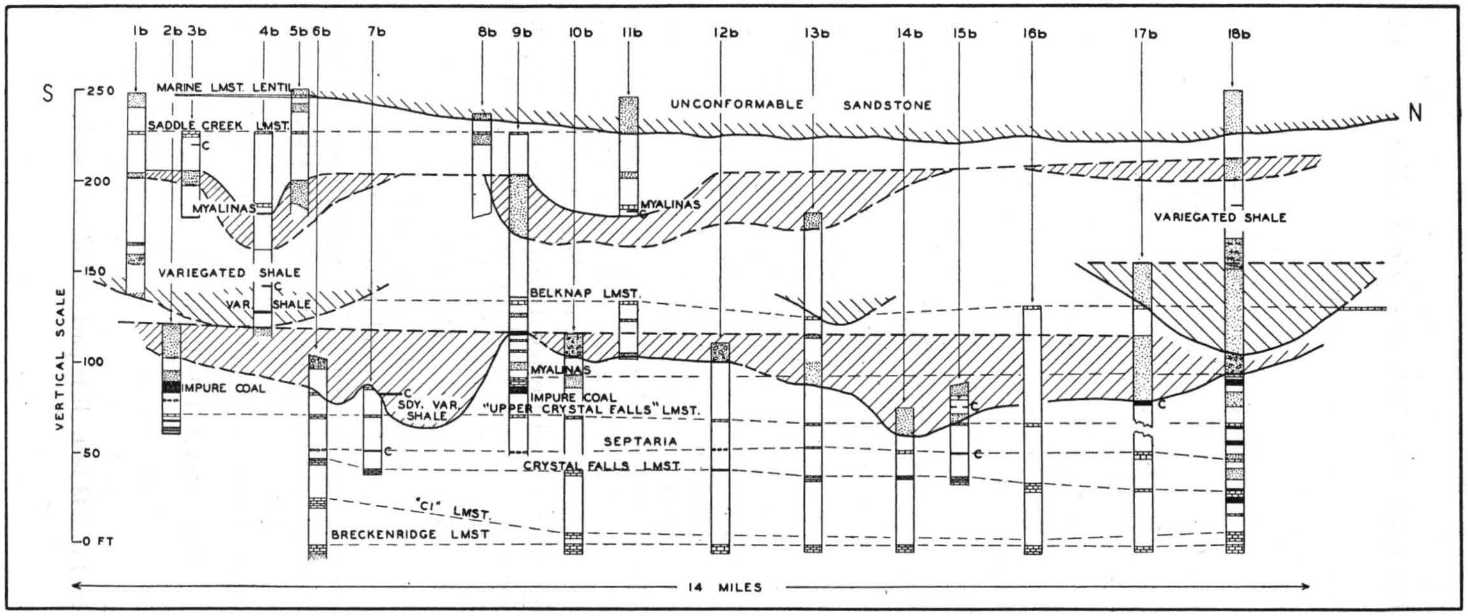

Fig. 4. Generalized cross section of the Harpersville formation from outcrops between Crystal Falls, Stephens County, and McCann Bridge, Young County, Texas. Geology by Wallace Lee. Localities indicated by numbers on Pl. VI as follows: (1b) butte near railroad on Hamm ranch; (2b) railroad cuts northwest of Crystal Falls; (3b) first bluff east of mouth of Kings Creek; (4b) on road one-fourth of a mile southeast of Huffstettle School; (5b) on highway east of Huffstettle School; (6b) 1½ miles northeast of Crystal Falls; (7b) 2 miles northeast of Crystal Falls; (8b) on scarp west of Wagon Timber Branch; (9b) head of Wagon Timber Branch; (10b) old pipe line ditch east of Wagon Timber Branch; (11b) northeast of Donnell ranch house; (12b) south side of Gage Creek in Donnell Ranch; (13b) Lookout Mountain south of Fish Creek; (14b) northeast of Caudle ranch near highway; (15b) butte in pasture 1½ miles northeast of Nash & Windfohr pool; (16b) Nash & Windfohr No. 1 Graham; (17b) Plummer and Moore's locality, 7 miles southwest of Newcastle; (18b) Reed & Taylor No. 1 Graham.

limestones, relatively thin lenticular sandstones, variegated sandy and clay shales, and thin coals. This complex series of beds—(fig. 4), interrupted by unconformities expressed in large and small channels, extends with progressive changes upward beyond the limits of the Harpersville formation to the middle of the Moran formation.

The first limestone bed in the Harpersville lies a few feet above the top of the Breckenridge. It is nameless but was designated by the symbol "Cl" by the coöperative mapping committee of the American Association of Petroleum Geologists in preparing the stratigraphic section of the Pennsylvanian rocks for the outcrop maps of the counties of north-central Texas.

The bed is gray, hard, crystalline, and sparsely fossiliferous. In most places it weathers to lumpy masses in a chalky and marly matrix from which fusulinids can be washed in considerable quantities.

In the Crystal Falls area the bed is 5 feet thick and is separated from the Breckenridge by 20 feet of red shale. Near McCann Bridge its thickness is reduced to 1½ feet, and the underlying shale is only 3 feet thick, the greater part of the thinning of both beds occurring within 5 miles of Crystal Falls. This limestone thins in the same areas in which the shale interval between it and the Breckenridge thins, but the interval from the top of the Breckenridge to the top of the next higher limestone, the Crystal Falls limestone member, is essentially constant. Intervals measured about 2 miles apart show the following thicknesses: 1½ miles north of Crystal Falls, 47 feet; Gage Creek, 41 feet; Fish Creek, 40 feet; west of McCann Bridge, 41 feet. Most of the logs do not record these thin beds.

If the "Cl" bed is assumed to be a part of the Breckenridge (a not unnatural assumption where the beds are close together) considerable variation in the intervals from the Blach Ranch limestone to the top of the Breckenridge limestone and from the Breckenridge to the Crystal Falls limestone would appear to exist, the former being irregularly increased and the latter correspondingly decreased. This should be borne in mind in examining drill logs, for in most logs the beds are reported as a unit. For instance, the Nash & Windfohr-Graham No. 1 well, 4 miles west of McCann Bridge, shows an abnormal thickness for the Breckenridge limestone and a reduced interval up to the Crystal Falls limestone.

The remainder of the interval up to the Crystal Falls limestone is chiefly shale, although there are some discontinuous streaks of sand and sandy shale a short distance below the Crystal Falls.

Crystal Falls limestone member.—The accompanying sketch (fig. 5) shows the relation of the upper and lower beds of the Crystal Falls limestone. The lower bed is gray and at its thickest point about 3 feet thick. The upper bed is yellowish and averages less than 1 foot thick. Both are fossiliferous and contain fusulinids. The wavelike surface of the upper bed was at first thought to be caused by weathering and swelling of the underlying shale, but an outcrop in the first railroad cut northwest of Crystal Falls shows the unusual relation of these beds to each other.

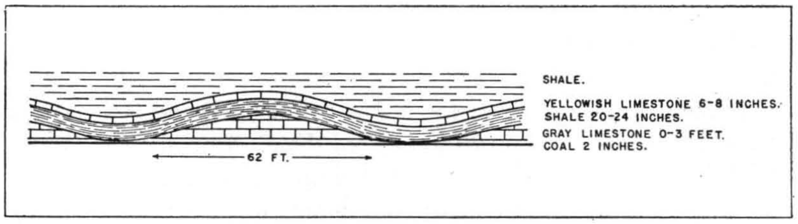

Fig. 5. Sketch showing details of Crystal Falls limestone member in railroad cut, Crystal Falls, Stephens County, Texas.

The lower bed was apparently subjected to wave, tidal, or other erosion in such a way as to produce a hummocky surface with hillocks about 3 feet high and 100 to 150 feet from center to center. This surface was then covered evenly with about 2 feet of shale, which was followed by the conformable deposition of the upper limestone bed. Near Crystal Falls the lower bed is underlain by a thin streak of coal, which at this point was not disturbed by the erosion. At one place where erosion completely removed the lower limestone, mounds of similar shape were built up of sand and small pebbles, and the overlying 2-foot shale bed contains a few fragments of coal. The upper member here, as at Crystal Falls, lies in billows. The mounds are distributed irregularly on the topographic benches formed by the Crystal Falls limestone, like hayricks in a field. Erosion of the mounds produces circular central areas of gray limestone enclosed by rims of dipping yellowish limestone like miniature Wyoming anticlines.

The hummocky character of this bed extends from Crystal Falls northward along the outcrop for a distance of at least 18 miles, but toward the north the mounds are larger and less numerous. It is believed that the hummocky surface of the lower limestone represents a phase of near-shore erosion.

At a few places west of Eliasville somewhat similar mounds affect the upper part of the Breckenridge limestone, but the phenomenon is not general at this horizon.

Crystal Falls limestone member to so-called "Upper Crystal Falls limestone."—The interval from the top of the Crystal Falls limestone to the top of the next persistent limestone of the Harpersville formation, called by some writers the "Upper Crystal Falls limestone," increases slightly for 15 miles northward from Crystal Falls to the McCann Bridge area. Its thickness is 25 feet 1½ miles north of Crystal Falls, 28 feet on Gage Creek, 30 and 29 feet at two measurements on Fish Creek, and 30 feet southwest of McCann Bridge. This interval is 37 feet in the log of the cored well on the Graham ranch and 33 feet in the carefully kept log of Nash & Windfohr No. 1 Graham well, 4 miles west of McCann Bridge.

The local variations, which make the Harpersville formation so chaotic, begin above the Crystal Falls limestone. The greater part of the section up to the so-called "Upper Crystal Falls limestone" is shale, but some erratic coals and limestones are present in the interval. Five feet above the Crystal Falls limestone, at an excellent outcrop 1½ miles northeast of Crystal Falls, there occurs a bed containing septaria. These are about 8 inches in diameter and, though not seen in places elsewhere, were encountered in the bed of Wagon Timber Branch and on the lower slope of a hillside on the north side of Gage Creek. They were not observed farther north and they are not numerous enough to constitute a very good datum, but their presence should indicate nearness to the horizon of the Crystal Falls limestone.

On Fish Creek a 6-inch bed of earthy fossiliferous limestone, not present toward the south unless it may be correlated with the bed containing the septaria, is found 12 feet above the Crystal Falls. A mile farther north the interval has increased to 16 feet. Southwest of McCann Bridge, 2 miles farther north, a thin coal bed but no limestone occurs at this horizon. Impure coal is not unusual a short distance below the Upper Crystal Falls limestone, but both its thickness and the interval are variable. Thus in the second railroad cut just northwest of Crystal Falls nearly 6 feet of dirty coal in thin layers alternating with carbonaceous shale is present a foot below the limestone. On the Caudle ranch, on Fish Creek, there is 4 feet of black slate and carbonaceous shale laminated with coal at the same horizon. Midway between these exposures, on Wagon Timber Branch on the Donnell ranch, north of the Crystal Falls-Eliasville road, a thin coal with carbonaceous shale occurs beneath 7 feet of gray clay shale with some carbonaceous streaks that immediately underlies this limestone. Coal was noted at other places, but although these deposits are no doubt essentially contemporaneous, the outcrops rarely show more than a few inches of dirty coal and they are not continuous.

The Upper Crystal Falls limestone is yellowish, of earthy texture, with crystalline streaks, and very fossiliferous. It is much like the upper bed of the Crystal Falls limestone member but does not contain fusulinids. It weathers to a brownish color with reddish and purplish splotches on the surface. Its greatest thickness is 2½ feet, but it is usually less than a foot thick. Like the next overlying limestone it is in some places cut out by a channel. The following section was measured 1½ miles northeast of Crystal Falls, north of the Crystal Falls-Eliasville road:

Partial section of Harpersville formation, one and one-half miles northeast of Crystal Falls Bridge, north of Eliasville-Crystal Falls road.

	Thickness Feet	Thickness Inches
20. Conglomerate of fine angular pebbles and sand	6	
19. Shale and thin beds of sandstone	9	
18. Sandstone, forming bench	1	
17. Shale, limy	3	
16. Limestone, gray, earthy, fossiliferous, chiefly shell fragments but no fusulinids; weathering to rounded blocks, with some iron stain; cut out by channel nearby	1	
15. Not exposed; probably shale	11	
14. Limestone, earthy, with crystalline streaks, fossiliferous but without fusulinids, brownish, weathering brownish, mottled reddish and purplish (Upper Crystal Falls limestone of some writers)	2	6
13. Not exposed; probably shale	16	6
12. Septaria in shale	1	
11. Shale	4	
10. Crystal Falls limestone member:		
Limestone, light yellowish to buff, with patches of reddish iron stain, fossiliferous, dense to earthy; contains fusulinids	1	

	Thickness Feet	Inches
Shale	1	6
Limestone, gray, finely crystalline, sparsely fossiliferous; carries fusulinids	1	
9. Clay shale, bluish and gray	6	6
8. Shale with clay ironstone	1	6
7. Shale, red	5	
6. Sandstone, greenish, lenticular (0–4 feet)		6
5. Shale, red	5	6
4. Limestone, gray, medium to fine grained; weathers gray, lumpy, and marly; sparsely fossiliferous, many fusulinids ("Cl" bed)	5	
3. Shale, red	20	
2. Limestone, gray, fine texture; weathers bluish to gray, rough surface; breaks down to boulders; bottom part platy and nodular, sparsely fossiliferous, with fusulinids in abundance near top (Breckenridge limestone member)	5	
1. Sandstone, greenish, laminated		6
	108	

"Upper Crystal Falls limestone" to Belknap limestone member.—The interval from the so-called "Upper Crystal Falls limestone" to the Belknap limestone member of Plummer and Moore is 65 feet in the Nash & Windfohr No. 1 well, 4 miles west of McCann Bridge. On Lookout Mountain, on the Caudle ranch south of Fish Creek, a surface measurement gave 58 feet for this interval. At the head of Wagon Timber Branch, on the Donnell ranch 5 miles west of Eliasville, a composite section makes the interval about 64 feet. The interval presents considerable confusion because it contains a good many small unconformities involving at least three discontinuous thin limestones, several thin streaks of impure coal, and at least one major channel unconformity whose concavities are filled with variegated shales, in some places showing thin coaly beds followed by conglomeratic sandstone. In view of their erratic character and number, the detailed correlation of the thin limestone beds of this interval with the Waldrip limestones of the Colorado River section seems unwarranted.

On the old road to Eliasville 1½ miles northeast of Crystal Falls, there is a limestone bed 12 feet above the Upper Crystal Falls limestone. This bed is gray, earthy, and fossiliferous and weathers in roundish blocks. It is cut out within 100 feet of the outcrop recorded in the above section by a channel refilled with sandstone and conglomerate. Half a mile farther north it crops out 16 feet above the Upper Crystal Falls. At this point also it is interrupted by a similar and probably connected channel, which cuts deeper and has eroded also the Upper Crystal Falls bed. Here the lower part of the channel is filled with variegated shale and near the horizon of the upper limestone contains a few streaks of dirty coal. The upper part of this channel is filled with sandstone and conglomeratic sandstone which overlap the limestone and extend to the top of the hill. The sandstone of this unconformable deposit contains a great many chert pebbles like those of earlier conglomeratic beds, erratically distributed, both vertically and horizontally. Channeling occurs along the outcrop of these beds north of Fish Creek. Unconformity at this horizon is general along Clear Fork and, though of lesser relief, is comparable to the Avis in its widespread occurrence. Northwest of Cisco an imposing mass of sandstone and conglomerate occurs below the Saddle Creek limestone, and this may prove to be contemporaneous with the conglomerates of this interval on Brazos River. The top of the conglomeratic sandstone in Young County is 45 feet above the Upper Crystal Falls limestone and about 110 feet below the Saddle Creek limestone. It cuts at least 10 feet below the Upper Crystal Falls, and the relief of the unconformable surface is at least 55 feet.

The channel deposit occurs at the horizon of the Newcastle coals and cuts them out on the borders of Clear Fork and in other places. The lowest of the coals, however, crops out in a bank of Wagon Timber Branch, where some exploratory openings were once made half a mile south of the Eliasville-Woodson highway at a place named Carbondale, which is still marked on some maps of the county, though practically all signs of settlement have long since been obliterated. This coal, which is 86 to 90 feet above the Breckenridge limestone, is overlain by 4 feet of shaly fossiliferous limestone or limy shale capped by 1 foot of gray crystalline fossiliferous limestone. These fossiliferous beds are crowded with *Myalina* but contain no fusulinids. Coal overlain by limestone is reported at this horizon in the log of the core-drill hole on the Graham ranch, in a section measured northwest of McCann Bridge by Plummer and Moore, and in the log of the Belknap Coal Co.-J. J. Perkins No. 1 well, half a mile east of Newcastle, but this coal is exposed in few places chiefly, perhaps, because it is cut out by the unconformity in so many parts of the area.

The following composite section of part of the Harpersville formation was measured on Wagon Timber Branch, where the unconformity mentioned above has not cut very deeply into the underlying section:

Composite section of part of Harpersville formation below the Belknap limestone, measured on west side of Wagon Timber Branch, south of Eliasville-Woodson highway.

	Thickness Feet	Inches
20. Limestone, gray with greenish cast, coarsely crystalline, fossiliferous (Belknap limestone member)	2	
19. Not exposed, probably shale	5	
18. Sandstone, gray to yellowish, irregularly bedded to massive; forms bench	2	6
17. Shale, yellowish	3	
16. Shale, red and gray	5	6
15. Sandstone, limy, nonfossiliferous		3
14. Not exposed, probably shale	3	6
13. Limestone, dark to gray, sparsely fossiliferous, lenticular		3
12. Shale	5	
11. Sandstone, yellowish to gray, flaky and impure	1	
10. Clay, gray to white	6	
9. Sandstone, brownish, platy	4	
8. Shale, gray, sandy	4	
7. Limestone, flaky and earthy		6
6. Limestone, gray, crystalline, fine texture, dark to black, weathering gray, fossiliferous, no fusulinids	1	
5. Limestone, earthy and weathered, or limy shale, fossiliferous	4	
4. Shale, carbonaceous or coaly	1	
3. Coal and shale, weathered (one of Newcastle coals)	2	
2. Not exposed	12	
1. Limestone, earthy, brownish to yellowish, very fossiliferous, platy (Upper Crystal Falls limestone)	1	
	63	6

At the head of Wagon Timber Branch, just south of the highway, there occur at 27 and 33 feet below the Belknap limestone two discontinuous limestones, neither one more than 4 inches thick. They contain crinoid stems and seem to be cut out by equally discontinuous sandstone beds whose maximum observed thickness is less than 10 feet. On the east side of Wagon Timber Branch considerable float from one of these beds was seen but the bed was not found in place.

Belknap limestone member.—The Belknap limestone is unique among the limestones in this area. It is gray and crystalline and on fresh surfaces has a slight greenish cast. It is very fossiliferous and is the highest limestone in the area in which any fusulinids were found. It is characterized also by the presence of large productids and Pinnas and unusually large specimens of several other species. On account of its relative purity, it erodes easily and does not form good outcrops, although it has a thickness of 2 feet. One of the best outcrops is beside the Eliasville-Woodson road, on Wagon Timber Branch. It crops out widely in the area of the Nash & Windfohr pool 4 miles west of McCann Bridge, where on account of its unique characteristics it is easily distinguishable from the underlying limestones. It is cut out by unconformity, however, in the exposures a mile to the east. It is present on the south slope of Lookout Mountain at Fish Creek but seems to have been cut out by unconformable sandstones on the north slope of the mountain. In the vicinity of Newcastle it loses something of its purity and is less surely identifiable by its physical characteristics, but it still carries the distinctive fusulinids.

In the area between Crystal Falls and Wagon Timber Branch the Belknap limestone appears to be cut out and its horizon is occupied by massive sandstone. It is also replaced by sandstone in the cored well on the Graham ranch, 3 miles down the dip to the west, and in much of the sandstone area northeast of Newcastle and locally at intermediate points. This sandstone is the highest bed carrying chert pebbles and may be the equivalent of the conglomeratic sandstone of the Cisco Lake area in Eastland County, which is below the Saddle Creek limestone.

Belknap limestone member to Saddle Creek limestone member.—The interval above the Belknap in southern Young County to the next higher limestone, identified by Plummer and Moore as the Saddle Creek limestone, is 93 feet. The only satisfactory outcrop found showing the top and bottom of this interval is at the head of Wagon Timber Branch, where it is crossed by the highway from Eliasville to Woodson. The variable character of the deposits of this interval is well illustrated by the presence on the highway of

34 feet of bedded reddish sandstone whose top is 24 feet below the top of the Saddle Creek, whereas 1000 feet to the south, on a shoulder of a ridge, a continuous exposure shows 45 feet of variegated clay shale with no sandstone at the corresponding horizon. The changing relations between these outcrops are masked by slumping. In the same interval sandstone is present in some places and thin limestones and *Myalina*-bearing shale beds overlain by shale in others. It is possible that the contrasting deposits are due to erratic contemporaneous deposition, but in view of the numerous observations of channeling it seems not unlikely that obscure and frequent fluctuations of sea level permitted rapid channeling and equally rapid filling.

Section of upper part of Harpersville formation one and one-half miles northeast of the Eliasville-Woodson highway and north of the Donnell ranch house.

	Thickness Feet	Inches
Pueblo formation:		
9. Sandstone, massive and bedded	19	
Harpersville formation:		
8. Limestone, earthy, porous (Saddle Creek limestone member)		6
7. Shale, white, gray, and violet-colored	21	
6. Sandstone, gray, earthy, with limonite specks, lenticular	3	
5. Shale, gray to yellowish	9	
4. Shale, gray and yellowish; talus littered with clay-ironstone chips	6	
3. Shale, yellowish, limy, fossiliferous, many Myalinas	2	
2. Limestone, earthy, dark brown, fossiliferous		2
1. Coal		2
	59	10

Section of upper part of Harpersville formation on the highway south to Crystal Falls from Huffstettle School.

	Thickness Feet	Inches
13. Limestone (Saddle Creek limestone member)	1	
12. Not exposed, probably shale, no sandstone float	38	
11. Limestone, thin plates in yellow fossiliferous shale, contains a great many Myalinas but no other fossils	2	
10. Limy sandstone plates 1 inch thick in limy yellow shale	2	
9. Shale, yellowish, limy	1	
8. Sandstone, massive and irregularly bedded	18	
7. Sandstone, yellowish plates in yellowish shale	2	
6. Shale, gray, yellowish, and red, mottled and variegated	17	

	Thickness Feet	Inches
5. Clay, coaly		6
4. Shale, variegated, with streak of greenish laminated sandstone 2 inches thick	14	
3. Sandstone, soft, gray, laminated, impure	1	
2. Shale, variegated, with ironstone concretions in band	8	
1. Sandstone, massive and irregularly bedded, gray	5	
	109	6

Myalina-bearing limestone of the above sections is represented in the cross section of the Harpersville formation (fig. 4) as deposited in channels formed subsequent to the deposition of the sandstone, though the evidence does not preclude its deposition contemporaneously with the sandstone.

On the west side of Wagon Timber Branch at the crest of the escarpment on the road the Saddle Creek limestone is immediately underlain by 6 feet of coarse sandstone. In the road outcrop east of Huffstettle School, 1½ miles farther west, it is immediately underlain by a shale section with streaks of coal and coaly shale. On the bluff of the first ridge east of the mouth of Kings Creek it is underlain by shale.

Section of upper part of Harpersville formation on first ridge east of the mouth of Kings Creek.

	Thickness Feet	Inches
Pueblo formation:		
7. Sandstone, forming bench	4	
6. Shale	12	
Harpersville formation:		
5. Saddle Creek limestone member:		
Limestone, earthy		4
Shale, gray, fossiliferous	1	6
Limestone, gray, crinoidal		8
Shale		4
Limestone, brown, sandy, fossiliferous	1	
4. Shale, with streaks of coal	19	
3. Sandstone, gray, thin-bedded	8	
2. Shale, yellowish	16	6
1. Coal; base not exposed		3
	63	7

Saddle Creek limestone member.—In the exposures on Wagon Timber Branch the Saddle Creek limestone member consists of a single bed of very earthy, tough, unlaminated dark limestone. It is about 8 inches thick and only sparsely fossiliferous, the fossils consisting chiefly of brachiopods and pelecypods. It weathers to rough, porous buff-gray boulders. Farther west from Huffstettle School and in the area near the mouth of Kings Creek, as shown in the above section, there are generally two similar limestone beds in the outcrop. In ordinary exposures they are buff-gray, tough, porous, and earthy. They weather to roundish boulderlike lumps and are seldom found exactly in place. In the cored well on the Graham ranch the horizon of the Saddle Creek is occupied by thick sandstone, and the limestone seems to be absent in the intervening area around the head of Fish Creek, where the Belknap limestone member has been confused with it. Limestone outcropping 2 to 3 miles north of the Nash & Windfohr pool is probably the Saddle Creek.

The following composite section of the Harpersville formation shows the intervals between the principal beds, but the great variability of the sedimentation cannot be indicated in a single section.

Composite section of the Harpersville formation, Donnell ranch, southwestern Young County.

	Thickness Feet	Inches
35. Limestone (Saddle Creek limestone member)	1	
34. Shale, yellowish, limy		6
33. Sandstone, platy, yellowish gray	5	
32. Shale, variegated, in places with coal streaks	18	
31. Sandstone, platy, brownish, soft	34	
30. Shale, variegated	33	
29. Shale, yellowish, limy, fossiliferous	2	
28. Limestone, greenish gray, crystalline, fossiliferous (Belknap limestone member)	1	6
27. Shale	10	
26. Sandstone	2	6
25. Shale, variegated	8	6
24. Sandstone, limy		8
23. Shale	3	6
22. Limestone, lenticular, crinoidal		4
21. Shale	5	
20. Sandstone, yellowish, flaky	1	
19. Clay, gray-white	6	
18. Sandstone, brown, platy, top of channel deposit	4	
17. Shale, gray, sandy	4	
16. Limestone, earthy, and flaky		6
15. Limestone, gray, crystalline, fossiliferous	1	
14. Shale, limy, fossiliferous	4	
13. Shale, carbonaceous	1	
12. Coal and shale	2	

	Thickness Feet	Inches
11. Shale	12	
10. Limestone, buff, fossiliferous ("Upper Crystal Falls limestone")	2	
9. Shale	2	
8. Coal and shale; local development	3	
7. Shale	18	
6. Septaria	1	
5. Shale	4	
4. Limestone, in two benches separated by shale (Crystal Falls limestone member)	4	
3. Shale	18	
2. Limestone ("Cl" bed)	5	
1. Shale, red	15	
Breckenridge limestone member of Thrifty formation.		
	233	

PUEBLO FORMATION

The Pueblo formation includes the beds from the top of the Saddle Creek limestone to the top of the Camp Colorado limestone (Pl. IV).

No opportunity was afforded to check the identity of the Camp Colorado limestone member, and the work of the coöperative mapping committee of the American Association of Petroleum Geologists in correlating this member on Colorado River with the outcrops in Throckmorton County has been accepted. The Pueblo formation as so defined is 207 feet thick on Clear Fork of Brazos River.

Saddle Creek limestone member of Harpersville formation to base of Camp Colorado limestone member of Pueblo formation.—The lower half of the Pueblo formation is distinctly sandy in character, whereas the upper half is predominantly composed of shale. Up to the middle of the formation the sequence continues variable, as in the Harpersville formation, and contains increasing numbers of lenticular sandstone bodies, which are characterless and without notable continuity and in few places as much as 15 feet in thickness. Not uncommonly the topmost layer of the sandstones shows the worn remains of pelecypods, in some places altered by iron carbonate. The limestone beds that are present are only 2 or 3 inches thick, impure, nonfossiliferous, and discontinuous. The shales are variegated and differ in thickness and character.

In this interval there first appears a striking lime conglomerate, found at intervals throughout the rest of the section up to the Coleman Junction limestone member, at the top of the Putnam formation.

The conglomerate consists of pebbles of dense, earthy, nonfossiliferous limestone closely cemented with a matrix of the same material. It is gray, with a greenish cast, and tough and hard to break. The pebbles range from a quarter to half an inch in diameter, and few of them are well rounded. The conglomerate deposits are from 1 to 8 feet thick and from 6 to 100 feet wide. The deposits are flat on top with a convex base and cannot be correlated with one another. It seems probable that they were derived from local beds of the same character—some of which, not more than 3 inches thick, were seen in place—and that they were broken up by wave action and deposited in tidal channels.

In the area half a mile east of Huffstettle School the following section was measured immediately above the Saddle Creek limestone. This section, because of the presence of an impure limestone bed containing crinoid stems, appears to indicate the temporary return of marine conditions near the base of the Pueblo formation. This bed is also present on the ridge northwest of the head of Wagon Timber Branch, as shown on the areal geologic map.

Section of basal part of Pueblo formation near Huffstettle School.

	Thickness	
	Feet	*Inches*
Pueblo formation:		
5. Sandstone, red and brown, in blocks and plates	3	
4. Limestone, sandy and conglomeratic, as if broken and recemented, purplish, very hard; has a few crinoid stems		8
3. Shale, gray	4	
2. Sandstone, brown, massive and platy, unconformable at base on underlying limestone; thickens toward the west	4	
Harpersville formation:		
1. Limestone (Saddle Creek limestone member)		
	11	8

The upper half of the Pueblo formation is composed chiefly of variegated shales, near the top of which are a few thin inconspicuous beds of fine sandstone interstratified with the shale and capped by the Camp Colorado limestone member. The shales present an extraordinary series of colors, including pastel tints of red, pink, purple, lavender, violet, blue, white, gray, and yellowish, in bands from a few inches to several feet thick. Interstratified with them are a few streaks of sandstone measurable in inches and some thin layers of earthy nonfossiliferous limestone and tidal deposits of lime conglomerate. Near the top some plant fossils were found in the shale, associated with a streak of coal not over 1 inch thick.

Camp Colorado limestone member.—The Camp Colorado limestone, where a full section has survived the succeeding erosion, contains several limy fossiliferous beds separated by thin beds of sandy shale. In the road cut near the filling station on the Stephens-Throckmorton County line four fossiliferous beds are present within 11 feet. The two upper beds are limy sandstone, and the two lower beds impure limestone. The entire 11 feet probably represents the Camp Colorado limestone, but in most exposures the upper beds have been cut out, and in some places the entire section is replaced by sandstone.

The following section of the Camp Colorado limestone member was measured on the escarpment half a mile east of the filling station at the point where the Breckenridge-Throckmorton highway crosses the Stephens-Throckmorton County line.

Section showing Camp Colorado limestone member in northwest corner of Stephens County.

	Thickness *Feet*
Moran formation:	
6. Sandstone, massive	12
5. Sandstone, thin bedded and platy, in part limy	1
Pueblo formation:	
4. Limestone, gray, coarsely crystalline in upper part; earthy below, very fossiliferous; weathers smoothish and gray at top and rough, pitted, and yellowish at bottom (Camp Colorado limestone member)	2
3. Shale, yellowish, with thin clay-ironstone partings; upper part limy, with large numbers of Myalinas; lower part with thin sandy partings	15
2. Sandstone, fine grained, flaky	2
1. Shale, carbonaceous	12
	44

The sandstone (beds 5 and 6) at the top of the above section rests directly and unconformably upon the Camp Colorado limestone. In places where the exposures are good, in the drainage basin of Rust's Kings Creek, the limestone is seen to be cut out and the sandstone rests directly on the underlying *Myalina*-bearing shale (bed 3), which in this area is almost everywhere present.

The sandstone is a persistent feature of the section and forms an escarpment stretching across the country, which can be followed where the limestone is locally cut out or concealed.

The following section showing a variation of the Camp Colorado limestone was measured 4¼ miles east of Woodson, in Throckmorton County, 300 yards southeast from a road corner, in a small drain.

Section showing Camp Colorado limestone member four and one-quarter miles east of Woodson, Throckmorton County.

	Thickness Feet	Inches
Moran formation:		
10. Sandstone, brown and iron specked, heavy bedded	11	
9. Clay shale, greenish yellow, with clay-ironstone partings, 6-inch limestone concretions near base, at bottom 1-inch purplish limy shale	13	
8. Shale, yellowish, limy	3	
7. Sandstone, thickening to 9 feet on road 200 yards distant		3
Pueblo formation:		
Camp Colorado limestone member:		
6. Limestone, earthy, brown, fossiliferous, elsewhere cut out by sandstone lens; no Myalinas		2
5. Shale, yellowish, limy, fossiliferous; contains crinoids, Bryozoa, and echinoid spines but no Myalinas	3	
4. Limestone, earthy, brown, fossiliferous		3
3. Shale, yellowish, limy, fossiliferous, with many Myalinas	2	
2. Limestone, earthy, crowded with fossils, including Myalinas		4
1. Shale, yellowish gray	10	6
	43	6

The Camp Colorado limestone (beds 4 to 6 of the above section) is cut out in the exposure on the nearby road by the thickening of the sandstone (bed 7), which there rests on shale carrying Myalinas (bed 3).

The Camp Colorado limestone seems to be represented west of Murray by a very sandy limestone bed carrying chiefly Myalinas and overlain by thick sandstone.

South of Clear Fork the Saddle Creek caps an isolated butte near the railroad track on the Hamm ranch but was seen only in float on the ridge west of Crystal Falls.

The following composite section of the Pueblo formation was measured on the north side of Clear Fork from Huffstettle School west to a butte half a mile east of the county-line filling station on the Breckenridge-Throckmorton highway, where the upper 100 feet of the section was measured.

Composite section of Pueblo formation in southwestern Young County and northwestern Stephens County.

	Thickness Feet	Inches
Moran formation:		
31. Sandstone, gray, massive, in beds 2 to 3 feet thick	6	
Pueblo formation:		
29. Limestone, gray, coarsely crystalline, fossiliferous (Camp Colorado limestone member)	2	
28. Shale, yellowish buff; upper part limy, with Myalinas, lower part with sandstone partings	15	
27. Sandstone, platy, fucoidal, limy; plant fossils	2	
26. Shale, flaky, carbonaceous, with some coal partings	11	
25. Limestone, earthy, brown		2
24. Shale, pinkish purple	28	
23. Shale, pale purple	8	
22. Shale, purplish, grading downward to buff-gray, with sandy partings	14	
21. Limestone, earthy		3
20. Shale, bluish, vivid color	5	
19. Shale, yellowish, weathering bluish along joints	3	6
18. Shale, bluish	2	
17. Shale, yellowish with purplish seams	5	
16. Limestone conglomerate lens, a few hundred feet long, composed of rolled pebbles of limy shale; sandstone nearby at same horizon	2	
15. Shale	7	
14. Limestone, brown, fossiliferous, impure (Stockwether limestone member?)		6
13. Shale, carbonaceous	24	
12. Sandstone, top layer covered with pelecypods, limy	2	
11. Shale	6	
10. Sandstone, platy, replaced in part by limestone conglomerate 8 feet thick	10	
9. Shale	8	
8. Limestone, a concretionary band, nonfossiliferous		6
7. Shale, gray	3	
6. Sandstone, massive; thickens locally to 5 feet and thins within a few hundred feet to thin pebbly nonfossiliferous limestone conglomerate	2	
5. Shale, gray and purplish; in places contains in upper 10 feet four or more bands of gray buff nonfossiliferous earthy limestone lenses 2 to 4 inches thick	16	
4. Sandstone, massive, ferruginous, changing to laminated gray sandstone; in places has small limy		

	Thickness Feet	Inches
pebbles cemented in red-brown limonitic sand; in places dark and calcareous	2	
3. Shale, fissile, lilac-colored, carbonaceous, with yellow limonite partings; upper 3 feet sandy	16	
2. Sandstone, dark, ferruginous, weathering purplish; breaks down to yellowish chips and flakes	3	
1. Not exposed; probably shale	9	
Harpersville formation:		
Saddle Creek limestone member.		
	207	

The Stockwether limestone member of the Colorado River section, which occurs in the middle part of the Pueblo formation, could not be positively identified. It may be represented by a thin brown earthy fossiliferous limestone (bed 14 in the above section) that lies 105 feet below the Camp Colorado limestone and is best exposed in a small drain a mile east of the Breckenridge-Throckmorton highway just north of Clear Fork.

PERMIAN SYSTEM

WICHITA GROUP REDEFINED (BASAL PART)

The Moran and Putnam formations were placed in the Pennsylvanian Cisco group by Plummer and Moore and were formerly so classified by the United States Geological Survey, but the Texas Bureau of Economic Geology now considers them to belong to the Permian Wichita group.[5] They are so included in this report, but the Permian-Pennsylvanian boundary of this region is still a debated question.

MORAN FORMATION

Camp Colorado limestone member of Pueblo formation to Sedwick limestone member of Moran formation.—The Moran formation is 213 feet thick. At its top is the Sedwick limestone member, and at its base is a sandstone deposit, with which some shale is interstratified, resting unconformably upon the underlying Camp Colorado. In some places a few feet of shale rest conformably on

[5]Sellards, E. H., Adkins, W. S., and Plummer, F. B., The Geology of Texas, Vol. I, Stratigraphy: Univ. Tex. Bull. 3232, pp. 140–144, 1932 [1933].

the Camp Colorado below the unconformable sandstone, and this shale, as it lies below the unconformity, should properly be considered a part of the Pueblo formation, but in this area the overlap is negligible (Pl. IV).

The lower half of the Moran formation, like the lower half of the Pueblo formation, contains many thin lenticular sandstone beds, unconformable at their base. The upper part is also similar to the upper part of the Pueblo formation in that it consists very largely of shale. Both parts of the Moran, however, contain numerous fossiliferous limestone beds, which are rare in the Pueblo.

As the basal sandstone deposits of the Moran are underlain by the thick shale section of the Pueblo, they form the top of an escarpment which cuts across the region from southwest to northeast. In the lower 100 feet of the formation there are four or more impure fossiliferous limestone beds from 8 to 18 inches thick, but they are nearly all followed closely by unconformable sandstones, none over 15 feet thick, which cut out the limestones from place to place. As the limestones are all similar in general character and are interrupted along the outcrop they are very difficult to follow and are best identified by their position under the sandstone benches, which can be followed more easily. These limestones are generally gray, in sharp contrast to the limestones in the upper half of the Moran formation, which in places are brilliantly yellow.

The upper 100 feet of the formation consists chiefly of shale interstratified with thin limestones. The shale beds are exposed in few places and, as the limestones are not very resistant, the resulting topography is rolling. The limestones of the upper part of the Moran formation are earthy and fossiliferous and generally dark gray, weathering to rather brilliant yellow or brown, with smoothish surfaces on exposure. They occur at intervals of 20 to 30 feet and form a group that in color is unlike the limestones of any other part of the section.

Sedwick limestone member.—The Sedwick limestone, at the top of the formation, consists of two limestone beds, each about 1 foot thick, separated by 7 feet of shale. These beds, which are similar in texture and color to those below, are distinguished by the presence of silicified fossils, chiefly small gastropods. The lower bed also contains small amounts of diffused chert. Good outcrops of this bed occur on a crossroad south of the schoolhouse $3\frac{1}{2}$ miles west of Woodson, where the bed is repeatedly exposed in and along the road for a distance of $1\frac{1}{2}$ miles.

The following composite section was measured by plane table from the escarpment crossed by the Breckenridge-Throckmorton highway in southeastern Throckmorton County to the vicinity of the school mentioned above. The lower part was measured in the basin of Rust's Kings Creek, southeast of Woodson.

Composite section of Moran formation in southeastern Throckmorton County.

	Thickness	
	Feet	*Inches*
35. Sedwick limestone member:		
Limestone, thin bedded, buff; contains tiny silicified gastropods	1	
Shale, limy	7	
Limestone, dark gray, crystalline, weathering buff and yellowish; contains diffused chert and silicified gastropods; other fossils include numerous Myalinas	1	
34. Not exposed; probably shale	21	
33. Limestone, drab to gray, weathering buff, with rough pitted surface, nonfossiliferous	1	
32. Not exposed; probably shale	23	
31. Limestone, medium crystalline; color varies from light gray to dark brown and chocolate-brown, weathering to smooth yellowish surface; upper part has finer texture and no fossils; lower part laminated and fossiliferous	1	
30. Shale	30	
29. Limestone, earthy and sandy, fossiliferous; locally carries Myalinas		6
28. Not exposed; probably shale	3	
27. Limestone, dense, crystalline, very dark, weathering to drab, gray, buff, bright yellow, or brown, fossiliferous	1	
26. Not exposed; probably gray shale	6	
25. Sandy shale, with macerated leaf fragments, in places 10 feet or more thick; apparently cutting into underlying sandstone	6	
24. Sandstone plates and soft sandy shale in bands with small tidal channels filled with sandstone every hundred yards along road cuts	9	
23. Not exposed; probably sandy shale	17	
22. Sandstone, thick bedded and cross-bedded; contains lenses of conglomerate of earthy nonfossiliferous limestone; 20 feet or less in thickness; where thick, the beds below are cut out	13	
21. Shale, yellowish, limy, capped with residual lumps of leached buff, earthy nonfossiliferous limestone; thickness varies	3	

	Thickness Feet	Thickness Inches
20. Limestone, crystalline, fossiliferous, gray to brown, weathering away easily; basal part earthy and sandy		6
19. Not exposed; probably shale	3	
18. Sandstone, hard, limy, and ripple-marked; this bed is more persistent locally than the associated limestones; the thickness is as much as 3 feet or more; it usually forms a bench	1	
17. Sandstone, limy, in plates and flakes	3	
16. Limestone, crystalline, gray, brown, and yellow; in places this bed is grainy and pebbly and contains broken fossils; discontinuous	1	6
15. Shale, yellowish, gray, weathered	6	
14. Not exposed; probably shale	5	
13. Red shale	8	
12. Clay shale, bluish drab	8	
11. Sandstone, flaky, bleached white	2	
10. Sandstone, platy, specked with ironstone		6
9. Not exposed	7	6
8. Limestone, impure, fossiliferous		6
7. Not exposed	11	
6. Limestone, earthy, platy, fossiliferous		6
5. Sandstone, reddish; forms a bench	2	
4. Not exposed	9	
3. Sandstone, in plates 1 to 3 inches thick	1	
2. Sandstone, shaly	1	
1. Sandstone, in plates 6 inches thick	1	
Camp Colorado limestone member of Pueblo formation.		
	215	6

A series of tidal channels filled with sandstone are exposed in successive road cuts along the highway 1½ miles southeast of Woodson.

PUTNAM FORMATION

Sedwick limestone member of Moran formation to Coleman Junction limestone member of Putnam formation.—The identification of the Coleman Junction limestone member—the top of the Putnam formation—by the coöperative mapping committee of the American Association of Petroleum Geologists is herein accepted. (See Pl. IV.) In southwestern Throckmorton County the Putnam formation is 205 feet thick. Practically the whole of the section is shale, though the lower part, which crops out under the outwash at the base of the Coleman Junction escarpment, was not seen. The shale is for the most part mildly variegated in color, and in the upper 50 feet there are some thin, inconspicuous sheets of fine-grained sandstone involved with irregularities of deposition that suggest contemporaneous erosion.

At 51 feet below the Coleman Junction limestone there is a bed of very earthy limestone about 1 foot thick, which carries a gastropod fauna. This bed was noted north of the point where the highway west from Woodson crosses the escarpment. It is discontinuous and seems to have been eroded and replaced locally by a thin deposit of red shaly sandstone, which elsewhere lies immediately above it.

Coleman Junction limestone member.—The Coleman Junction limestone member in southern Throckmorton County is only 15 inches thick. It is dark and fine textured, weathers to dark gray, yellow, or chocolate-brown, and is fossiliferous, though collecting is difficult, for it is resistant to erosion and weathering. Its resistance, combined with its position above the thick shale section of the Putnam formation below, results in a strong escarpment, the most prominent topographic feature of the county, striking across the region from southwest to northeast.

The following composite section was measured along the road west from Woodson in Throckmorton County:

Composite section of Putnam formation west of Woodson, Throckmorton County.

	Thickness Feet	Inches
30. Coleman Junction limestone member	1	3
29. Shale	5	
28. Sandy limestone, smooth textured, gray, nonfossiliferous, weathering to fine sandstone	1	
27. Shale, weathered	19	
26. Shale, limy, yellowish, gray, and greenish	20	
25. Shale, red	2	
24. Earthy limestone, weathered to leached red crusts, nonfossiliferous		6
23. Sandstone, red, flaky		6
22. Shale	2	
21. Limestone, earthy, dense, greenish, weathering to leached brown porous lumps, fossiliferous, containing especially gastropods	1	
20. Shale, red and brown	1	
19. Sandy shale, greenish	3	
18. Sandstone, fine grained, greenish	1	
17. Shale, greenish	5	6
16. Shale, limy, forming a band		3
15. Shale, greenish	1	
14. Shale, purplish and gray	3	6
13. Clay, with small chalky concretions where weathered	1	
12. Shale, brown, coaly, with purple and yellow partings	1	

	Thickness Feet	Inches
11. Shale, bluish, coaly, brown partings	1	6
10. Clay shale, olive-green	3	
9. Shale, fissile, bluish and brownish, coaly	3	
8. Not exposed; probably shale	47	
7. Sandstone, soft, reddish gray	1	
6. Sandstone, limy, in flakes and plates	1	
5. Not exposed; probably shale	15	
4. Limestone conglomerate, composed of small pebbles, nonfossiliferous earthy limestone, lenticular	1	
3. Shale, limy, bluish gray	3	
2. Sandstone, limy, greenish; weathers to flaky laminae	3	
1. Not exposed; probably shale; local deposits of limestone conglomerate near base	57	
Sedwick limestone member of Moran formation.		
	205	

SUMMARY OF FORMATIONS

The following list shows the thickness of formations measured along Brazos River in Young, Stephens, and Throckmorton counties. Unconformities are indicated only where they occur between the formations. Details of the sedimentation are shown in the columnar section (Pl. IV).

Thickness of formations along Brazos River in Young, Stephens, and Throckmorton counties.

	Feet
Permian system:	
Wichita group redefined (basal part) (418 feet):	
Putnam formation	205
Moran formation	213
Unconformity.	
Pennsylvanian system:	
Cisco group restricted (1148 feet):	
Pueblo formation	207
Unconformity.	
Harpersville formation	233
Thrifty formation (top of Breckenridge limestone to top of No. 9b limestone of Wayland shale)	151
Unconformity and overlap.	
Graham formation (top of No. 9b limestone of Wayland shale member to base of Salem School limestone member)	557
Unconformity.	
Canyon group in part (161 feet):	
Caddo Creek formation (base of Salem School limestone to top of Ranger limestone member)	161
	1727

DEPOSITIONAL CYCLES

In the many depositional cycles seen in the Cisco group there does not seem to be anything systematic in the sequence of deposits beyond that ordinarily to be expected where an eroded area changes from a land area to a marine basin and back again. Only to the extent that the first deposits on the eroded surfaces are usually but not invariably sandstone and that this is usually followed by the return of marine conditions is there any orderly sequence of beds in the cycles of deposition.

A skeleton outline of the sequence of deposition for the most distinct cycles is given below, the beds in each cycle being arranged in chronologic order from the top down. All the cycles except the first are interrupted at the top by erosion surfaces, the later beds of each cycle having been removed. The sequence in the Kisinger cycle is the most nearly complete noted.

Kisinger channel cycle:

6. Fossiliferous shale.
5. Black shale, gypsiferous.
4. Fossiliferous limestone (Salem School limestone).
3. Fossiliferous shale (thin).
2. Sandy shale, coaly in places (macerated leaf fragments).
1. Conglomeratic sandstone.

Post-Bunger No. 1 cycle:

4. Fossiliferous limestone.
3. Sandy shale and thin sandstone streaks with macerated plant fragments.
2. Fossiliferous limy sandstone.
1. Conglomeratic sandstone.

Post-Bunger No. 2 cycle:

2. Clay shale.
1. Conglomeratic sandstone.

Post-Bunger No. 6 cycle:

4. Limestone, sparingly fossiliferous.
3. Lenticular sandstones and sandy shale.
2. Sandy fossiliferous limestone and coral bed.
1. Sandstone (conglomeratic in center of channel).

Post-Bunger No. 9 cycle (including Wayland shale):

6. Fossiliferous limestone (No. 9b limestone).
5. Nonfossiliferous clay shale (with fossiliferous limestone lentil).
4. Fossiliferous shale.
3. Fossiliferous limestone (No. 9 limestone).
2. Sandy shale, macerated plant fragments, in places almost coaly.
1. Conglomerate with limestone and chert pebbles derived from local sources (thin, probably a buried stream gravel).

Beds 3 to 6 in the above cycle are Wayland shale. Beds 1 and 2 are channel deposits.

The orderly recurrence of beds in the cyclothems of the interior basins recognized by Weller, Wanless, Moore, and others was not observed in the cycles of this area. The fluctuations of sea level here seem to have been too violent and too frequent and sedimentation too erratic to leave a record of rhythmic deposition. It is probable that in some cycles, as the No. 2 cycle, the advance of the sea was only partial and the region was reelevated before the return of marine conditions. In the No. 1 and No. 6 cycles repetitions of marine limestone appear to have taken place before the following reexposure. In the No. 9 cycle there were three distinct marine limestones but the intervening nonfossiliferous shale may also be marine.

GEOLOGIC HISTORY

The total thickness of the strata from the Salem School limestone in southeastern Young County to the top of the Coleman Junction limestone in southern Throckmorton County is 1556 feet. This figure, of course, does not include overlapping unconformable deposits or channel deposits, which in the aggregate amount to several hundred feet. It is evident that the period during which the sediments were laid down was much longer than that indicated by the present thickness of the strata, for much time is represented by deposition of beds later eroded, by erosion, and by redeposition, although the simple channels, even when deep, represent relatively short intervals of time. The periods in which general erosion took place, as during the No. 1, No. 3, No. 7, and No. 9 post-Bunger cycles of the Graham formation, the pre-Avis and post-Avis cycles of the Thrifty, and perhaps an erosion period below the Saddle Creek, were undoubtedly of considerable duration.

The history of the region was one of frequent and at times extensive withdrawals of the sea. These oscillations, as shown by the conglomeratic deposits of the Canyon group in Palo Pinto County, had been going on for a long time before the Cisco epoch. These deposits not only represent withdrawal of the sea from the area but also reelevation of the Ouachita Mountains and their extension, from which the great quantities of chert were derived. The fact that the highest cherty conglomerates of the section occur in the upper part of the Harpersville formation indicates that the Ouachita Mountains were still being elevated up to that time.

Using the thickness of the sedimentary rocks as a rude time gage, it may be said that the fluctuations of sea level were intermittent in the early part of the Graham epoch and became increasingly more frequent and pronounced toward its end. In its final stage there was a period of stability during the deposition of the Wayland shale.

This sedimentation was followed by extensive withdrawals of the sea both before and after the Avis epoch, in early Thrifty time, and by relatively quiet conditions during the deposition of the late Thrifty beds, though the presence of the stump of a tree in place in the upper part of the formation indicates that oscillation was still going on, though not expressed by obvious unconformity. The Harpersville formation began at a time of moderate fluctuation, during which there were brief conditions favorable to the formation of coal, but the deposition of the Newcastle coal was followed by at least one notable withdrawal of the sea, during which there was extensive erosion and the final deposition in this area of conglomeratic sandstone. Oscillation of sea level continued during the early part of the Pueblo epoch, and this area was apparently near the shore line, which, though fluctuating, remained relatively constant in position. Although there was considerable oscillation of a minor character, with erosion, which locally removed thin limestones and other beds during early Pueblo time, none of these periods of erosion seem to have cut very deeply into the deposits, and there are no thick beds of sandstone or conglomerate.

During the later part of Pueblo time conditions were again relatively more stable, but during early Moran time conditions favorable to limestone deposition alternated with conditions during which erosion of the limestones was followed by the deposition of sandstone.

In later Moran time and during Putnam time, now considered to be Permian by the Texas Bureau of Economic Geology, the sediments were deposited under more stable and quiet conditions than during any part of the Cisco epoch. These deposits, which consist of thick shale beds and thin yellow limestones, show scarcely any evidence of near-shore deposition, though lenticular deposits of nonfossiliferous lime conglomerate occur at intervals in what appear to be tidal channels.

As regards diastrophism, evidences of oscillation of sea and land are relatively few in the lower Graham, but sea withdrawals became more frequent in late Graham time, with increasingly violent expression up to the erosion period that followed the deposition of the Avis sandstone. After this event there was relative quiet, the oscillations increasing again through the Harpersville epoch and declining in violence to middle Pueblo time. Late Pueblo time was a period of quiet, but during early Moran time disturbances of a minor character were again recorded, and through late Moran and Putnam time static conditions prevailed.

The diastrophic division points, as indicated in the Brazos Valley, would seem to be at the close of the No. 8 post-Bunger cycle, at the top of the Avis, in the middle of the Pueblo, and in the middle of the Moran, each point recording in this area a cessation of active oscillatory movements.

It is worthy of comment that the greatest change in the fusulinids occurs between post-Bunger cycles No. 8 and No. 9, *i.e.*, just prior to the Wayland shale. Seven (perhaps nine) of the seventeen species of fusulinids recognized in the collections from the Cisco first appear in the Wayland shale and four species present in older beds of the Cisco are not found in the Wayland shale or higher beds. (See chart of Lloyd G. Henbest in another part of this report.) This member of the Graham formation and the underlying shales rest on one of the most maturely dissected and deeply eroded surfaces in the Cisco group and this fact together with the introduction of so many new fusulinids in this member indicates important changes and a longer than usual interruption between the cycles.

ECONOMIC APPLICATION OF RESULTS

There has been heretofore much confusion in the correlation of the discontinuous outcrops of the thin limestone beds in southern Young County and adjoining areas. The determination of the relative position of the limestone beds in the stratigraphic column should make possible the working out of structure in some areas in which the folding has heretofore been obscure. It should be possible also to add to the available datum planes used in determining structure, the tops of some of the sandstone deposits, though on account of the numerous unconformities that occur it will be necessary to proceed with considerable caution in their use, for not all are of equal value as datum planes. In order to use a sandstone it will be necessary to make sure that its top has not been eroded. Where a sandstone is overlain conformably by shale and a sharp break in sedimentation occurs, as at the top of the sandstone of the No. 2 post-Bunger cycle, the contact is valuable as a datum but the top of the sandstone that overlies the Gonzales limestone is not a good datum, for it grades into the overlying shale with interbedded sandstones so that its top is indefinite and cannot be identified from place to place.

The recognition of the various types of sand bodies should contribute materially to their understanding where they are encountered by the drill in oil pools. The development of an oil pool in a lenticular sand deposit of the channel type would proceed rather differently from that of a pool in sand of the sheet type. The recognition of the nature of these sand bodies may help to explain the eccentricities of some oil pools and hence aid in their economic development.

The presence of gas in the Shell (Roxana)-Jacob Whittenburg survey A-1860 No. 1 well in the sandstone of the Kisinger channel, noted by Lloyd E. Wells in the course of his work in the Bunger pool, though not important in itself, shows that such channel deposits under favorable structural conditions may furnish traps for the accumulation of oil and gas.

Perhaps the most significant discovery is the extraordinary relief at the base of the beds of the No. 9 post-Bunger cycle of erosion. This surface, which has a relief of not less than 200 feet, formed a range of hills now exposed north and northeast of Graham, capped by a group of limestones here named the Rocky Mound limestone member. The Wayland shale originally overlapped on this range of hills but was later partly eroded where it had been deposited over the crest. The buried ridge with its flanking deposits of shale was later covered by Avis sandstone and still later sealed by the deposition of late Thrifty shales. This limestone-capped buried ridge and its overlying and flanking sandstone where deeply enough buried would present conditions favorable to the accumulation of oil, in somewhat the same way as buried reefs. The differential compaction on the flanks of the ridge may have produced arching over the crests of the ridge, and the sandstone overlying it and the ancient weathered limestone itself might provide adequate porosity for the accumulation of migrating oil.

Although no work has been done on the problem, there is reason to suspect that some of the pools of Archer County and northern Young County occur where the structure is of this type. The recognition of the actual conditions should result in more economical development of established pools and the development of extensions from the subsurface data now available.

STRATIGRAPHY OF THE CANYON AND CISCO GROUPS ON COLORADO RIVER IN BROWN AND COLEMAN COUNTIES, TEXAS

C. O. NICKELL[1]

PENNSYLVANIAN SYSTEM

STRAWN GROUP

MINERAL WELLS FORMATION

The base of the Canyon group in the Brazos River valley, where it was first described by Cummins in 1891, is the base of the Palo Pinto limestone. Neither this limestone nor its horizon has yet been fully identified in the Colorado River valley, so that the exact base of the Canyon group and top of the Strawn group in that area are still in doubt. The Palo Pinto limestone has at various times been correlated with the Capps limestone and higher

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[1]Since the field work of this report was completed by C. O. Nickell in Brown and Coleman counties a similar section by Dr. Fred M. Bullard and Dr. Robert H. Cuyler of The University of Texas has been published for McCulloch County, Texas, south of Colorado River (Upper Pennsylvanian and lower Permian section of Colorado River valley, Texas: Univ. Texas Bull. 3501, p. 191, 1935 [1936]. Some differences appear in the measured sections of the two reports. Since the maps join at Colorado River it is possible to compare the beds as mapped where they cross. It thus appears that the Home Creek, Ranger, and "Cherty limestone" of Nickell's report are the same respectively as Bunger, Home Creek, and Ranger limestone of Bullard and Cuyler, a conflict anticipated and fully explained in the Nickell text.

A discrepancy in thickness occurs between the top of the Winchell formation and the top of Plummer and Moore's Home Creek (the Bunger of Bullard and Cuyler), the corresponding beds of Bullard and Cuyler's section being over 100 feet thicker than Nickell's for this interval. Wells on the Gill ranch starting just above the outcrop of the Home Creek north of the river show the interval from the top of this bed to the base of the Adams Branch as 400 and 410 feet. The same interval in the measured sections of Bullard and Cuyler is 392 feet and only 305 feet in the Nickell section. The latter section is therefore in error by this difference. The error is cumulative, the greater part, however, occurring in the shale section of the Brad formation. It is perhaps due to slumping of the rim rocks in the bluff sections of Colorado River where the component sections were measured or to errors introduced in the compilation of Nickell's notes.

Another discrepancy appears in the interval between the Chaffin limestone and the Gunsight limestone which Nickell found to be 260 feet but Bullard and Cuyler only 190 feet. In this case two wells, Humphreys Bros. No. 1 Floyd and Rutherford No. 1, drilled 2 miles and 2½ miles respectively west of Whon support Nickell. These wells starting just below the outcrop of the Chaffin or Breckenridge limestone found the interval to be slightly in excess of 260 feet to the top of the Gunsight. The log of the Floyd well shows the Speck Mountain and *Bellerophon* beds below the Chaffin. Nickell has traced both these beds across the area to Colorado River, where at the type locality they are below the Chaffin limestone correlated with the Breckenridge. No mention is made of the *Bellerophon* bed south of the beds. Cheney,[2] in 1932, suggested the correlation of the Palo Pinto with a thin yellow limestone 100 feet above the Capps limestone.[3] This change in correlation, of course, augments the thickness of the Strawn, throwing into that group the Capps limestone and a considerable part of the shale that was formerly included in the lower part of the Graford formation when the horizon of the Palo Pinto limestone was considered to be below these beds. The Capps limestone is here treated as a member of the Mineral Wells formation, the upper formation of the Strawn group. The older Ricker sandstone is also a member of the Mineral Wells formation.

Ricker sandstone member.—The Ricker member is composed of sandstone and conglomerate, and is undoubtedly an unconformable deposit laid down after one of the periods of erosion that were so frequent in Pennsylvanian time in this region. It was named by Drake for a post office east of Brownwood and is shown at the base of the section measured near Brownwood. This bed corresponds closely in position with a sandstone bed in the section measured by R. T. Hill 10 miles farther north, but toward the south the conglomerate bed at the mouth of Clear Creek (bed 13 of the Winchell section, p. 99), identified by Drake as the Ricker, seems to be considerably higher in the section. (See fig. 6.)

On State highway No. 7, 6 miles east of Brownwood, near the type locality, the Ricker member consists of 6 feet of conglomerate and an estimated thickness of 20 feet of sandstone beneath it. The conglomerate is irregularly stratified, coarse sandstone and conglomerate grading upward into brown sandstone. It contains some dense, hard, fossiliferous limestone pebbles 3 inches or less

river and though conspicuous north of the river it may be absent or obscure there. The outcrop of the *Bellerophon* bed so mapped north of the river seems to be at the approximate horizon of the Speck Mountain limestone shown south of the river.

Above the Chaffin limestone the sections are essentially in accord as to thickness. Nickell, however, accepted the identification of the coöperative mapping committee of the American Petroleum Geologists of the Sedwick and Horse Creek limestones in Coleman County. These two beds are mapped south of the river by Bullard and Cuyler as Hardin School limestone and Sedwick limestone respectively. The intervals, however, are the same, though there may be some doubt as to which is the Sedwick limestone.—*Wallace Lee.*

[2]Sellards, E. H., Adkins, W. S., and Plummer, F. B., The Geology of Texas, Vol. I, Stratigraphy: Univ. Texas Bull. 3232, p. 110, 1932 [1933].

[3]Plummer, F. B., in a letter to Wallace Lee dated May 28, 1935, indicates that unpublished data tend to show that the Adams Branch limestone may ultimately be correlated with one of the members of the Palo Pinto limestone, but this information was not available during the writing of the present report.

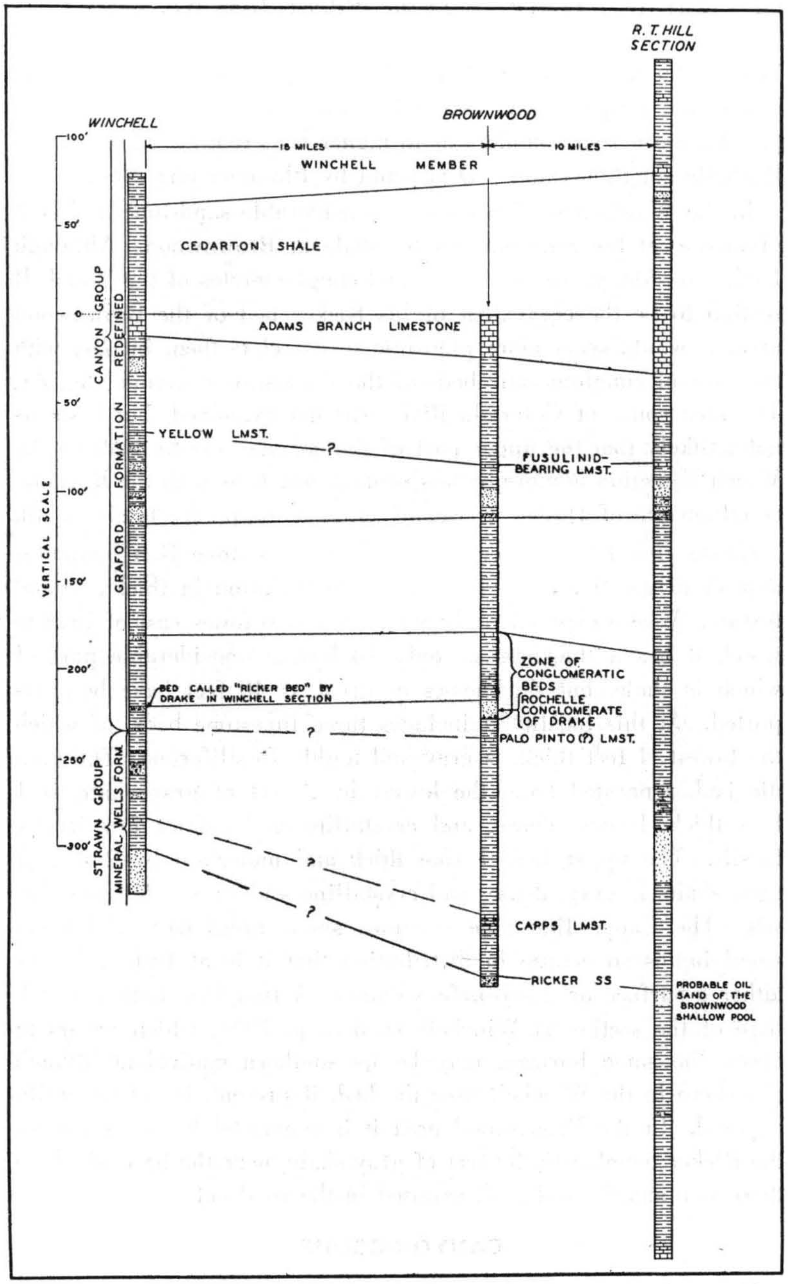

Fig. 6. Comparison of measured sections of lower part of Graford formation (redefined) and upper part of Strawn group in Brown County, Texas.

in diameter and many small pebbles of chert—red, brown, yellowish, white, purple, gray, and a few black and green. The green pebbles are not so abundant as in higher beds that have been called Rochelle conglomerate by Drake and by Plummer and Moore.

In the Winchell section there is considerable sandstone and conglomerate at horizons marked by shale at Brownwood. Although Drake considered the sandstones and conglomerates of the Winchell section to be the equivalent of his Ricker bed of the Brownwood area, it would seem more plausible to correlate them in part with the zone of conglomeratic beds of the Brownwood section (fig. 6). The area south of Colorado River was not examined, but it seems not unlikely that the upper part of the coarsely clastic beds in the Winchell section is more or less contemporaneous with the Rochelle conglomerate of Drake, whose principal outcrops are to the south.

Capps limestone member.—The Capps limestone is a lenticular deposit of small area and considerable variation in thickness and texture. Where exposed on highway No. 7, 6 miles east of Brownwood, it has a thickness of only 10 feet, a considerable part of which is shale, but thicknesses as great as 40 feet have been reported. At this locality it includes three limestone beds, of which the lowest, 4 feet thick, is gray and highly fossiliferous. The middle bed, separated from the lowest by 2 feet of gray shale, is 1 foot thick, brown, dense, and crystalline and carries few if any fossils. The upper bed, 1 foot thick and underlain by 2 feet of gray shale, is gray, dense, and crystalline and carries but few fossils. The Capps limestone occupies small areas east of Brownwood but is so erratic in distribution that it is of little value as either a surface or a subsurface datum. A thin limestone near the base of the section at Winchell (bed 3, p. 100), which occurs at about the same horizon, may be its southern equivalent, though elsewhere in the Winchell area the bed, if present, is not generally exposed. In the Brownwood area it is separated from the top of the Ricker member by 30 feet of gray shale, near the base of which there is a small coral reef, exposed in the road cut.

CANYON GROUP

The following table shows the subdivisions of the Canyon group in the Colorado River Basin as presented by Plummer and Moore in 1921 and more recently by Sellards, Adkins, and Plummer in 1933. The descriptions of the formations that follow are based chiefly on the divisions indicated in the later report.

Plummer and Moore[4]	Sellards, Adkins, and Plummer[5]
Canyon group:	Canyon group:
Caddo Creek formation:	Caddo Creek formation:
Home Creek limestone member.	Home Creek limestone member.
Hog Creek shale member.	Hog Creek shale member.
Brad formation:	Brad formation.
Ranger limestone member.	Ranger limestone member.
Placid shale member.	Placid shale member.
	Graford formation:
Clear Creek limestone member [and Adams Branch limestone member of Palo Pinto County].	Merriman limestone member (formerly Clear Creek).
Cedarton shale member.	Cedarton shale member.
Graford formation:	
Adams Branch limestone member.	Adams Branch limestone member.
Brownwood shale.	Brownwood shale member [restricted].
	Palo Pinto formation.
	Strawn group:
	Mineral Wells formation:
Shale.	Shale.
Capps limestone lentil.	Capps limestone member.
	Shale.
Rochelle conglomerate.	Ricker sandstone member.
Palo Pinto limestone (not present).	
Strawn group.	

PALO PINTO FORMATION

The Palo Pinto formation whose type locality is in Palo Pinto County in the Brazos Basin, is the lowest formation of the Canyon group. Its exact equivalent in the Colorado River Basin has not yet been determined with complete satisfaction. For purposes of discussion, Cheney's provisional identification is herein accepted with the realization that further revision will probably be necessary. The bed of limestone correlated by Cheney with the Palo Pinto lies 221 feet below the top of the Adams Branch limestone in the Brownwood area. It has a thickness of about 1 foot and is dense in texture and yellowish in color.

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[4]Plummer, F. B., and Moore, R. C., Stratigraphy of the Pennsylvanian formations of north-central Texas: Univ. Texas Bull. 2132, 1921.

[5]Sellards, E. H., Adkins, W. S., and Plummer, F. B., The Geology of Texas, Vol. I, Stratigraphy: Univ. Texas Bull, 3232, 1932 [1933].

GRAFORD FORMATION REDEFINED

The Graford formation as originally defined by Plummer and Moore in the Brazos River valley, its type area, consists of all the strata from the top of the Palo Pinto limestone up to the top of the Adams Branch limestone as identified in that area. The so-called "Adams Branch limestone" of the Brazos River valley, however, was later reported by Cheney[6] to be a higher limestone and the same as Drake's Clear Creek limestone of the Colorado River section, and also the same as Reeves' Merriman limestone member in the Ranger district, intermediate between Palo Pinto and Brown counties. In order to make the Graford formation of the Colorado River section conform to that of the type locality, in the Brazos River region, the top of the Graford as previously drawn in the Colorado River Basin was raised by Sellards, Adkins, and Plummer[7] to the top of the Clear Creek limestone of Drake, and the term "Adams Branch" was abandoned in the north, on account of its double use. "Clear Creek" was also abandoned by them, because the name was preëmpted, and the term "Merriman limestone" was expanded and used as a substitute. The limestone zone under discussion is, however, decidedly variable, being in some places a thick limestone bed and in others broken by shale partings. As defined in the Ranger district the Merriman limestone of Reeves consists of a single 4-foot bed of limestone. On Colorado River the Clear Creek of Drake consists of two limestone beds, and in Palo Pinto County the beds used as the top member of the Graford formation consist of several prominent limestone beds separated by shale. The Clear Creek limestone of Drake, who introduced the name, consists of two limestone beds separated by shale, the upper weathering yellowish or brownish. As so defined, it contains only the two lowest of a group of four limestone beds that appear to thicken and coalesce in central Coleman County, where the limestone is nearly solid and is more than 100 feet thick, as shown in logs of wells only 15 to 20 miles distant from the type locality.

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[6]Cheney, M. G., Stratigraphic and structural studies in north-central Texas: Univ. Texas Bull. 2913, p. 19, 1929.

[7]Sellards, E. H., Adkins, W. S., and Plummer, F. B., The Geology of Texas, Vol. I, Stratigraphy: Univ. Texas Bull. 3232, p. 111, 1932 [1933].

In view of the fact that doubt exists as to the exact relations of the Clear Creek limestone of Drake on the south to the thick group of limestones on the north and to the single 4-foot bed in the Ranger district, midway between, and as the Clear Creek itself, a definite unit, is only a part of the limestone group whose members thicken down the dip and tend to coalesce, the name "Merriman" seems undesirable for this member. It is proposed, therefore, to include under the name "Winchell member" the group of limestones, in places separated by shales, occurring between the Cedarton shale member and the shale underlying the Ranger limestone member, which was included in the Placid shale of Plummer and Moore, and to consider the Winchell as the uppermost member of the Graford formation in the Colorado River region. The upper member of the Graford in Palo Pinto County and the Brazos Valley consists of similar deposits, including a group of limestone beds that thicken and thin, with shale beds of varying thickness between them. To draw the division line between the Graford and Brad formations at the top of this group of limestones probably makes a closer approach to the point of division between these formations in the Brazos Valley than to draw it at the top of the Clear Creek and consequently is more in keeping with the originally proposed limits of these formations.

The interval from the top of the Palo Pinto limestone of Cheney to the top of the Winchell member, an interval which may ultimately be found to include parts of the Palo Pinto of other areas, is 357 feet. It will be convenient to refer to the Winchell member and the Cedarton shale member (136 feet thick) as the upper part of the Graford and to the Adams Branch limestone and the underlying shale (221 feet thick) as the lower part of the Graford formation. The following composite section of the lower part of the Graford was measured in the Brownwood area in central Brown County, the intervals between conspicuous beds not superposed in the topography being determined by plane-table projections.

Composite section, in the Brownwood area, of lower part of Graford formation and upper part of Strawn group down to Ricker sandstone member.

	Thickness Feet	Inches
Canyon group:		
Graford formation:		
25. Adams Branch limestone member (221 feet to Palo Pinto of Cheney): Limestone, hard, crystalline, chiefly gray, fossiliferous	24	
24. Shale, light colored	2	
23. Shale, red to purple	2	6
22. Sandstone, light colored, soft	1	
21. Shale, red to purple	1	6
20. Sandstone		6
19. Shale, gray, weathering yellowish, some red and purple; streaks of light colored sandstone 6 to 18 inches thick near top	46	6
18. Limestone, with fusulinids		6
17. Shale, gray	12	
16. Sandstone, buff to brown, soft, massive; has sandy shale parting in lower part	11	
15. Shale, greenish gray, with stringers of brown sandstone 1 to 3 inches thick	6	
14. Sandstone, limy, brown, hard, fucoidal markings		8
13. Shale, greenish gray, soft	64	
Zone of conglomeratic limestone beds (38 feet):		
12. Limestone conglomerate and sandy lime, exposed on old Coleman road south of old brick plant	2	
11. Shale, gray	23	
10. Limestone conglomerate, exposed in southern part of Brownwood near shallow oil pool	1	
9. Shale, gray	4	
8. Limestone	1	
7. Sandstone and sandy shale, cross-bedded, exposed at shale pit of Texas Brick & Tile Company	6	
6. Gravel conglomerate, with some limestone pebbles	1	
5. Shale, gray	11	
4. Palo Pinto limestone of Cheney (limestone, yellow, dense)	1	
Strawn group:		
Mineral Wells formation:		
3. Shale, greenish gray, in part fossiliferous	111	
2. Capps limestone member (10 feet):		
Limestone, gray, crystalline, fossiliferous	1	
Shale, gray	2	
Limestone, brown, crystalline	1	
Shale, gray	2	
Limestone, contains many corals	4	
1. Shale, gray	30	
Ricker sandstone member.		
	373	2

The following composite section of the lower part of the Graford formation was measured in the Winchell area near Colorado River.

Composite section of lower part of Graford formation in Winchell area, Brown County.

	Thickness *Feet*	*Inches*
Graford formation:		
Adams Branch limestone member (225 feet to approximate horizon? of Palo Pinto limestone of Cheney):		
41. Limestone, gray, bedded, fossiliferous	11	
Shale member (214 feet to approximate horizon? of Palo Pinto):		
40. Sandstone, gray, soft	1	
39. Shale, gray	12	
38. Sandstone, soft, brown	2	
37. Shale gray	1	
36. Sandstone, soft, yellow, about 1 foot of conglomerate at the base	6	
35. Shale, gray, some red and purple in upper part	34	
34. Limestone, yellow, crystalline, fossiliferous in parts	1	
33. Shale, gray, with some red and purple	6	
32. Sandstone, gray, soft, bedded	3	
31. Shale, gray, some purple, some parts sandy	6	
30. Sandstone, gray, soft, cross-bedded	5	
29. Shale, gray, some red at top	12	
28. Sandstone, gray, soft, part cross-bedded	3	
27. Shale, gray, sandy	3	
26. Sandstone, gray, soft, cross-bedded	8	
25. Shale, gray, with clay-ironstone bands in upper and lower parts; near middle some blue shale with small plant fragments	44	
24. Limestone, fossiliferous		6
23. Shale, gray, fossiliferous	8	
22. Shale, limy, fossiliferous		6
21. Shale, gray	7	
20. Limestone, nodular, yellow, fossiliferous		6
19. Shale, limy		6
18. Shale, gray	3	
17. Sandy lime, fossiliferous	3	
16. Sandy shale, gray	2	
15. Shale, blue, fossiliferous	6	
14. Shale, covered	23	
13. Cherty gravel conglomerate	3	
12. Shale, gray to greenish gray	10	
11. Sandstone (approximate horizon? of Palo Pinto limestone of Cheney)		6
Strawn group:		
10. Shale, gray to greenish gray	15	
9. Gravel conglomerate, not so much chert as that above or below, some purple, some fossils	1	
8. Shale	6	
7. Sandstone, brown, and cherty gravel conglomerate; most pebbles half an inch or smaller in diameter,		

	Thickness Feet	Inches
some as much as 2 inches; some green pebbles but brown and white predominant	7	
6. Shale and sandy shale	10	
5. Sandstone, white, soft, massive; some ripple marks	3	
4. Shale	12	
3. Limestone, very fossiliferous (Capps? limestone member)	1	
2. Shale, gray, sandy; weathers yellow	17	
1. Sandstone, soft, brown, in creek bed	30	
	327	6

The sections measured at Brownwood and Winchell are compared with the hithereto unpublished section measured by R. T. Hill 10 miles north of Brownwood, given by Mr. Hill's permission in figure 6. As Winchell is 18 miles southwest of Brownwood, the cross-section has a spread of 28 miles. Several thin limestones are omitted from the sections.

LOWER PART OF THE GRAFORD FORMATION

Lower shale member.—The base of the Graford formation is tentatively considered to be at the top of the thin limestone which Cheney has provisionally correlated with the Palo Pinto limestone. The character of its beds below the Adams Branch limestone is shown in the preceding sections measured at Brownwood and Winchell and in the accompanying graphic section (fig. 6). In the Brownwood section, in the basal part of the lower shale member, there is a zone of conglomeratic beds (beds 6 to 12), 38 feet thick, whose top is 172 feet below the top of the Adams Branch limestone. These conglomeratic beds are thin and seem to represent unconformities of no great magnitude in this locality. The upper two beds (10 and 12) consist of broken and eroded fragments of limestone and are the remains of earlier, probably thin limestone beds at approximately the same horizon. The lowest conglomerate bed (bed 6) contains limestone pebbles in a thin chert conglomerate and is overlain by 6 feet of sandstone. These beds suggest that the locality was at the time a marginal area where the advance and retreat of the sea alternately caused deposition and erosion of limestone beds. It is probable that landward, where relief caused by retreat of the sea was greater, the same movements may have caused greater erosion and more pronounced unconformity.

Eleven feet below the lowest of these conglomerates (bed 6 of the Brownwood section) is the thin bed of yellow dense limestone that has been provisionally correlated by Cheney with the Palo Pinto limestone of the Brazos Basin. It is not strikingly different from the partly eroded limestones above, and they may all belong to a group representing the fingering out of the Palo Pinto limestone toward the Central Mineral region, on whose flanks the eroded pre-Pennsylvanian surface was still not completely covered by the deposits of the Pennsylvanian seas. With the possible exception of the highest of these limestones (bed 12) they are not represented in the Winchell section, their place being occupied by a series of erratic sandstone beds which extend down to the horizon of the Ricker bed as identified by Drake in the Brownwood area.

The sandstone and basal chert and limestone conglomerate (beds 6 and 7 of the Brownwood section) are 7 feet thick and no doubt represent an unconformity. This sandstone is notably thicker at some points between Brownwood and Colorado River, and Drake, who also worked south of the river,[8] considered that it might be the equivalent of his Rochelle conglomerate (probably on account of the basal conglomerate). The approximate equivalence of the conglomeratic sandstone of the Winchell section (identified in that area by Drake as the Ricker bed) with that at Brownwood is suggested in figure 6.

That part of the lower shale member of the Graford (bed 13 of the Brownwood section) immediately above the conglomeratic zone is well exposed in the shale pit of the Brownwood Brick & Tile Company, not far southwest of Brownwood. This deposit consists of 64 feet of greenish-gray soft shale. It is overlain by 8 inches of limy sandstone and 6 feet of greenish-gray shale interstratified with thin stringers of brown sandstone. Above this shale there is a persistent bed of soft massive brown sandstone interstratified with some breaks of sandy shale. At the shale pit the limy sandstone is 11 feet thick, but elsewhere it is about 6 feet.

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[8]Drake, N. F., Report on the Colorado coal field of Texas: Univ. Texas Bull. 1755, p. 28, 1917.

West of Brownwood it forms a prominent bench about halfway down the slope of the escarpment formed by the Adams Branch limestone. In the Winchell area a group of sandstones interstratified with shale 46 feet in total thickness (beds 26 to 33 of the Winchell section) occurs at this horizon. In this area the beds are soft, porous, and partly cross-bedded.

Fusulinid-bearing limestone.—A thin fusulinid-bearing limestone (bed 18) occurs in the section on the highway west of Brownwood 12 feet above a sandstone bed and 54 feet below the Adams Branch limestone. In the Winchell section this thin limestone (bed 34) is 6 feet above a sandstone bed and 56 feet below the Adams Branch limestone.

Although this fusulinid-bearing bed is less than 1 foot thick it forms the top of the first escarpment east of the Adams Branch escarpment in the Winchell area. It has a wide distribution and has been correlated by Cheney[9] with a thin bed near Metcalfe Junction, Palo Pinto County, in the Brazos River Basin.

That part of the lower shale member of the Graford from the top of this thin limestone bed up to the base of the Adams Branch limestone in the Brownwood area consists largely of gray shale weathering yellowish but showing some red and purple beds. The uppermost 8 feet is chiefly red to purplish and contains two thin beds of sandstone. In the Winchell area the same characteristics persist except that the upper sandy deposit is 22 feet thick and the bottom 5 feet of soft yellow limestone is preceded by a basal conglomerate 1 foot thick. The variable thickness of this sand, together with the presence of a basal conglomerate in the area of greatest observed thickness, suggests that there may be an unconformity shortly below the base of the Adams Branch limestone.

Adams Branch limestone member.—The escarpment of the Adams Branch limestone is a prominent topographic feature from Brownwood south to Colorado River. At the Santa Fe quarry, south of Brownwood, it has a thickness of 24 feet, but the thickness seems to vary considerably. At the bridge over Colorado River near Winchell the thickness of the Adams Branch is only 11 feet, and midway between Brownwood and the river, in a road cut, the member consists of interstratified limestone and shale only 6 feet thick.

[9]Cheney, M. G., Stratigraphic and structural studies in north-central Texas: Univ. Texas Bull. 2913, p. 19, 1929.

Robert T. Hill gives it a thickness of 30 feet 10 miles north of Brownwood, but farther north, toward the Cretaceous overlap, it is reported to thin rapidly. The thickness of the scarp-forming limestones is difficult to determine, for although the beds stand out prominently, weathering commonly removes the upper beds from the high point of the escarpment, and the topmost bed is likely to crop out inconspicuously some distance down the dip slope.

At the Santa Fe quarry the limestone is white, but weathers bluish. It is stratified in beds 1 inch to 2 feet thick, of uneven texture and separated by wavy partings. Most of the beds are hard, crystalline, and finely marked with veins of calcite. The limestone is fossiliferous, containing conspicuous crinoid stems and brachiopods. At the base of the member, in the quarry, a single 1-foot bed of gray sandy limestone is separated from the thick mass of limestone above by a 3-foot bed of gray sandy shale containing pyrite crystals.

The so-called "Adams Branch limestone" of Palo Pinto County, at one time correlated with the Adams Branch limestone of the type locality in Brown County, has been found to be equivalent not to the Adams Branch but to the higher Clear Creek limestone of Drake. To avoid confusion and duplication, the name "Clear Creek" was dropped and "Merriman limestone" was substituted. This correlation was first published by Cheney,[10] in August, 1929, and earlier references in the literature to the Adams Branch in the area north of the Cretaceous overlap probably refer not to beds now considered to be equivalent to the Adams Branch limestone member of the type locality in Brown County, but to beds equivalent to the younger Clear Creek of Brown County, which were later assigned to the Merriman limestone by the Texas Bureau of Economic Geology. The Adams Branch limestone of Brown County was correlated by Cheney with a thin limestone, previously named the "Staff limestone member," in Palo Pinto County.

UPPER PART OF THE GRAFORD FORMATION

The redefinitions of the Graford and Brad formations proposed in Bulletin 3232 of the Texas Bureau of Economic Geology have already been mentioned. In accordance with those redefinitions the

[10]Cheney, M. G., Stratigraphic and structural studies in north-central Texas: Univ. Texas Bull. 2913, p. 19, 1929.

Winchell member (including the Clear Creek limestone of Drake and the Merriman limestone of Reeves) and the Cedarton shale are here included in the upper part of the Graford formation instead of in the lower part of the Brad formation as originally defined.

Cedarton shale member.—The Cedarton shale is exposed on the lower part of the escarpment formed by the Winchell member, and its lower part in most places is in the valley between the escarpments of the Winchell member and Adams Branch limestone and is in consequence exposed in few places. It consists chiefly of gray to yellowish and red shales but contains also some thin lenses of limestone and sandstone. The interval determined by plane-table survey near Winchell is 64 feet from the top of the Adams Branch limestone to the base of the lowest limestone bed of the Winchell member.

In a section measured three-fourths of a mile north of Winchell a thin fossiliferous yellowish to gray limestone bed occurs 24 feet below the lowest Winchell limestone bed. It is overlain by red shale. One-half mile northwest of Winchell, in a road section, two beds of hard yellow weathering limestone, each 6 inches thick, separated by 6 inches of shale, occur at 12 feet below the lowest Winchell limestone bed, the intervening shales being red and gray. These limestone beds were not observed in other sections of this interval and are believed to be local and lenticular in character. Thin sandstone beds from 1 inch to 2 feet thick occur in the upper 15 feet of the Cedarton shale in the outcrops nearest Winchell but they also are local and lenticular in character.

Plant fragments were noted in the gray shale 43 feet below the top of the Cedarton shale west of Winchell and marine fossils occur in shale slightly higher. The cross section of figure 7 shows the upper part of the Cedarton shale in the sections measured in the vicinity of Winchell.

The following section was measured near Winchell:

Section of upper part of Graford formation near Winchell, Brown County.

	Thickness Feet	Inches
Winchell member (50 feet):		
13. Limestone, hard, gray, fossiliferous, iron-stained; weathers to rough slabs (limestone 3 of the Winchell member)	4	
12. Shale, gray	10	

	Thickness Feet	Inches
11. Sandstone, brown	7	
10. Shale, gray, with some blue and purple	9	
9. Limestone, gray, hard; weathers yellow-brown; slabs and blocks, fossiliferous (limestone 2 of the Winchell member)	3	
8. Shale	5	
7. Shale, red and gray	6	
6. Limestone, hard, gray (limestone 1 of the Winchell member)	6	
Cedarton shale member (42½ feet):		
5. Shale, red and gray; some layers of sandstone about 1 inch thick	12	
4. Limestone, hard; weathers yellow		6
3. Shale, gray		6
2. Limestone, hard; weathers yellow		6
1. Shale, blue to gray; contains plant fragments	29	
	92	6

Winchell member.—The name "Winchell member of the Graford formation" is here applied to the group of thin limestones separated by thick shale beds and thin sandstones in the Winchell area, in Brown County, which to the west develop into a conspicuous limestone bed, as recorded in logs of wells drilled in central Coleman County. This group of limestones includes the Clear Creek limestone of Drake and of Plummer and Moore, plus some higher beds heretofore included in the Placid shale member of Plummer and Moore. Both Drake and Plummer make special mention of a limestone of a characteristic brown color as marking the topmost bed of the Clear Creek limestone. In this report limestone beds as much as 55 feet higher than the brown limestone are included in the Winchell member. As herein described, the lowest limestone of the member is taken to be that one which caps the escarpment west of Winchell, and the top is taken as the limestone bed that forms the broad bench about 1 mile northwest of Winchell, on which the United States Geological Survey bench mark is set at an altitude of 1417 feet.

The cross section (fig. 7) shows the sections of the Winchell member measured near Winchell. The following section is the most satisfactory:

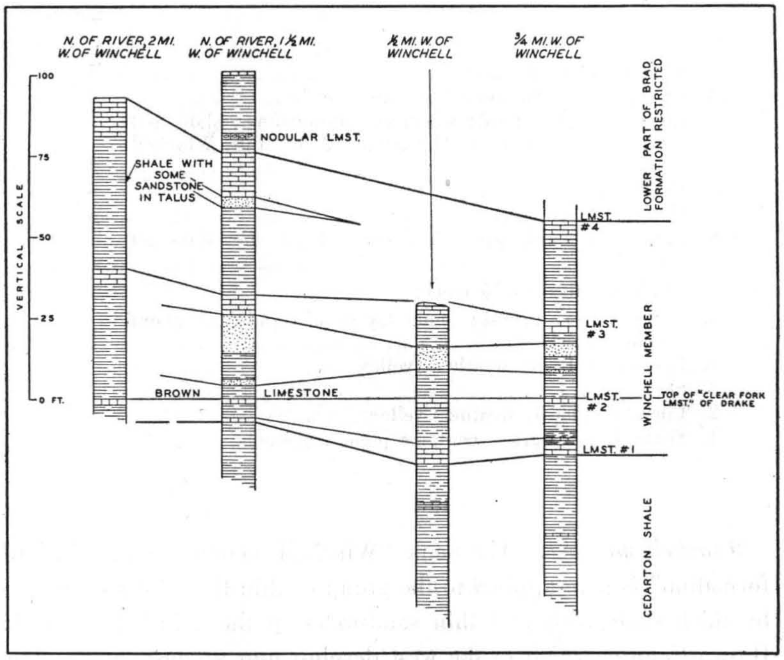

Fig. 7. Comparison of sections of the Winchell member of the Graford formation (redefined) measured near Winchell, Brown County, Texas.

Section of Winchell member three-quarters of a mile north of Winchell above United States Geological Survey bench mark 1358.

	Thickness	
	Feet	*Inches*
Winchell member (72½ feet):		
17. Limestone, gray, hard, fossiliferous; weathers to large slabs (limestone 4 of the Winchell member)	7	
16. Shale, gray, some purple	24	
15. Limestone, gray, hard, fossiliferous, iron-stained (limestone 3 of the Winchell member)	4	
14. Shale, gray; not well exposed	3	
13. Sandstone, yellow, soft, stratified	4	
12. Shale, gray to yellow	4	6
11. Sandstone, yellow, soft	1	
10. Shale, gray	8	
9. Limestone, gray, hard; weathers to yellow-brown slabs and blocks (limestone 2 of the Winchell member)	1	6
8. Shale, gray	8	6
7. Shale, red	2	
6. Sandy limestone, fossiliferous		6
5. Shale	1	6

	Thickness Feet	Inches
4. Limestone, gray, hard, fossiliferous; weathers to slabs with rough surface (limestone 1 of the Winchell member)	3	
Cedarton shale member:		
3. Shale, red	24	
2. Limestone, gray to yellow, fossiliferous		6
1. Shale, gray to blue	16	
	113	

The thickness of the Winchell member here is 72 feet, but in sections measured 1½ to 2 miles farther west it has become thicker by the increase in thickness of both the shale and the limestone beds. The limestones (of which four are recognizable west of Winchell) constitute the conspicuous parts of the member, but they are variable in thickness and character. The second bed from the bottom weathers brown or yellowish brown and was taken by Drake and by Plummer and Moore as the top bed of the Clear Creek because it furnishes a recognizable datum. The other beds are typical Canyon limestones, with their dull-gray color, rough weathered surface, and semicrystalline texture. In this area they are thicker than the brown bed. These limestones are all fossiliferous, but on account of the denseness of the limestone, collecting is difficult.

Sandstone occurs at two horizons in the Winchell member. The more conspicuous sandstone lies between the brown limestone and the limestone next above. It is brown to reddish brown and shows some cross-bedding. In the section measured three-quarters of a mile north of Winchell it is split by several feet of sandy shale. North of the river, 1½ miles west of Winchell, a 3-foot bed of gray to brown sandstone occurs immediately below the topmost limestone. This sandstone was not noted in the section measured nearest to Winchell, but float from it was recognized farther west. The shale beds intervening between the sandstones and the limestones are in general gray, though some reddish and purple beds were seen. The variegated beds do not seem to occur at any definite horizon and are probably in part the result of weathering in place.

BRAD AND CADDO CREEK FORMATIONS

READJUSTMENT OF BOUNDARY LINES

Considerable confusion arose during the course of the work owing to the previous double use of the term "Home Creek limestone." On Home Creek, in southeastern Coleman County, Drake noted two thick beds of limestone above the shale later designated the "Placid shale member" by Plummer and Moore and called the lower bed the "Cherty limestone" and the upper bed the "Home Creek limestone."[11] There is on Home Creek, above the typical Home Creek limestone of Drake and below the beds distinguished by abundant *Campophyllum*, a group of thin limestone beds separated by shale. These beds are not very conspicuous, and Drake apparently included them in his somewhat vaguely described *Campophyllum* bed, which overlies his Bluff Creek shale and which was subsequently called "Gunsight limestone member" by Plummer and Moore.

The type locality of the Home Creek limestone is clearly stated in Drake's report, and both the Cherty limestone and the Home Creek limestone are so accurately described that there can be no doubt of the beds so named. The lower bed is 35 feet thick and contains about 25 per cent of chert. The upper bed is also about 35 feet thick and at this point contains no chert. The two beds are separated by an interval of sandstone and shale only 8 feet thick. This interval increases gradually toward the northeast. In the same direction the Cherty limestone thins and splits into two or more beds, which finger out and disappear in the area west of Brooksmith, less than 8 miles to the northeast.

Drake's Home Creek limestone also becomes somewhat thinner or is interstratified with shale toward the northeast, and some of the beds contain minor amounts of chert. The Cherty limestone of the section in Home Creek is absent in northern Brown County, and as the overlying bed there carries chert in minor amounts, Drake apparently identified it with his Cherty limestone of the Home Creek section. As the next overlying limestone becomes thicker and more conspicuous toward the north and forms an escarpment, it

[11]Drake, N. F., Report on the Colorado coal field of Texas: Univ. Texas Bull. 1755, pp. 33–36, 1917.

was natural to apply the name "Home Creek" to this bed, which is not prominent on Home Creek.

Plummer and Moore in carrying their correlations southward from the Brazos Basin used Drake's Home Creek as identified in northern Brown County, so that their Home Creek limestone as at present used north of Colorado River has become the equivalent of the group of thin limestone above the Home Creek of the type locality, and has been so mapped in most of Brown County. In the same way, the Ranger limestone of northern Brown County, being next below the Home Creek of Plummer and Moore, has become the equivalent of the Home Creek of the type locality.

Except for a small area in the vicinity of Home Creek, the names as used by Plummer and Moore have been used consistently in the literature and on the maps of Brown County since 1921, whereas the name "Home Creek" as used at the type locality has had no other usage north of Colorado River. Drake, however, apparently used the name consistently south of Colorado River, and more recently Fred M. Bullard and Robert H. Cuyler[12] have used the limestone of Drake's type locality as a basis for stratigraphic work south of the river, in McCulloch County.

There are, therefore, at the present time, two limestones bearing the name of "Home Creek," one north of Colorado River and the other south of it. As Drake's Cherty limestone continues south of the river, there are also two beds bearing the name "Ranger limestone," which has been applied to the next limestone below the Home Creek of the type locality, and also to the true Home Creek limestone. The existing confusion is shown in figure 8, where the conflicting use of names is indicated.

The type localities of both the Brad and Caddo Creek formations are in the Brazos Valley, but the type localities of some of the members are in the Colorado River Valley. In so far as their equivalence can be determined in the two areas, the same beds should be included in the same formations. The Brad formation of the Colorado River section should therefore include the Home Creek of the type locality if it proves to be the equivalent of the Ranger limestone of the type locality of the Brad formation. The group

[12]Bullard, F. M., and Cuyler, R. H., Upper Pennsylvanian and lower Permian section of Colorado River valley, Texas: Univ. Texas Bull. 3501, p. 191, 1935.

of limestone beds between Drake's Home Creek limestone and the Gunsight limestone member, which has been erroneously mapped north of Home Creek, must still be considered the upper member of the Caddo Creek formation, by whatever name it may be called.

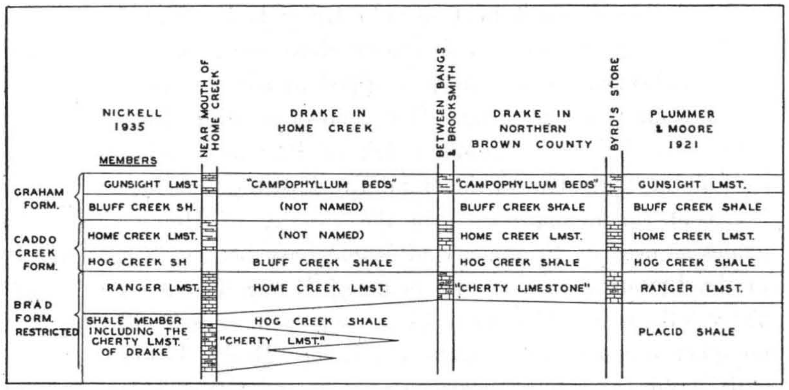

Fig. 8. Columnar sections showing different uságes of names for subdivisions of Brad, Caddo Creek, and Graham formations, Brown County, Texas.

The limestone beds of this group (Home Creek limestone of northern Brown County) thicken and coalesce abruptly southwest from Home Creek, and where they cross Colorado River they form a single bed 34 feet thick, the interbedded shales having almost completely fingered out. South of the river this member seems to be a partial or complete equivalent of the limestone mapped in McCulloch County as Bunger limestone by Bullard and Cuyler. This member, by whatever name it may ultimately be called, seems to represent the upper member of the Caddo Creek formation—provided, of course, that no error has been introduced in carrying the correlation across the Cretaceous outlier between the two river basins. For the present, until the correlation of these beds with those of the Ranger district north of the Cretaceous outlier can be checked, the names in general use north of Home Creek in Brown County will be retained in discussing the members of the Brad and Caddo Creek formations. The Home Creek limestone of the type locality will be discussed under the name "Ranger limestone." The Cherty limestone of Drake will be called by this name, and the name "Home Creek," in conformity with general usage in Brown County, will be applied to the group of thin limestone beds on Home Creek that lies above the bed so named by Drake and lower than the beds called "Gunsight limestone" by Plummer and Moore.

BRAD FORMATION REDEFINED

As the Cedarton shale and the Winchell member (including the Clear Creek limestone of Drake and the lower or limestone-bearing part of the Placid shale member of Plummer and Moore) have been found to be included in the typical Graford formation of the Brazos River Basin, as explained on preceding pages, the Brad formation now consists only of a shale member at the base, and the overlying Ranger limestone member (Drake's Home Creek of the type locality).

Shale member.—The beds here included under the designation "shale member" represent the upper part of the Placid shale member of Plummer and Moore, the lower part of which is here included in the Winchell member of the Graford formation. This lower member of the Brad formation as here defined consists of shale, some sandstone, and the Cherty limestone of Drake. It was difficult to decide whether to include the Cherty limestone of Drake in this member of the Brad formation or to consider it a lower bed of the Ranger limestone member. Toward the northeast, where the Cherty limestone fingers out (see cross section, Pl. VII) and the corresponding interval is occupied by shale, the Cherty limestone appears to be a part of this shale member. To the south, however, it becomes so massive and continues so closely below the Ranger that it seems to be a lower part of the Ranger. On Home Creek the separating beds include a thin sandstone deposit increasing in thickness toward the north. The interval between the beds, though thin, continues as far south as it was observed by Drake,[13] and the Cherty limestone can therefore be distinguished from the overlying limestone. The base of the Ranger is therefore definite toward the south. Farther north, where the Cherty limestone fingers out, the base of the Ranger limestone is the only available point of division. In this report, therefore, the Cherty limestone is considered to be a part of the shale member of the Brad formation. This decision is supported by the presence of the thin but persistent sandstone bed

[13]Drake, N. F., Report on the Colorado coal field of Texas: Univ. Texas Bull. 1755, p. 35, 1917.

beneath the Ranger, a bed more appropriately regarded as occurring beneath a limestone member than within it.

The thickness of the shale member of the Brad formation as here delimited is 111 feet, as indicated by the following section measured on the north side of Colorado River 2 miles west of Winchell:

Section showing shale member of Brad formation 2 miles west of Winchell.

	Thickness *Feet*
Brad formation:	
Ranger limestone member (34 feet):	
13. Limestone, gray, hard	5
12. Not exposed	12
11. Limestone, gray, hard, cherty	17
Shale member (111 feet):	
10. Shale slope	32
9. Limestone, gray, hard	8
8. Shale slope	10
7. Limestone, gray, hard, cherty	25
6. Shale, gray, hill slope	36
Graford formation (95 feet in part):	
Winchell member and Cedarton shale member:	
5. Limestone, gray, hard, bedded	12
4. Shale, including some sandstone in talus	41
3. Limestone, gray, hard	4
2. Shale	36
1. Limestone, brown	2
	240

Beds 7 and 9 represent the unbroken Cherty limestone exposed at this horizen on Home Creek. Bed 10 shows the widening interval of a shale below the Ranger.

The following section, all of which lies above the Winchell member, shows the almost complete disappearance of the Cherty limestone west of Brooksmith.

Section of lower part of Brad formation 1 mile west of Brooksmith.

	Thickness *Feet*
Ranger limestone member:	
10. Limestone, cherty	8
Shale member:	
9. Shale, not well exposed on hill slope	30
8. Sandstone	2
7. Shale, yellowish, sandy	12
6. Sandstone	4
5. Shale, yellowish, sandy	9

	Thickness *Feet*
4. Sandstone	8
3. Shale, gray and yellowish	12
2. Limestone	2
1. Shale, gray, sandy, base not exposed	20
	107

Bed 2 of the above section may represent a portion of the lower part of the Cherty limestone, but it is more probably a local lens.

On the bluff on Colorado River half a mile west of the mouth of Home Creek, the beds between the Cherty limestone and the Ranger are only 6 feet thick, and the upper half is sandstone. In Home Creek this interval is 8 feet, and at the top of the interval at least 2 feet of limy sand is present. Farther northeast, sandstone continues below the Ranger limestone, but as the Ranger thins it is not entirely clear whether the sandstones observed in the sections represent the same bed or whether other beds come in with the increasing interval. The latter seems likely. Still farther northeast, the lower of the two sandstones thickens to 45 feet and contains some conglomerate at the top, suggesting that if there was no actual unconformity at this horizon there was a close approach to shore-line conditions, and that the northeastward fingering out of the Cherty limestone represents the pulsating advance and retreat of conditions favorable to deposition of shale and unfavorable to that of limestone, the area at and southwest of Home Creek having remained during this interval of time beyond the reach of shale sediments.

On the south bank of Colorado River just east of the mouth of Tom Dean Creek, 2 miles upriver from the mouth of Home Creek, there is an outcrop of 10 feet of conglomerate overlain by 3 feet of brown sandstone. In walking the bench between the base of the Ranger limestone and the top of the Cherty limestone it was found that this conglomerate occurs at the horizon of the thin sandstone beneath the Ranger on the bluff on the north side of the river a mile to the northeast and also on Home Creek. Conglomerate was also found at this horizon 3 miles southeast of Bangs, in west-central Brown County, where it overlies a thick section of sandstone.

The Cherty limestone changes rapidly in thickness, texture, and appearance. In general it varies in color from dark to light gray and pinkish, is dense and crystalline in texture, and is sparsely fossiliferous. It is massive where chert is present in considerable quantity but shows bedding planes northeast of Home Creek, where chert is less abundant. The volume of the chert, which occurs in bands and nodules, is about 25 per cent on Home Creek, but to the northeast the chert content decreases rapidly. The map of Brown County, prepared by the coöperative mapping committee of the American Association of Petroleum Geologists, shows in the Home Creek area and the southwest corner of the county the Cherty limestone as bed "Yf," but the bed is dropped from the map in the area in which it begins to thin.

Ranger limestone member.—As already explained, the Ranger limestone member appears to be the equivalent of Drake's Home Creek limestone at the type locality. As exposed on Home Creek, it is about 35 feet thick. It is a massive bluish-gray noncherty limestone. In weathering the lower parts of the bed break off into large blocks 10 to 20 feet long and 5 to 10 feet wide. The upper part is broken by bedding planes. The massive phase of the bed is localized on Home Creek and along Colorado River. Farther northeast the beds are generally interstratified with beds of shale. Three miles east of Home Creek the bed contains some chert, and from this point northeastward chert in minor quantities is a common constituent. The Ranger limestone is only sparsely fossiliferous. The top of the Ranger, like that of each of the thick limestone beds of the Canyon group, is difficult to map or to measure because in many places there are at the top thin limestone beds which in weathering tend to retreat down the dip slopes from the edge of the escarpment. Weathering also dulls the edge of the escarpment, and the interval as measured at the escarpment is in consequence in many places less than the thickness shown in logs of nearby wells.

In the section measured on the river bluff half a mile west of the mouth of Home Creek the Ranger is 70 feet thick but broken at 46 and 58 feet from the bottom by benches that probably represent the position of thin shale beds. As the limestone section of the Ranger passes into the overlying Home Creek of northern Brown County by a series of relatively thin limestone beds interstratified with shale, it is difficult to know where to place the top of the member and the top of the Brad formation. Along Colorado River, however, the shale partings are so thin that it seems reasonable to place the top of the Ranger at the top of the unbroken limestone and to consider the first thick shale as the first bed of the Caddo Creek formation. The greatly increased thickness of the Ranger where it crosses Colorado River toward the south and its close approach to the underlying Cherty limestone seem to indicate that the increased thickness of the Ranger occurs by thickening of its lower part at the expense of the immediately underlying shale. (See Pl. VII.)

CADDO CREEK FORMATION

The Caddo Creek formation consists of the Hog Creek shale member, whose type locality is in northern Brown County, and the overlying Home Creek limestone of northern Brown County, which has been correlated with a limestone also called "Home Creek" occurring at the same horizon in the Brazos River Basin in Palo Pinto County. Although these members are distinguishable in northern Brown County and in the area along the river, it is not practicable to separate them in much of the intermediate area, for the reason that the Home Creek is broken into a number of relatively thin limestone beds interbedded with shale, with no obvious dividing line between them. The following section shows the character of the interval between the top of the Ranger limestone (Drake's Home Creek limestone of the type locality) and the base of the Graham formation.

Section on the west side of Mukewater Creek half a mile above its junction with Home Creek, in southeastern Coleman County.

	Thickness Feet	Thickness Inches
Cisco group:		
Graham formation:		
Bluff Creek shale member:		
24. Limestone, brownish yellow	1	
23. Shale	5	
Canyon group:		
Caddo Creek formation (69 feet):		
Home Creek limestone member (30 feet):		
22. Limestone, gray	1	
21. Shale	5	
20. Limestone, gray		6
19. Not exposed	5	
18. Limestone, gray	2	
17. Not exposed	10	
16. Limestone, gray, forming bench		6
15. Not exposed	5	
14. Limestone, gray	1	

	Thickness Feet	Inches
Hog Creek shale member (39 feet):		
13. Shale	12	
12. Limestone, gray, platy		6
11. Shale	12	
10. Limestone, gray, lumpy		6
9. Shale	6	
8. Sandstone	1	
7. Shale	7	
Brad formation:		
Ranger limestone member (35 feet):		
6. Limestone, gray	2	6
5. Talus, not exposed	7	
4. Limestone, gray	4	
3. Talus, not exposed	1	6
2. Limestone	3	6
1. Talus, not exposed	16	6
Shale member (exposed in part):		
Limestone, cherty.		

Hog Creek shale member.—The Ranger limestone on Mukewater Creek is incompletely exposed and probably contains more limestone than was seen in the measured outcrop. The base of the Hog Creek shale, which has been rather loosely used to indicate the shale below the Home Creek limestone wherever identified, is placed at the top of the highest limestone below the thin sandstone in the lower part of the Hog Creek shale. This sandstone, though thin and not found everywhere in place, is usually represented in the float. It occurs over most of southeastern Coleman County and southwestern Brown County and furnishes a convenient and valuable datum above the Ranger limestone.

Home Creek limestone member.—The term Home Creek limestone as here used is the Home Creek limestone of Plummer and Moore and of Drake in northern Brown County which has become established in the literature of the region to the north and not the Home Creek limestone of the type locality. The top of the Hog Creek shale is somewhat indefinite in the region about Home Creek in Coleman County, and the beds of thin limestone and shale pass into the Home Creek limestone without notable interruption, the limestone beds becoming thicker as the top of the Home Creek limestone is approached. The top of the Home Creek limestone in much of southern Brown County also is vague. As mapped by Hudnall and Pirtle, whose maps were used in compiling the Brown County map prepared by the coöperative mapping committee of the American

Association of Petroleum Geologists for the Texas Bureau of Economic Geology, the top of the Home Creek limestone was set at the highest gray limestone, a short interval below the persistent thin yellowish-brown limestone bed[14] (bed 24 of the above section). This yellow limestone is lithologically different from the typical gray limestones of the Canyon group.

To the southwest, between Home Creek and the river, the limestone beds in the Home Creek member thicken sharply, and where they cross the river the shales have fingered out and the limestones are all combined into a single bed 34 feet thick. The brownish limestone mentioned above remains a separate bed, however, where the underlying limestones coalesce. In the absence, therefore, of any more definite characteristic feature, it is assumed that the top of the Home Creek limestone as here defined and the top of the Canyon group in the Colorado River area occur at the top of the highest gray limestone a short interval below the yellowish-brown bed that furnishes a distinguishable datum for at least 13 miles northeast of Colorado River. Northward from Home Creek one or more of the beds constituting the Home Creek limestone thicken and locally form rim rocks, which stand out strongly in the topography, though it appears that the escarpment is not everywhere formed by the same bed.

Measured sections of the Home Creek limestone in the northern part of Brown County given in reports on the area vary materially in thickness. Much of this variability seems to be due to the fact that the Home Creek limestone in many places consists of a group of limestone beds separated by shale without very definite limits at top or bottom, so that usually only the more prominent beds have been measured. The thinner inconspicuous beds at the top outcropping on the dip slope or at the bottom covered by talus are sometimes omitted.

The beds are all similar, being gray, hard, semicrystalline, and sparsely fossiliferous. Some of the beds contain notable numbers of *Syringopora* corals. Syringoporas occur also in the Ranger limestone, but they are more abundant in the Home Creek.

In the Brazos Basin, in southeastern Young County, as reported in another part of this report, a marked unconformity occurs between the Home Creek limestone of that area and the overlying

[14]Hudnall, J. S., personal communication to Wallace Lee.

Graham formation. This unconformity is expressed in a deep, sharp channel. No evidence of unconformity was noted along Colorado River at this horizon. This is perhaps not surprising, for in Young County there is nothing to suggest unconformity a few feet beyond the margin of the channel.

CISCO GROUP (RESTRICTED)

The Cisco group as originally defined by Cummins was intended to include all the beds from the top of the Canyon to the base of the Permian. The line between Pennsylvanian and Permian has been variously defined. Plummer and Moore drew the top of the Cisco group at the top of the Coleman Junction limestone, the top member of the Putnam formation, but the dividing line has been successively lowered by others on the basis of paleontologic interpretations. Sellards, Adkins, and Plummer[15] place the top of the Pennsylvanian at the top of the Pueblo formation, including in the Cisco group only the Graham, Thrifty, Harpersville, and Pueblo formations, and that definition is here followed.

GRAHAM FORMATION

In the Colorado River Basin the Graham formation has been divided, from the top down, into the Wayland shale, Gunsight limestone, and Bluff Creek shale members. These members have a total thickness of 243 feet from the top of the Home Creek limestone of northern Brown County up to the base of the *Bellerophon* bed of Drake.

Bluff Creek shale member.—The Bluff Creek shale member was defined by Drake as including the shale interval from the top of his Home Creek limestone to the base of his *Campophyllum* beds, the name being derived from a locality south of Colorado River, where his term "Home Creek limestone" was used consistently. The name was used by Plummer and Moore to include the beds from the top of the Home Creek limestone of their report (a higher limestone than the Home Creek limestone on Home Creek) to the base of the Gunsight limestone, and that usage is followed here.

[15]Sellards, E. H., Adkins, W. S., and Plummer, F. B., The Geology of Texas, Vol. I, Stratigraphy: Univ. Texas Bull. 3232, pp. 140–144, 1932 [1933].

Section of the Bluff Creek shale and Gunsight limestone member one and one-half miles northeast of Mitchell Crossing of Colorado River, southeastern Coleman County.

	Thickness *Feet*
Cisco group:	
Graham formation:	
Wayland shale member.	
Gunsight limestone member (36 feet):	
10. Limestone, gray; contains *Campophyllum* corals	5
9. Shale, marly; contains fusulinids	5
8. Shale, gray, fossiliferous	20
7. Limestone, gray; contains *Campophyllum* corals	6
Bluff Creek shale member (47 feet):	
6. Shale, marly	5
5. Shale, gray	5
4. Shale, gray, fossiliferous, ammonoid zone	27
3. Limestone, yellowish brown	2
2. Talus, not well exposed, probably shale	8
Canyon group:	
Caddo Creek formation:	
Home Creek limestone member:	
1. Limestone, gray	35

The yellowish to brown limestone (bed 3 of the above section) is persistent in the Colorado River Basin and is distinguished from the underlying gray limestones of the Home Creek member by its contrasting color. It remains distinct from the gray Home Creek limestones where they coalesce. The shales of the middle part of the Bluff Creek member are very fossiliferous in some localities, notably on the Gill ranch, east of Whon, where a notable ammonoid fauna was collected. The Bluff Creek shale in some places occupies the lower part of an escarpment formed by the somewhat more resistant Gunsight limestone member above.

Gunsight limestone member.—The Gunsight limestone member was named for an outcrop near Gunsight post office, in Stephens County, by Plummer and Moore, who identified the beds with the *Campophyllum* beds of Drake in the Colorado River area. The Gunsight member consists of two gray, highly fossiliferous limestone beds, both containing large numbers of *Campophyllum* corals. The limestone is in part relatively soft, and the corals weather out freely and litter the underlying slopes. The shale interval between the limestone beds, which contains abundant fusulinids, is marly at the top and fossiliferous. Although the Gunsight limestones are conspicuous for the extraordinary numbers of *Campophyllum* that occur in them, there are many outcrops that contain few or none. At the type locality, near Gunsight, in Stephens County, very few if any occur.

Wayland shale member.—The Wayland shale member was called "Trickham shale" by Drake, for a Coleman County type locality, and "Wayland shale" by Plummer and Moore, for a locality in Stephens County. Although the name "Trickham" has priority, the name "Wayland" has been adopted, because it has had much wider usage and is better established. The member consists of a series of bluish shales with thin clay-ironstone partings, interstratified with thin lenticular beds of earthy fossiliferous yellow-weathering limestone and some lenticular beds of sandstone as much as 6 feet thick. There is good reason to suspect that unconformable relations exist on the Colorado River between the underlying Gunsight and the Wayland. Just north of Mitchell Crossing the following section was measured on and near the road to Whon.

Section a quarter of a mile north of Mitchell Crossing of Colorado River, southeastern Coleman County.

	Thickness *Feet*
10. Sandstone	2
9. Not exposed	2
8. Sandstone, brown, soft, cross-bedded	3
7. Sandy limestone and limestone gravel conglomerate	4
6. Not exposed	2
5. Limestone, gray, hard, nodular (Gunsight limestone)	3
4. Not exposed	5
3. Limestone, gray, hard, platy (Gunsight limestone)	2
2. Not exposed (probably Bluff Creek shale)	45
1. Limestone (Home Creek limestone)	35
	103

The limestones (beds 3 and 5 of the above section) occur at the horizon of the lower limestone bed of the Gunsight. The presence of a sandstone above the limestone, not elsewhere observed along Colorado River, and the absence of the upper Gunsight bed suggest that the pronounced unconformity noted in the Brazos Valley at the base of the Wayland shale is expressed at this point by the replacement of the upper part of the Gunsight by sandstone.

Between Whon and Mitchell Crossing a lenticular bed of cross-bedded sandstone 6 feet thick occurs 37 feet above the base of the member. It thins southwestward to 1 foot and becomes limy. Near Trickham a similar bed occurs at essentially the same interval above the Gunsight. Here it thickens irregularly, suggesting unconformable relations, though it may represent merely a lenticular bed deposited contemporaneously with the shale. The Wayland shale in Young County is not known to contain any sandstone beds.

There are several thin limestones in the Wayland shale of the Colorado River section. One occurs at 23 feet above the base of the member. This bed is 1 foot thick, gray to yellowish, earthy, and nodular and is typical of the limestone beds of the Wayland in the Brazos River Basin. Another thin bed occurs at 66 feet above the base of the member and still another bed of sandy limestone containing many fusulinids is present 84 feet above the base. These limestones are lenticular and do not appear in all the sections measured.

The following composite section shows the character and thickness of the Wayland shale south of Whon:

Composite section of Wayland shale member 4 miles south of Whon, southeastern Coleman County.

	Thickness Feet	Inches
Thrifty formation:		
18. Limestone ("*Bellerophon* bed").		
17. Shale, marly	2	
16. Sandstone, soft, white to yellowish, bedded (Avis sandstone member)	0–40	
Graham formation:		
Wayland shale member (121 feet):		
15. Shale, sandy, gray to yellow; plant fragments	12	
14. Shale, gray to yellow; plant fragments	25	
13. Sandy lime, soft; fusulinids	1	
12. Sandy lime, hard		6
11. Shale, blue to gray; plant fragments	17	
10. Lime concretions, yellow		6
9. Shale, blue; fossils; clay ironstone bands	6	
8. Shale, blue; many fossils	10	
7. Shale; not well exposed	12	
6. Sandstone, cross-bedded, lenticular	6	
5. Shale, gray; hill slope not well exposed	8	
4. Lime, gray to yellow, nodular	1	
3. Shale, gray; fossils	6	
2. Sandstone, yellow		1
1. Shale, gray	16	
Gunsight limestone member.		

THRIFTY FORMATION

The Thrifty formation, the type locality of which is at Thrifty, in Brown County, consists of a series of shales and thin limestones, with some lenticular bodies of sandstone that locally attain considerable thickness. The following members and beds (most of which were named by Drake) were included in the Thrifty formation by Plummer and Moore:

Chaffin limestone
Parks Mountain sandstone
Lohn shale
Speck Mountain limestone
Speck Mountain shale
Bellerophon limestone
Avis sandstone

The following composite section of the Thrifty formation was measured in the area between Rockwood and Parks Mountain, Coleman county.

Composite section of the Thrifty formation.

	Thickness *Feet*
Thrifty formation (137 feet):	
Chaffin limestone member:	
13. Limestone in thin beds interbedded with shale; hard gray, crystalline, fossiliferous	11
Lohn shale member:	
12. Carbonaceous shale (horizon of Chaffin coal)	2
11. Shale, yellow, sandy	3
10. Sandstone, brown, hard, pitted (may represent margin of Parks Mountain sandstone member 0 to 99 feet thick)	2
9. Shale, covered	5
8. Limestone, nodular; contains many fusulinids and other fossils	1
7. Shale, gray, rarely well exposed	53
Speck Mountain limestone member:	
6. Limestone, gray, hard, rough	5
Shale member (Speck Mountain clay of Drake):	
5. Shale, gray, has some sandstone in lower part; in few places well exposed	39
Bellerophon limestone:	
4. Limestone, gray, hard	2
3. Shale, not well exposed	7
2. Limestone, gray, hard	3
1. Shale, marly	4
Avis sandstone member, 0–50 feet.	

Avis sandstone member.—The *Bellerophon* limestone conformably overlies a sandstone of variable thickness resting on the Wayland shale. This sandstone was observed 4 miles south of Whon, three-quarters of a mile west of the road from Whon to Mitchell Crossing. At this point the top of the sandstone is 3 feet below the *Bellerophon* limestone and is 6 feet thick. It is soft, gray, and fine grained and in part bedded. To the northeast it wedges out rapidly. To the west it thickens to 20 feet within half a mile, the top being 5 feet below the *Bellerophon* limestone. This sandstone bed is 40 feet thick on the north side of Colorado River at the southeast end of Parks Mountain but only 1 foot thick half a mile to the east. Drake describes this bed in Brown and Coleman counties in considerable detail, and says that it is of variable and increasing thickness toward the north but is not everywhere present. He describes it as attaining thicknesses of 50 feet or more and in places as being conglomeratic. He recognized the unconformable relation that it bears to the underlying Wayland. There can be little doubt that this bed is the Avis sandstone of the Brazos Basin, as it lies unconformably on the Wayland shale, but in Brown and Coleman counties it seems to have been deposited in smaller areas and contains fewer pebbles.

Bellerophon limestone.—The term "*Bellerophon* bed" was applied by Drake to a limestone immediately overlying the Trickham or Wayland shale along Colorado River. He reported its continuity in Brown and Coleman counties interrupted progressively toward the north. In the outcrops along the river south of Parks Mountain it is from 3 to 5 feet thick. It is a hard crystalline bed, weathering dark gray and breaking into slabs and chunks. In places the upper part is soft, and weathering produces a yellowish nodular mass. On the west side of Parks Mountain, southwest of Whon, two beds of limestone appear to be present, as shown in the composite section given above. The upper bed is 2 feet thick and the lower bed, which is separated from the upper by 7 feet of shale is not well exposed and is 3 feet thick; both beds are hard limestone. This division of the *Bellerophon* shale was not noted at any other point.

Shale member (Speck Mountain clay of Drake).—This shale member of the Thrifty formation consists largely of sandy shale, with lenticular bodies of sandstone in the lower part overlain by a persistent limestone bed. The following sections less than half a mile distant from each other show its character:

Section half a mile northwest of the most southerly point of Parks Mountain, southern Coleman County.

	Thickness *Feet*
Thrifty formation:	
Speck Mountain limestone member:	
4. Limestone	3
Speck Mountain clay of Drake (49 feet):	
3. Sandy shale, gray to yellowish	24
2. Sandstone, cross-bedded	25
Bellerophon limestone:	
1. Limestone, gray, rough, hard	4
	56

Section at end of long ridge 1 mile northwest of most southerly point of Parks Mountain, Coleman County.

	Thickness *Feet*
Thrifty formation:	
Speck Mountain limestone member:	
6. Limestone, gray, hard, rough	5
Speck Mountain clay of Drake (32 feet):	
5. Shale, sandy, gray and yellow and some red, plant fragments	2
4. Shale, gray, upper part sandy	18
3. Sandstone, white, soft	2
2. Shale, gray, in part red	10
Bellerophon limestone:	
1. Limestone, gray, hard	2
	39

The sandstones of this member are lenticular and variable in character and suggest contemporaneous erosion and deposition. As the Avis sandstone of the Brazos Valley has an unconformity at its top, the sandstone lenses and sandy shales of this shale member may possibly represent offshore deposition of material eroded from the northern area during the post-Avis erosion period, during which the Colorado River area may have remained below sea level. The hypothesis receives some support by the fact that some of the shales are red and others contain comminuted plant material in the sandy shale.

Speck Mountain limestone member.—The Speck Mountain limestone member, named by Drake from a locality in McCulloch County, is a bed 3 to 5 feet thick. Its usual color is dark gray, but on the road between Whon and Rockwood, where it forms a dip slope, it weathers to a slightly yellowish color. The surface weathers rough and somewhat resembles that of the *Bellerophon* limestone. About half a mile east of the new highway bridge over Colorado River 9 feet of limestone is present. The upper 4 feet is gray and nodular at the outcrop and was not observed at any other point. Like the other beds in the lower part of the Thrifty, this member is in many places north of the river cut out by the unconformity at the base of the Parks Mountain sandstone.

Lohn shale member.—Drake gave the name "Lohn bed" to the coal-bearing shale overlying the Speck Mountain limestone and underlying the Chaffin limestone, from its outcrop near the settlement of Lohn, south of Colorado River in McCulloch County. It consists of clay and shale and in some places contains near the top streaks of impure coal called the "Chaffin coal" by Drake. This coal was once exposed by openings south of the river a mile northeast of Waldrip, where it was examined and described by Drake. The coal proved too poor in grade to mine, and as the openings have long since fallen in, the coal can no longer be seen. On the north side of the river there are some carbonaceous streaks in the shale immediately below a bed of coal that appears to represent the Chaffin coal of the type locality.

Plant fossils collected 2¼ miles east of Rockwood a few feet below the top of the member were submitted to Charles B. Read, of the United States Geological Survey, who reported:

> The material here is all a late segregate or subspecies of *Neuropteris ovata* Hoffman. This form is common in the late Pennsylvanian of this country.

The thickness of the Lohn shale varies materially, partly because of the unconformable relations it bears to the Parks Mountain sandstone, which in some places cuts it out, and partly because of another somewhat higher unconformable sandstone, which in places cuts into it.

No detailed sections could be examined near the river on the north side, because immediately north of the river, where good exposures might be expected, the beds have been replaced by the Parks Mountain sandstone. In areas farther north, back from the river, the relief is low and exposures are poor. The greatest thickness measured is in the road exposure 2 miles east of Rockwood, where the interval from the Speck Mountain limestone member to the Chaffin member is 53 feet. This section shows a bed of soft gray limestone less than a foot thick 15 feet above the base of the shale and a bed of nodular gray limestone about a foot thick containing many fusulinids and other fossils about 12 feet from the top. This upper bed has been considered by some observers to be the lower part of the Chaffin limestone, but as described by Drake the Chaffin limestone does not split here, but farther to the north, where the shale between the two parts is uniformly red.

Parks Mountain sandstone member.—The member called the "Parks Mountain bed" by Drake is an unconformable deposit whose base on the east side of Parks Mountain south of Whon cuts out Thrifty beds to a horizon within 10 feet of the *Bellerophon* limestone and whose top on account of the poor outcrops is not exactly determinable, though it is at or near the top of the Lohn shale as defined by Drake.

The interval from the top of the Lohn shale to the lowest observed beds of the Parks Mountain deposits is 99 feet, but there is some reason to believe that the top of the Parks Mountain member lies a short distance below the top of the Lohn as defined by Drake, so that the relief of the unconformity at its base is probably somewhat less than 99 feet. In describing the Parks Mountain bed in outcrops near the mouth of Rough Creek, Drake reports rather vaguely that "10 to 25 feet of clay of the Lohn shale overlies the sandstone." In the section measured east of Rockwood, included in the composite section already presented, 2 feet of sandstone occurs 5 feet below the top of the Lohn shale. This may represent a marginal sandy deposit of the Parks Mountain, but no outcrop of the Chaffin coal, the topmost bed of the Lohn shale member, was found over the main body of sandstone.

The Parks Mountain sandstone member may therefore ultimately prove to lie within the limits set by Drake for the Lohn shale and may be represented in the Brazos River area by one of the sandstone lentils below the Blach Ranch limestone, though no pronounced unconformity was noted in that area.

The Speck Mountain limestone is cut out by the Parks Mountain sandstone at the south end of Parks Mountain, and 2½ miles south of Whon almost the entire Thrifty formation is missing, the Parks Mountain sandstone coming down to a horizon within 10 feet of the *Bellerophon* limestone. In the area between Rockwood and

Colorado River the Lohn shale is generally absent and is replaced by these deposits.

The Parks Mountain deposits comprise brownish sandstone and conglomeratic sandstone. The pebbles of the conglomerate consist of subangular chert of various kinds, such as occur in the Cisco and Strawn deposits in the Brazos River Basin. The brown sandstone constitutes the greater part of the deposit and is more widespread than the conglomeratic phase. The remains of plants and trees are also found in it, but very sparingly. Drake reported other areas of Parks Mountain sandstone farther north in Brown County, and it seems probable from his descriptions that the deposits which occur within 3 miles of the river are not unique and that areas of this sandstone occur in other parts of the region. The thickness and distribution of the deposit and its strikingly unconformable relation to the older deposits of the Thrifty formation seem to indicate that it was deposited in the area near the river in a channel about 2 miles wide and 100 feet deep.

Chaffin limestone member.—The Chaffin limestone was named by Drake for a locality a mile or so northeast of Waldrip, in McCulloch County, near Colorado River. It crops out above the Chaffin coal at the type locality, where it has a thickness of 20 feet. Within 200 yards to the north it is cut out by unconformity and replaced by sandstone of later age. This sandstone interrupts the continuity of the Chaffin limestone throughout the greater part of the distance between Colorado River and the village of Rockwood, though there is an isolated patch of limestone on the crest of a hill just north of the river. Where the Chaffin limestone reappears east of Rockwood two limestones are present, separated by 12 feet of shale. Some observers have considered these two beds to represent a bifurcation of the Chaffin limestone as it appears south of Colorado River, but the presence of carbonaceous shale in the position of the Chaffin coal below the thick upper limestone near Rockwood suggests that the lower bed there may be a separate limestone bed in the Lohn shale member.

Drake found a bifurcation of the Chaffin limestone north of Home Creek, north of the area examined for this report. He says that the interval between the two parts increases toward the north and that the parts are consistently separated by red shale. No red shale occurs between the two beds near Rockwood, and the lower bed is therefore placed in the Lohn shale member.

Plummer and Moore correlated the upper and lower limestone beds of the split Chaffin limestone with the Breckenridge limestone and Blach Ranch limestone, respectively, of the Brazos River Basin, where the Blach Ranch limestone, like the Chaffin limestone, has a thin coaly bed below it.

At the type locality the Chaffin is 20 feet thick. It is a hard gray massive to bedded sparsely fossiliferous limestone. It breaks down in slabs and probably contains some shale partings, for the beds slump, though no shale crops out. At the northern outcrop, near Rockwood, it is 11 feet thick. It is there interbedded with some shale, and the limestone beds are hard, gray, semicrystalline, and only sparsely fossiliferous.

HARPERSVILLE FORMATION

The Harpersville formation, the type locality of which is in Stephens County, contains several thin limestone members, described by Drake in his report on the Colorado River valley under the names "Saddle Creek bed" and "Waldrip bed." The beds to which he applied the name "Waldrip" consist of several thin limestones separated by shales and some thin sandstones, and constitute most of the Harpersville formation. The shales in the lower part of the formation contain thin impure variable coal seams of no commercial value, though attempts were once made to exploit them on Bull Creek, near Rockwood. The sandstones vary rapidly in thickness, and at least one of them was deposited unconformably. In the following composite section, the major intervals were determined by plane-table projection and the details filled in by local sections measured southwest of Rockwood.

Composite section of Harpersville formation southwest of Rockwood, Coleman County.

	Thickness Feet	Inches
Saddle Creek limestone member:		
33. Limestone, gray, hard, bedded; has white flecks suggesting fragments of fossils		6
Waldrip bed of Drake:		
32. Sandstone, white to yellowish	3	
31. Shale, gray; weathers yellow	16	
30. Limestone, sandy, nodular, brownish	2	

		Thickness	
		Feet	Inches
29.	Shale, gray; not well exposed	7	
28.	Limestone, brown, nodular	2	
27.	Limestone, brown, hard, fossiliferous	1	
26.	Not exposed, probably shale	6	
25.	Waldrip limestone No. 3, gray, hard, crystalline	2	
24.	Shale, gray and red	11	
23.	Sandstone, soft, brownish	5	
22.	Sandstone, soft, white, massive (local only)	10	
21.	Shale, red and yellow	14	
20.	Waldrip limestone No. 2, gray, hard, fossiliferous; has fucoidal tracings on bottom	1	6
19.	Shale, gray, fossiliferous	9	6
18.	Sandstone, soft, bedded, green	1	
17.	Coal	1	
16.	Shale, gray		6
15.	Sandstone, soft, white to gray	6	
14.	Shale, gray, some red, and green in upper part	14	
13.	Waldrip limestone No. 1, brownish gray; weathers nodular	2	
12.	Shale, gray to yellow, fossiliferous	5	
11.	Shale, sandy, red, yellowish, and white	9	6
10.	Sandstone, cross-bedded, brown	5	
9.	Shale, sandy, gray	10	
8.	Sandstone, brown to red	5	
7.	Not exposed; probably shale	32	
6.	Sandstone, cross-bedded, brown	10	
5.	Shale, gray	1	
4.	Coal	1	
3.	Shale, not well exposed, gray where seen	29	
2.	Sandstone, stratified, yellowish to brown	2	
1.	Not exposed; probably shale	8	
	Thrifty formation.		
		238	

Waldrip bed of Drake.—The relations of the sandstones to the associated beds of the Harpersville formation are obscure, but at least one of them was deposited on an eroded surface. The Chaffin limestone member of the Thrifty formation a short distance north of the type locality is cut out by a sharp unconformity, and its place is occupied by sandstone whose thickness is at least 20 feet but the position of whose top is uncertain. The erosion represented by the unconformity removed the Chaffin limestone for about 3½ miles between the river and Rockwood. The geographic position of the replacing sandstone is in part the same as that of the Parks Mountain sandstone, which it seems to overlap, confusing the relations of the Parks Mountain and higher sandstone beds. It is believed that the sandstone above the Chaffin represents a new cycle of erosion. Its top may be represented by the thin sandstone 10 feet above the top of the Chaffin in the section southeast of Rockwood.

A thin coal bed occurs 24 feet above the Chaffin limestone. It is about 1 foot thick and was mined in a small way in the 1890's in Bull Creek, southwest of Rockwood. The ash and sulphur content is high, and the coal is nowhere more than 15 inches thick and is broken by shale partings. Almost in contact with and above the Bull Creek coal is a sandstone bed 10 feet thick on Bull Creek. It thickens in places, cutting out the coal, and Drake considered that this bed might be part of the same sandstone that cuts out the Chaffin limestone. The outcrops are inadequate to determine this as a fact, however, and it seems more likely that this and other sandstones, though perhaps indicating unconformable relations, represent unconformities of no great magnitude. Such relations occur at many places in the Harpersville section of the Brazos Basin. The fact that some depressions in the unconformities in the Harpersville in the northern area are partly or completely filled with shale deposits, which in places contain coal streaks, may account for some of the eccentricities of sedimentation in this formation in the Colorado River Basin. The higher sandstones in the interval below the limestone that has come to be locally known as "first Waldrip limestone" or "Waldrip limestone No. 1" are separated by shale and seem to have been deposited without interruption.

The first Waldrip limestone is 2 feet thick, in part hard and thin bedded, in part gray, soft, and impure, and weathers lumpy and nodular. It lies 109 feet above the base of the formation. The interval from the first Waldrip limestone to the second Waldrip limestone is 34 feet. The lower part of this interval is occupied by variegated shales, which are overlain by 6 feet of sandstone, with a streak of impure coal at the top, and above the coal 9 feet of gray fossiliferous shale.

The second Waldrip limestone is 1½ feet thick at Rockwood. It is gray to brownish, hard, and fossiliferous and weathers pebbly. It shows limy fucoidlike markings on the bottom in some places. East of Rockwood and in the town site it is broken down locally to a limestone conglomerate and shows evidence of having been exposed to erosion before being covered. Drake reports it to thin toward the north, and it is not unlikely that a minor unconformity occurs at this horizon. The interval from the second Waldrip limestone to the top of the third Waldrip limestone is 40 feet. It is occupied by gray and variegated shale, with a lenticular body of sandstone near the middle. On the south side of Bull Creek this sandstone is only 5 feet thick, but on the north side the thickness has increased to 15 feet.

The third Waldrip limestone is gray to dark olive-buff, hard, and crystalline, and weathers to rough blocks. It contains fusulinids and some other fossils. On Bull Creek it is 2 feet thick. The interval from the top of the third Waldrip limestone to the base of the Saddle Creek limestone is 33 feet on the Colorado River bluff west of the mouth of Bull Creek and 37 feet on a bluff 1½ miles to the southwest. At the latter locality the third Waldrip limestone is followed by three thin limestone beds (beds 27, 28, and 30 of the section) separated by shale, but these beds are not present in the section just south of the mouth of Bull Creek, the interval there showing only gray shale, weathering yellow. The Saddle Creek limestone is underlain by sandstone 3 feet thick in the river sections.

The limestones of the Waldrip bed of Drake are reported by him to thin out toward the north, but though similar beds occur in the Harpersville formation in Young County and northern areas, there seems little evidence for the detailed correlation of the beds, as they are for the most part thin. Some are lenticular and probably were not deposited over broad areas, and others are interrupted by the numerous but insignificant unconformities which affect this formation.

Saddle Creek limestone member.—The Saddle Creek limestone was named by Drake for its outcrop on Saddle Creek just south of Colorado River. It is a hard gray bedded limestone with white flecks in the upper part of the bed, suggesting the presence of fragmental fossils in the matrix. Southwest of Rough Hollow it is 6 feet thick. Southwest of Bull Creek, there is at the base a somewhat sandy bed 1 foot thick, gray weathering yellow, but this bed is not generally present. The Saddle Creek is resistant to weathering, and as it overlies less resistant beds it forms a strong escarpment cutting across the country from southwest to northeast.

PUEBLO FORMATION

The type locality of the Pueblo formation is in Callahan County. It consists, in descending order, of the Camp Colorado limestone member, a series of shale beds with some sandstones and thin limestones, the Stockwether limestone, Coon Mountain sandstone, and Camp Creek shale members—all named by Drake from localities in the Colorado River Basin. Near the base of the Camp Creek member is a striking limestone bed. The following composite section is made up from outcrops extending from a point just north of the mouth of Rough Hollow to a point on the north side of the river west of Saddle Creek.

Composite section of Pueblo formation on north side of Colorado River, Coleman County.

	Thickness *Feet*
Pueblo formation:	
31. Limestone, gray, hard; contains much blue chert (Camp Colorado limestone member)	8
30. Shale, red	35
29. Limestone, sandy, gray to yellow; some fossils	3
28. Limestone, gray, hard	1
27. Shale, red	12
26. Limestone, gray; contains fusulinids	1
25. Shale, red	15
24. Sandstone, yellowish, massive	5
23. Not exposed	10
22. Sandstone, yellowish to brown, soft, massive	10
21. Shale, red	10
20. Shale, sandy, white	4
19. Limestone, sandy, nodular, yellowish	3
18. Shale, sandy, yellowish	6
17. Sandstone, soft or limy, yellowish, bedded	4
16. Limestone, gray, hard, stratified; contains yellow chert (Stockwether limestone member)	15
15. Sandstone (Coon Mountain sandstone member)	0–8
Camp Creek shale member (74 feet):	
14. Shale, red	9
13. Limestone, sandy, nodular, yellow	1
12. Shale, sandy, yellowish and soft	14
11. Shale, yellowish to gray	10
10. Sandstone and sandy limestone, yellowish to red	4
9. Sandstone, soft, yellow	2
8. Shale, sandy, yellowish	4
7. Sandstone, soft, yellowish	2

	Thickness *Feet*
6. Limestone, sandy, yellowish, fossiliferous	2
5. Shale, red	12
4. Limestone, dark gray to bluish; weathers to roundish balls; contains fusulinids	1
3. Sandstone, soft, white to yellow	1
2. Shale, gray and red	9
1. Shale, limy, fossiliferous	3
Harpersville formation:	
Saddle Creek limestone member.	
	216

Camp Creek shale member.—The Camp Creek shale member is 74 feet thick where not overlain by Coon Mountain sandstone. It begins at the base with 12 feet of shale, which in some places has a 1-foot bed of sandstone at the top. This is overlain by a hard fossiliferous limestone 1 foot thick, which usually weathers to roundish boulders 8 to 10 inches in diameter like cannon balls. The limestone is persistent in the river area, and Drake noted a bed at about this horizon northwest of Rockwood, which, however, he described as flaggy. This unnamed limestone is overlain by 12 feet of red shale, capped by 2 feet of yellowish sandy fossiliferous limestone in the area northeast of Rough Hollow but not observed to the southwest. This bed was also noted by Drake northwest of Rockwood. This limestone is followed by shale and sandy shale, with which are interstratified some thin sandstone beds, some of which are limy but not fossiliferous. Northeast of Rough Hollow the member is capped by 9 feet of red shale, which is absent where the Coon Mountain sandstone is present.

Coon Mountain sandstone member.—Northeast of Rough Hollow the interval elsewhere occupied by the red shale at the top of the Camp Creek member is filled by a deposit of sandstone which Drake called the "Coon Mountain sandstone." This bed thins rapidly toward the south and is not present beyond the mouth of Rough Hollow. Toward the north it also thins rapidly to about 1 foot of limy ripple-marked sandstone, which continues for some distance. The Coon Mountain sandstone might be dismissed as just another sandstone contemporaneously deposited in the sandy shale at the top of the Camp Creek member, were it not for the fact that Drake describes it as a persistent deposit from 1 to 25 feet thick, containing conglomerate in places and thickening to 75 feet or more at Coon Mountain, in northern Coleman County, where he reported it as cutting down to the third Waldrip limestone. The conglomerate at Coon Mountain was reported by Plummer and Moore to be of Cretaceous age, but it seems unlikely that this is true at all the intermediate points described by Drake. Along Colorado River it was not observed to be thicker than 8 feet, but it may well represent a considerable unconformity.

Stockwether limestone member.—The Stockwether limestone was named by Drake for the Stockwether ranch, in southern Coleman County. It immediately follows the Coon Mountain sandstone or, in the absence of the sandstone, the red shale of the top of the Camp Creek shale member. It is 15 feet thick northwest of the mouth of Saddle Creek and 18 feet thick southwest of the mouth of Rough Hollow. It contains considerable quantities of yellowish to light-colored chert. The contrast in hardness between this resistant limestone and the underlying Camp Creek shale produces a prominent escarpment.

Shale member between Stockwether and Camp Colorado limestones.—The 119 feet of shale and sandstone between the top of the Stockwether limestone and the base of the Camp Colorado limestone contains three or more limestone beds in the lower part and several thin fossiliferous limestone beds in the upper part. The limestones are gray, hard, and fossiliferous, but none are more than 1 foot in thickness. Most of the shales are red.

Camp Colorado limestone member.—The Camp Colorado limestone was named by Drake for Camp Colorado, northeast of Coleman, in Coleman County. Northwest of the mouth of Saddle Creek, on the north side of Colorado River, it is 8 feet thick. It is gray, hard, and bedded and contains much bluish to blackish chert, being in this respect in contrast with the Stockwether limestone, whose chert is light-colored.

PERMIAN SYSTEM

WICHITA GROUP REDEFINED

MORAN FORMATION

The Moran formation was formerly included in the Pennsylvanian Cisco group but is now classified by the Texas Bureau of Economic

Geology as the lowest formation of the Permian,[16] and that classification is here adopted. It is described in this report, together with the overlying Putnam formation, in order to afford a comparative study of the Cisco group, as now restricted, with the immediately overlying formations. The type locality of the Moran is in Shackelford County. It consists of the following members, from the top down, all of which have their type localities in southern Coleman County:

Sedwick limestone member
Santa Anna shale member
Horse Creek limestone member
Watts Creek shale member

The Moran formation consists of red and gray shale, chiefly red, and a few thin sandstone beds, with which are interstratified ten or more thin limestones, most of which are less than 2 feet thick, and only two of which, the Horse Creek limestone in the lower part and the Sedwick limestone at the top of the formation, have been named in this area. The greater number of limestone beds occur in the lower part of the formation, where most of them are gray, hard, and noncherty, though a bed 4 feet above the base weathers yellowish, and another bed 29 feet below the Horse Creek is cherty. Two thin sandstones were noted in the lower part of the formation, but the Moran in this region contains very little sandstone. The Horse Creek limestone is 6 feet thick on Panther Creek. It is massive, hard, and light gray, but in some parts of the bed it weathers yellowish in slabs and rounded pieces.

The Santa Anna shale member, which constitutes the upper part of the formation beneath the Sedwick limestone member, is composed of gray shale with minor amounts of red shale and a few interbedded thin limestones. Only the uppermost limestone bed, which is sandy, weathers yellow. This is in strong contrast to the striking group of thin yellow limestone beds occurring in this part of the Moran formation in Shackelford and Throckmorton counties, to the north.

Plant fossils were collected from gray shale 23 feet above the Horse Creek limestone, 7½ miles southwest of Gouldbusk, and submitted to Charles B. Read, of the United States Geological Survey, who reported:

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[16]Sellards, E. H., Adkins, W. S., and Plummer, F. B., The Geology of Texas, Vol. I, Stratigraphy: Univ. Texas Bull. 3232, pp. 140-144, 1932 [1933].

This entire collection contains but one form, a new species of *Neuropteris*. In consequence I can say nothing concerning its stratigraphic significace.

The Sedwick limestone, where measured in Panther Creek, is only 3 feet thick, but much greater thicknesses, as much as 25 feet, have been observed elsewhere in Coleman County. The limestone is dense and gray to white but weathers to yellowish rounded chunks and slabs. It is well bedded and contains some chert. The bed is fossiliferous, and some of the coiled shells it contains are silicified.

The following composite section gives a total thickness of 172 feet for the formation along Colorado River:

Composite section of Moran formation in and southeast of Panther Creek, near Colorado River, Coleman County.

	Thickness *Feet*
Sedwick limestone member:	
31. Limestone, gray, weathering yellowish, bedded; contains chert, fossiliferous	3
Santa Anna shale member (65 feet):	
30. Shale, gray	8
29. Limestone, sandy, yellowish, nodular	2
28. Shale, gray	6
27. Limestone, gray	1
26. Limestone, gray, conglomeratic, fossiliferous	1
25. Shale, gray	10
24. Shale, red	4
23. Shale, gray	20
22. Limestone, sandy, nodular	1
21. Shale, gray	12
Horse Creek limestone member:	
20. Limestone, bluish to light gray, weathering to buff	6
Watts Creek shale member (98 feet):	
19. Not exposed	16
18. Limestone, gray to white, nodular	1
17. Shale, red	12
16. Limestone, gray; some fossils, some chert	2
15. Shale, red	8
14. Limestone, gray, hard; weathers to small round pieces	1
13. Shale, red	4
12. Sandstone, yellowish, soft, massive	4
11. Not exposed; probably shale	8
10. Sandstone, yellowish, soft, laminated	2
9. Shale, gray	3
8. Limestone, gray, hard, bedded	2
7. Shale, red	8
6. Limestone, gray, nodular	1
5. Shale, red; thin streaks of sandstone	5
4. Limestone, gray, hard, bedded	3
3. Shale, not well exposed	10

	Thickness *Feet*
2. Limestone, bluish, fossiliferous, bedded; weathers yellow	4
1. Shale, not well exposed	4
Camp Colorado limestone member of Pueblo formation.	
	172

PUTNAM FORMATION

The Putnam formation, named for the type locality near Putnam, in Callahan County, is composed of two members, the Coleman Junction limestone at the top and the Santa Anna Branch shale member below, the type localities of both of which are in Coleman County. The following is a representative section of the Putnam formation in southern Coleman County:

Section of Putnam formation four and one-half miles west and four miles south of Gouldbusk, on the north side of Mercers Creek, Coleman County.

	Thickness *Feet*
Coleman Junction limestone member:	
9. Limestone, bluish gray, weathering brown to olive-brown, blocky, fine grained, hard, sparsely fossiliferous	10
Santa Anna Branch shale member (138 feet):	
8. Shale, gray	15
7. Limestone, sandy, gray to yellowish, fossiliferous	5
6. Shale, gray	23
5. Sandstone and sandy limestone, fossiliferous, yellowish and soft	4
4. Shale, gray	25
3. Limestone, sandy, gray to yellow	1
2. Shale, gray	10
1. Shale, red, in part sandy	55
Sedwick limestone member of Moran formation.	
	148

The Santa Anna Branch member consists mainly of gray shale, but a part near the base is red. It contains some sandy fossiliferous limestone beds and one thin bed of soft limy sandstone, though the member as a whole is singularly free of sandstone. The Coleman Junction limestone is 10 feet thick and is interstratified with thin shale beds. The limestone is blue-gray when fresh, weathering to yellowish brown, is hard, fine grained, and semicrystalline, and contains some chert. It is fossiliferous, but the fossils do not weather out freely.

SUMMARY

The following table summarizes the thicknesses of the formations, overlaps excluded, measured on the north side of Colorado River in Brown and Coleman counties.

	Thickness *Feet*
Permian:	
Wichita group redefined (basal part, 320 feet):	
Putnam formation	148
Moran formation	172
Pennsylvanian:	
Cisco group restricted (795 feet):	
Pueblo formation	216
Harpersville formation	238
Thrifty formation	137
Graham formation	204
Canyon group (571 feet):	
Caddo Creek formation	69
Brad formation restricted	145[17]
Graford formation redefined (after Cheney)	357
	1686

[17]Should be increased to 240 or 260 feet. See footnote 1, p. 91.

COMPARISON OF BRAZOS AND COLORADO RIVER SECTIONS

WALLACE LEE

The table below shows a comparison of the thicknesses of the various formations as measured in the Colorado and Brazos River basins at localities about 115 miles apart. The formations of the Canyon group in the Brazos River area are taken from the columnar section of the study of the Bunger district by Lloyd E. Wells and are based on well logs. The fact that the Graham formation is bounded above and below and the Thrifty formation below by unconformities makes the determination of the comparative thickness of these formations difficult. In the Colorado River section the base of the *Bellerophon* limestone has, for convenience, been used as the division line between the Graham and Thrifty formations, although the underlying Avis sandstone is also present there, and in the Brazos section the top of the highest limestone of the Wayland member (the 9b limestone) is, for convenience, used as a division line, though there are remnants of Wayland shale about 30 feet higher and a considerable thickness of Avis sandstone below this horizon.

The base of the Graham formation in the Brazos section is, for the purpose of comparison, placed at the base of the Salem School limestone member, although there are some thin shale beds beneath it which also belong to the Graham as well as the deposits of the Kisinger channel.

The base of the Palo Pinto limestone in the Colorado River section is placed at the base of the thin limestone tentatively correlated with the Palo Pinto by Cheney. The top of the Palo Pinto limestone in the comparative section is placed at the top of a zone of conglomeratic limestones, but Plummer[1] gives evidence supporting the correlation of the Adams Branch limestone with one of the members of the Palo Pinto limestone, a correlation which would modify to some extent the details of the comparative columnar sections but would not materially alter the general conclusions.

[1]Plummer, F. B., letter, May 28, 1935.

Thicknesses of formations of lower Permian and upper Pennsylvanian age on Colorado River and on Brazos River, Texas

	Colorado River	Brazos River
Permian system:		
Wichita group redefined (basal part):		
Putnam formation	148	205
Moran formation	172	213
Pennsylvanian system:		
Cisco group restricted	(795)	(1148)
Pueblo formation	216	207
Harpersville formation	238	233
Thrifty formation	137	151
Graham formation	204	557
Canyon group	(571)	(1011)
Caddo Creek formation	69	161
Brad formation restricted	145[2]	250
Graford and Palo Pinto formations	357	600

The relation of the sections in the two areas is shown graphically in Plate X, in which the two sections have been coördinated on the Breckenridge limestone, the lowest of the nearly parallel members of the upper Cisco common to both areas. There is a slight convergence from north to south, amounting in all to about 85 feet, between the limiting limestone members of the Putnam and Moran formations,[3] now considered by the Texas Bureau of Economic Geology the lowest formations of the Permian.

The parallelism of the upper members of the Cisco as measured independently along Colorado River and in the Brazos Basin down to the ammonoid zone in the central part of the Graham formation is unusual especially when the distance (about 115 miles) is considered. Although the almost perfect correlation of the upper part of the Cisco is to a certain extent fortuitous, as local variations occur between datum beds in all the formations, it is evident that the surface remained essentially horizontal at least in the direction of the two sections while the beds of the upper Cisco were being deposited.

In the upper part of the Cisco the regularity of the intervals between the more conspicuous members of the two areas checks

[2]Log of wells starting a short distance above the outcrop indicate that this thickness should be increased to 240 or 260 feet.

[3]If the identification of the Sedwick limestone by Bullard and Cuyler proves correct, this convergence will be in the Moran formation rather than in the Putnam formation as shown on the cross-section (Pl. X). See footnote, p. 92.

with correlations arrived at independently. The identification by J. S. Williams, in another paper in this report, of the Belknap limestone of the Brazos River section with Waldrip limestone No. 2 of Drake in the Colorado River section, and the correlation of the ammonoid zone above the Bunger limestone of the Brazos section with the ammonoid zone below the Gunsight of the Colorado River section is perfectly sustained by the stratigraphy.

The purely speculative identification of the Stockwether limestone in the thin intermittent earthy fossiliferous limestone of the Pueblo formation on Clear Fork of Brazos River receives considerable support by its occurrence at the exact horizon of the Stockwether limestone in the Colorado River section.

The essentially parallel relation of the various members of the upper Cisco extends downward to the ammonoid zone and the Bunger limestone, though a slight convergence toward the south, amounting to about 50 feet, occurs between the Breckenridge limestone and the ammonoid zone, which is 29 to 34 feet above the Bunger limestone in the Brazos basin. From this horizon down to the base of the Canyon group there is a striking convergence, regular and approximately proportional to the depth and thickness of the formation along the line of the cross section, which is a southerly component of the actual direction of convergence. The thickness of the deposits in the Brazos River area from the ammonoid zone to the base of the Palo Pinto is 1348 feet, whereas in the Colorado River area the same interval (the exact base of the Palo Pinto being uncertain) measures about 616 feet, indicating that though both areas were subsiding the Young County area was subsiding more than twice as fast as the Brown County area. Most of the convergence occurs in the lower part of the Graham formation.

The Lacasa area, studied by Ross,[4] lies on the line joining the basal parts of the Graham formation in the two columnar sections and is shown on the cross section. It fits perfectly into the converging lines connecting the two columnar sections, even the thicknesses of the Home Creek and Ranger limestones and intervening beds corresponding to the southerly thinning of these beds.[5] The Lacasa

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[4]Ross, C. S., The Lacasa area, Ranger district, north-central Texas: U.S. Geol. Survey Bull. 726, p. 305, 1921.

[5]The thickness of the Brad formation on Colorado River shown in the cross-section is that measured on the outcrops. The thickness indicated by well logs shows the Brad on Colorado

section, however, is shown in the sketch a little farther south than its true geographic position, so that the convergence is actually a little sharper north of the Lacasa area and more gradual south of Lacasa than shown.

The interval from the Bunger limestone to the top of the Home Creek limestone is 303 feet in the Brazos River area, in southeastern Young County. In the Lacasa area, 30 miles to the south, on the line joining the lower Graham section of Brazos and Colorado rivers, the interval is 178 feet. In the Ranger area,[6] about 10 miles farther south, the interval has increased to 255 feet. The beds of this interval thin again between the Ranger area and southeastern Coleman County on the Colorado River until they nearly disappear.

From the Bunger limestone down to the base of the Canyon group the thick limestones either thin or finger out in the line of the section toward the south. The thinner limestones, such as the Gonzales and North Leon limestone of the Ranger oil field section, thin and disappear and the shale beds between them thin also.

The Gonzales limestone in the Lacasa area of the Ranger district, as reported by Ross, is stratigraphically closer to both the overlying Bunger limestone and the underlying Home Creek than in Young County. Not only is this true, but the overlying conglomeratic sandstone is thinner and its top is closer to the Bunger limestone in the Lacasa area than in Young County. These differences seem to indicate that the Young County area was subsiding faster during this interval than the Lacasa area, and the thinning of the corresponding shales in Brown County suggests that the Gonzales limestone, the North Leon limestone, and possibly the Bunger limestone, overlap on the margin of the subsiding basin and were never deposited in southern Brown County.

Insofar as there is uncertainty as to the exact position of the top of the Home Creek in southern Brown County, there is a corresponding uncertainty as to whether the Bunger limestone, which was deposited near the close of the subsiding movement, is represented in the Colorado River section, where it has not been positively identified. There seems reason to suspect that the Bunger limestone,

River of approximately the same thickness as the Brad in the Bunger Pool in the Brazos basin. There is therefore no convergence in the Brad formation.

[6]Reeves, Frank, Geology of the Ranger oil field, Texas: U.S. Geol. Survey Bull. 736, p. 115, 1922.

like the Gonzales and the North Leon limestones, overlaps the margin of the flexing basin and disappears, though it may be represented by the yellow limestone at the base of the Graham in the Colorado River section. If later work shows that the equivalent of the Home Creek of the Brazos area has been placed too high in the Colorado River section, it may even be represented by one of the gray limestones there included in the upper part of the Home Creek limestone. Such a development would not, however, modify the general conclusions.

The relation of the beds in the lower part of the Graham formation to each other indicates that the warping during Canyon time continued into the lower Cisco. After the deposition of the Gonzales and its subaerial exposure and partial removal the region was again warped. The trough so formed was filled to a certain level with sand and gravel derived from the rising terrane to the east (the southwestward extension of the Ouachita Mountains). The surface of the sandstone deposit was evidently warped or flexed in the same way as lower datum beds and covered by shale, which was in turn followed by the recurrence of marine deposits (the Bunger limestone). There appears to have been only slight warping of the Bunger limestone and the immediately overlying ammonoid zone but with these movements the subsidence to the east, which had been going on since early Strawn time, came to an end so far as the direct record shows.

Whether the flexing actually ceased at this time is open to question, for in both Young County and Brown County the parallel series of beds of the upper Cisco were measured west of the axis of the Bend flexure. The eastward extension of the upper Graham, Thrifty, and Harpersville on the active side of the axis of the Bend flexure has now been lost by erosion, but it is possible that these beds now eroded east of the axis might have shown convergence in that area. The Canyon beds in the Cross Cut-Blake area west of the Bend axis, as shown in the report of Edgar D. Klinger to be published elsewhere, are essentially parallel, although east of the axis they show divergence.

The regular subsidence of the northern area with respect to the south is indicated throughout the Canyon group by the convergence between the principal beds and by the thinning and fingering out of the limestones toward the southern area. The Palo Pinto limestone, the Winchell member, and the Home Creek limestone although not correlated without question between the two areas, tend to split up toward the south into a series of thinner limestone beds separated by shale in such relations as to suggest the approach in this direction to a land mass on whose flank the advance and retreat of shaly sediments interrupted the continuous deposition of limestone. The cross section, as it is based on only two areas, gives the impression that the convergence varies geometrically with the distance, a condition that probably does not exist, the rate of increase in thickness toward the north probably being variable.

The cross section is based on a north and a south section and therefore gives the impression that the changes took place in this direction. As a matter of fact the line joining the two measured sections is diagonal to the structural movements of the time and actually expresses in a qualitative way changes which actually occurred in a more nearly east-west direction, the northern section expressing in a qualified way changes taking place basinward to the east, and the southern section the more static conditions toward the west.

Cheney's work[7] shows that the Strawn group thickens into a synclinal area west of and parallel to the extension of the Ouachita belt of Paleozoic rocks (fig. 9). The flexing of the Canyon and lower Cisco beds is believed to express the continuing deformation and uplift of the same movement. The fact that Ouachita Mountain pebbles are present in most of the sandstone deposits up to late Harpersville indicates the continued elevation of the source area at least till that time.

Presumably the flexing recorded in the convergence of the early Cisco and Canyon was the continued expression of the more pronounced movements that took place in the Strawn. The subsidence of the synclinal basin postulated by Cheney seems to have been gradual, more or less regular, and recurrent, as indicated by the consistent convergence between recognizable datum beds that were deposited on its margin. Along with these movements, however, there occurred others which seemingly had no definite relation to them, for they took place during the period of subsidence not only in the

[7]Cheney, M. G., Stratigraphic and structural studies in north-central Texas: Univ. Texas Bull. 2913, pls. 3 and 8, 1929.

areas of convergence but also affected the parallel formations on the structurally static west side of the Bend axis in the upper Cisco. These movements resulted in the advance and retreat of the sea and are expressed in a series of unconformities, filled channels, beds that represent the pulsating advance and retreat of limestone and shale deposition, and other features. As these movements alternated throughout the period of differential subsidence of the synclinal area flanking the Ouachita belt of Paleozoic rocks and affected also the static area west of the Bend axis, it would seem that the fluctuations of sea level were independent of the immediate obvious local structural movements.

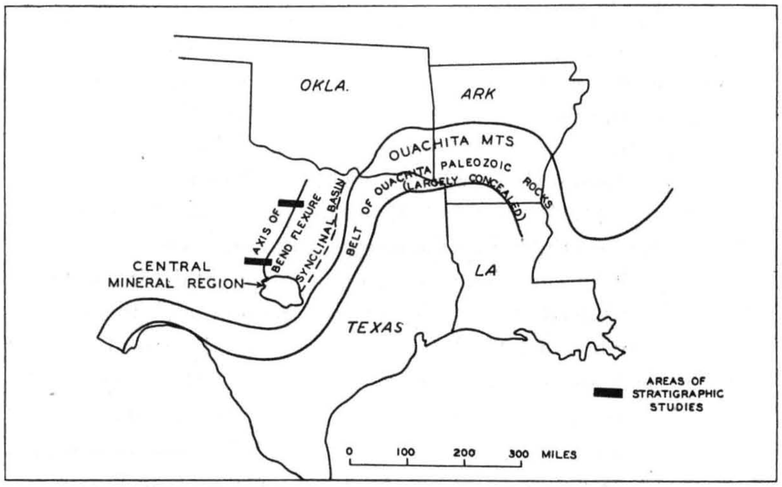

Fig. 9. Sketch showing the relation of areas studied to certain structural features of the region. (After Miser.)

Looked at as a whole, the stratigraphic column presents a record of almost continuous rise and fall of sea level. Some of the fluctuations were expressed in changing types of sediments, others by unconformities, by terrestrial deposits with tree trunks in place, by impure coal deposits, by tidal channels, and by marine deposits in a bewildering and disorderly sequence.

It is axiomatic that the sedimentary deposit of clastic material indicates erosion at the place of origin of the sediments, which have been transported from a land area and distributed and sorted by river, current, wave, and tide. The region from which they came must have been eroded in tidal channels or steep-sided ravines, or else it must show maturely eroded surfaces, depending on the length of exposure, hardness of rock, gradient, and other factors. Several of the erosion surfaces noted in the Cisco of the Brazos Valley have a relief approaching or exceeding 100 feet. Withdrawal of the sea far enough to provide a gradient for erosion of this magnitude might well be expressed in hundreds of miles. If the surface were tilted the distance would be less, but there is no evidence in the late Cisco of any tilting and very little in the early Cisco. It has been suggested that submarine scour of land streams might be effective in producing these surfaces, but even if it could be demonstrated that such continents and rivers existed this explanation seems to be eliminated by the fact that at least some of the unconformable surfaces were not merely channeled but maturely dissected. The deposits of the post-Bunger No. 2 cycle, for example, occupy a basin about 100 feet deep and not less than 10 miles wide. Other surfaces, such as that preceding the No. 7 cycle, the No. 9 cycle, and the Avis sandstone, show mature dissection. The Kisinger channel is cut through the Home Creek limestone, a 50-foot limestone bed, and its bottom is eroded into the Ranger limestone. The Home Creek was already hard enough to break off in huge solid blocks on the side of the channel during the erosion period, and there is no reason to suppose that the Ranger was not equally consolidated at the time. Such erosion seems to indicate a subaerially eroded valley, for a submarine current, not being dependent on gradient, would tend to broaden its channel in the softer shale beds rather than erode hard limestone. The size and velocity of the submarine current demanded for submarine erosion of the Kisinger and other channels would in any case seem to eliminate it as an explanation.

The weight of evidence seems to favor the withdrawal of the sea from the areas, even though this involves extraordinary fluctuations in sea level.

At the time the Kisinger channel was being eroded the Ouachita Mountains were still being raised and folded. The synclinal area which flanked the Ouachita belt of Paleozoic rocks to the west and north and in which in Texas the Strawn beds had been deposited was still subsiding. The abrupt tapering of the Kisinger channel toward the west indicates that it had a general easterly course and that the stream was not long. It probably drained into the intermittently subsiding synclinal basin to the east at a time when downward flexing had renewed the synclinal trough and simultaneous withdrawal of the sea had given the margin of the static area west of the syncline a definite topographic relief. After erosion the basin may have been filled with outwash deposits advancing from the east from the coincidentally elevated Ouachita belt with or without the return of the sea.

The source of the chert pebbles is definitely to the east, and, by whatever means it was accomplished, it is a fact that the coarse debris ultimately reached across the basin and was deposited in the dissected area on the west side. A possible example of how this may have been effected is illustrated by the conglomeratic sandstone overlying the Gonzales limestone, as shown in the cross section (Pl. X). The relations strongly suggest either the filling of an eroded and warped basin or the conditions represented by the Avis sandstone, mentioned below.

If the synclinal basin east of the axis of the Bend flexure continued to subside during late Cisco time, an explanation might be afforded for the localization of the erosion cycles on and near the axis of the flexure in much the same way as suggested for the Kisinger channel—that is, by downwarping east of the axis and simultaneous withdrawal of the sea, placing this area at the crest of a gentle eastward slope. In the absence of proof of late Cisco flexing east of the Bend axis, such an explanation, however plausible, is speculative, but all theories seem to call for remote withdrawal of the sea during the erosion periods.

The Avis sandstone, as shown in Plate X, furnishes an example of how some of the sandstones and conglomeratic beds may have been originally distributed. The top of the Avis sandstone is the one datum above the ammonoid zone that fails to show parallelism. This sandstone west of Graham extends upward almost to the horizon of the Blach Ranch limestone, and its upper surface is deeply dissected. On Colorado River the sandstone that corresponds in position to the Avis sandstone is conformably overlain by the *Bellerophon* limestone. The relations suggest that the Avis may have been deposited as an alluvial plain, the deposits sloping basinward from the land area. If in the Colorado River area the alluvial plain sank below sea level, limestone might be deposited upon it. Later erosion, dissecting the exposed parts of the plain in the northern areas, may have failed to remove all of the *Bellerophon* limestone (which Drake found interrupted by erosion in northern Brown County) in the southern area.

No effort has been made to correlate the sandstones of the higher formations of the Brazos area with those in the south, but the correlation by James S. Williams of the Belknap limestone with Waldrip limestone No. 2 should be of considerable aid in establishing the horizons of the unconformities across the interval.

CARBONIFEROUS INVERTEBRATE FOSSILS (EXCEPT FUSULINIDS) FROM NORTH-CENTRAL TEXAS

JAMES STEELE WILLIAMS*

INTRODUCTION

The collections here reported on were obtained in the summer of 1934, when this author was assigned to Wallace Lee's party to assist in stratigraphic and paleontologic studies of the areas described in this report. The writer was ably assisted in collecting at various times by H. D. Miser, Wallace Lee, Ivan J. Fenn, C. O. Nickell, and Fred Yockstick. The chief purpose of the author's field work was to obtain fossils from every fossiliferous bed, in order to augment existing knowledge of their faunas and to determine, if possible, faunal peculiarities by which the beds could be recognized and correlated by geologists making oil and gas and other economic surveys.

All the collections came from rocks now referred to the Pennsylvanian or the Permian. The oldest fauna was obtained from the Graford formation of the Canyon group; the youngest from the Coleman Junction limestone member of the Putnam formation, which is now tentatively assigned to the Wichita group (Permian).

By far the greater number of collections came from the Graham formation of the Cisco group, which is one of the most fossiliferous of Carboniferous formations. Not only are fossils abundant in it but at the localities where the most fossiliferous zones are exposed fossils are weathered out on the shale slopes and may be picked up free from matrix. Many of these weathered-out fossils preserve the details of morphology to a surprising degree. Collections from this formation contain a wide variety of species, and nearly every species is represented by a great number of individuals. One or more of nearly every invertebrate class known from Carboniferous rocks, including many species of each of the classes generally found, were obtained. The fossiliferous character of the Graham formation has been known for some time, and many palenotologists have collected from it. Despite this previous work, however, some new

*United States Geological Survey.

species were discovered and data of value in correlation were obtained, even from the better-known fossil zones. In addition, collections were obtained from some of the limestone beds that have until now supplied no material for published lists. One of the most interesting finds was the discovery by Mr. Lee of a piece of a nautiloid cephalopod that is probably larger than any cephalopod previously described from Pennsylvanian rocks. The stratigraphic and economic value of the collections is particularly high, because practically all the collections were carefully made from beds and localities whose positions relative to others in nearby regions had been determined by the detailed mapping of Mr. Lee's party.

Some collections contained only fusulinids and other microfossils. These, together with the fusulinids from macrofossil collections, were turned over to L. G. Henbest, of the United States Geological Survey, for study. A report on some of these collections is presented in another paper. (See pp. 237–247.) Other fusulinid collections are discussed on pages 48 and 49. Plant collections were studied by C. B. Read, also of the United States Geological Survey. His identifications and conclusions are presented on pages 14, 52, 53, 125, 135, and 136.

OUTLINE OF REPORT

The arrangement of this report is stratigraphic, and the collections are therefore discussed individually or collectively under groupings based on the formations from which they were obtained. Subordinate groupings indicate whether they have been collected from the Brazos River valley or from the Colorado River valley, the two areas in which Mr. Lee's party made surface studies. Collections from the oldest formations are discussed first. By this procedure the collections are arranged in the following order:

Collections from Graford formation redefined, Canyon group, Pennsylvanian. (Extends from top of Palo Pinto limestone up to top of Winchell member, which includes the Clear Creek limestone of Drake in the Colorado River region.)

Collections from Brad formation restricted, Canyon group, Pennsylvanian. (Extends from top of Ranger limestone member (the Home Creek limestone of Drake at type locality) down to top of Winchell member of Graford formation.)

Collections from Caddo Creek formation, Canyon group, Pennsylvanian. (Includes Hog Creek shale member of Plummer and Moore (typical), overlain by Home Creek limestone member of Plummer and Moore.)

Collections from Graham formation, Cisco group, Pennsylvanian. (Extends from top of Home Creek limestone member of Plummer and Moore up to top of Wayland shale member and includes Gunsight limestone member.)

Collections from Thrifty formation, Cisco group, Pennsylvanian. (Extends from top of Wayland shale up to top of Breckenridge limestone member in the Brazos River region and to top of Chaffin limestone member in the Colorado River region.)

Collections from Harpersville formation, Cisco group, Pennsylvanian. (Extends from top of Breckenridge limestone up to top of Saddle Creek limestone member.)

Collections from Pueblo formation, Cisco group, Pennsylvanian. (Extends from top of Saddle Creek limestone up to top of Camp Colorado limestone member.)

Collections from Moran formation, Wichita group, Permian. (Extends from top of Camp Colorado limestone up to top of Sedwick limestone member.)

Collections from Putnam formation, Wichita group, Permian. (Two collections from Coleman Junction limestone, the top member of the Putnam formation.)

Correlations, faunal characteristics, and age assignments of the various formations and their members are discussed under each formation after the faunas of the individual units have been described.

Complete fossil lists are not given for all collections, and therefore the faunas of some formations or members are incompletely represented. The chief emphasis has been laid on obtaining a representation of the faunal characteristics of each stratigraphic unit. To this end, collections were made and field data gathered to show the relative abundance of the individual elements in the faunules, as well as to furnish lists of the total faunal composition. The most detailed identifications were made of those forms that promised to have stratigraphic significance. Some of the other forms, especially those represented by poor material, were classified only as to their generic affiliations. This course was adopted because of the necessity of finishing the report in a short time. The examination of the thousands of individuals belonging to nearly all classes of invertebrate animals on which this report is based was completed in January to April, 1935. More detailed identifications of some of the lots will be made later when time is available.

LOCALITIES OF INDIVIDUAL COLLECTIONS

A very brief description of the locality for each collection individually considered is given under the faunas of the various zones. More complete descriptions are given in the register of localities (pp. 226–235).

DATE OF IDENTIFICATIONS

The fossils here reported on were identified during January, February, March, and April, 1935. Literature reaching the author's desk after April 1, 1935, has not been considered and changes in fossil names made in the literature or as a result of the author's investigations since that date have not been made here. They will be considered in future reports. In a few instances the author has not followed the usage of the most recent authors even though changes in nomenclature suggested by them were made before April 1, 1935. Some of these failures to follow these authors are because this writer definitely disagrees with them on philosophical or morphological grounds; others are due merely to a lack of sufficient time to investigate for himself changes about which the writer has some slight misgivings. With one or two exceptions, the fossil names about whose use there is some uncertainty are enclosed in quotation marks. In no instance should there be any doubt because of this situation as to which species is meant and it is therefore of interest only to paleontologists working on rocks of Carboniferous age.

COLLECTIONS FROM THE GRAFORD FORMATION

Collections were obtained from the Graford formation only in the Colorado River area. The following members, in ascending order, were seen in the field: basal member (Brownwood shale and limestone of some authors), Adams Branch limestone, Cedarton shale, and Winchell member (which includes four limestones). Collections were made during brief stops on a hasty trip with H. D. Miser, Wallace Lee, C. O. Nickell, and Fred Yockstick, to examine formations previously mapped by C. O. Nickell. No collections were made from this formation on the later trip because the main problems were not centered there.

Basal shale and limestone member.—Two collections, 7505 and 7506, were obtained from the basal shale and limestone member.

Both came from the same locality, on the north bank of Colorado River about 3 miles east of Winchell, in the Mercury quadrangle.

Collection 7506 came from a 3- to 6-inch bed of light olive-drab argillaceous limestone. This bed contains *Composita subtilita* (Hall) in abundance. A moderately large productid, *"Productus" (Dictyoclostus) portlockianus* Norwood and Pratten, large individuals of *Spirifer (Neospirifer) triplicatus* Hall, and crinoid stems are common. Specimens of *Spirorbis* and of an incrusting bryozoan were also collected, but these are rare, having been seen only on a few of the Compositas.

Collection 7505 came from a thin brown limestone conglomerate composed of crinoid stems and other fossils and lime pellets. This limestone is less than a foot thick. It is about 10 feet above the limestone that yielded collection 7506 and is separated from it by shale. Fossils are abundant. An incomplete list follows:[1]

Crinoid stems (va)
Fenestella, two or more species (r to c)
Polypora, one species (r)
Rhombopora lepidodendroides Meek (r)
Derbya crassa (Meek and Hayden) (vc)
"Productus" (Juresania?) nebrascensis n. var. aff. P. ovalis (Dunbar and Condra) (r to c)
"Productus" sp. undet., one fragment
Composita subtilita (Hall) (c)
Myalina subquadrata Shumard (vc)
Myalina recurvirostris? Meek and Worthen (r)
Deltopecten texanus? Girty, fragment of an immature individual (r)
Astartella concentrica (Conrad) (r)
Other pelecypods represented by fragments.

Adams Branch limestone member.—One collection, 7507, was made from limestones of the Adams Branch limestone member exposed a few feet northwest of a bridge over Colorado River on the highway in the south edge of Winchell, in the Mercury quadrangle. Fossils are rare in this locality. The collection listed was obtained from the solid rock on July 14, 1934, by Miser, Lee, Nickell, Yockstick, and Williams.

Crinoid stems (r)
Composita subtilita (Hall) (r)
Fragments of other brachiopods (r)

[1]In the fossil lists va signifies very abundant, a abundant, vc very common, c common, r rare, vr very rare.

Cedarton shale member.—Although it was investigated casually at two or three localities, the Cedarton shale member yielded no fossil collections.

Winchell member.—One collection, 7508, was obtained from No. 2 limestone (second limestone from base of the Winchell member and equivalent to top bed of Drake's Clear Creek limestone) along the south side of the road, at the first rise, about half a mile west of Winchell. Fossils are rare. Same date and party as collection 7507.

"Productus" (Dictyoclostus) portlockianus Norwood and Pratten, one incomplete specimen
Spirifer sp. undet., one fragment
Composita subtilita (Hall) (r)
Bellerophon? sp. undet., internal mold of a large form

Age and correlation of Graford formation and its members.—The members examined are so sparsely fossiliferous and the time spent in collecting from them was so inadequate that data sufficient for correlation were not obtained.

COLLECTION FROM THE BRAD FORMATION

Only one collection was obtained from the Brad formation. It came from the Colorado Valley from beds included in the Ranger limestone member of Plummer and Moore. This limestone is now considered to be the same as the Home Creek of Drake at the Home Creek type locality. A discussion of this question by Nickell is given elsewhere in this report.

The locality from which this collection came is on Mukewater Creek, east of Whon. The beds exposed here are bluish-gray finely crystalline to dense limestone, with darker stringers of calcite and scattered yellow-brown spots of iron oxide about the size of a pinhead. The beds contain many fossils, as shown by sections on the weathered surfaces, but identifiable fossils are difficult to obtain. The most abundant species are *Campophyllum torquium* (Owen) and a productid, *Marginifera? lasallensis* (Worthen), but *Composita subtilita* (Hall) is also common. The following species were identified in this collection, which is Carboniferous paleontology No. 7580.

Campophlyyum torquium (Owen) (vc)
Crinoid stems (r to c)
Enteletes hemiplicatus (Hall), imperfect specimens that may belong to the variety plattsburgensis (r)
"Productus" (Linoproductus) prattenianus Norwood and Pratten, young (r)
"Productus" (Echinoconchus) sp. undet., fragment (r)
Marginifera? lasallensis (Worthen) (vc)
Marginifera wabashensis (Norwood and Pratten) var. A. (r to c)
Spirifer (Neospirifer) triplicatus Hall (r to c)
Punctospirifer kentuckyensis (Shumard) (r)
Composita subtilita (Hall) (c)
Bellerophon? sp. undet., internal mold (r)
Fragments of bone.

Age and outside correlation of the Brad formation.—The lack of collections from the Ranger limestone member and other parts of the Brad formation of the Brazos River valley precludes correlation of the members in the two areas here considered. The one collection from the Colorado River valley is hardly a sufficient basis for a discussion of the faunal peculiarities of the Brad, although the presence in it of a species of *Enteletes* together with certain other species serves to limit the age range of the Brad in terms of the northern Midcontinent region. Such an age limitation is further suggested by the absence of certain species characteristic of other horizons. None of the species that are common in and definitely restricted to the Des Moines group occur in it. These include *Chaetetes milleporaceus* Edwards and Haime, *Prismopora triangulata* (White), *Chonetes (Mesolobus) mesobolus* Norwood and Pratten and its varieties, *Marginifera muricatina* Dunbar and Condra and its variety *missouriensis*, and *Spirifer rockymontanus* Marcou.

The *Enteletes* contributes toward limiting the age of the Brad because this genus is not known to occur in beds as low as the Wewoka formation of Oklahoma or in beds below the Kansas City group in the northern Midcontinent region. Another significant form in the Brad is *Marginifera? lasallensis* (Worthen), which although it has been questionably identified from the Wewoka (probably of Des Moines age) is more characteristic of the Kansas City group and higher beds. These two fossils seem to imply that the Brad is no older than the Kansas City and is hence younger than the Wewoka.

The upper limit of the Brad formation in terms of the Midcontinent section cannot be definitely determined from the collections available for study. No species in the fauna is limited to the

Kansas City group. One of the varieties that is questionably identified, *Enteletes hemiplicatus* var. *plattsburgensis* Newell, has a known range that extends from upper Kansas City to upper Lansing, but as the specimens obtained in this study are questionably identified, the range of this variety does not limit the Brad to a Lansing age. Data from overlying formations must be relied upon for determining how young the Brad formation is.

COLLECTIONS FROM THE CADDO CREEK FORMATION

In the area investigated the Caddo Creek formation consists of the Hog Creek shale member of Plummer and Moore at the base and the Home Creek limestone member of Plummer and Moore above.

Home Creek limestone member of Plummer and Moore.—The Home Creek limestone member, and in fact the whole Caddo Creek formation, is but sparsely fossiliferous, especially in the Brazos River valley. The lists here given are by far the largest published from that area. Fossils are not so rare in the Colorado River valley, but even there a long time is required to obtain a substantial collection.

Two collections, 7490 and 7546, were made in the Brazos River valley. Except for fusulinids, few fossils were obtained. Collection 7490, from Herron Bend, contains abundant fusulinids, crinoid stems, and echinoid spines and rare unidentifiable fragments of horn corals, brachiopods, and pelecypods. The only identifiable species found was *Squamularia perplexa* (McChesney) which is rare.

A larger collection, 7546, was obtained from the lower part of this member at Ming Bend, near the Ming Bend School, but a much longer time was spent in collecting. Here the rock is a medium gray limestone, dense to almost lithographic, with brown spots. The common species here are *Composita subtilita* (Hall) and *Squamularia perplexa* (McChesney). Other fossils are rare. The following list shows the species collected.

Fusulinids (r)
Horn coral, unidentifiable
Crinoid stems and plates (r)
Fistulipora sp. (r)
Marginifera wabashensis (Norwood and Pratten) var. A (r)
"Productus" (Dictyoclostus) sp. undet., fragmentary dorsal valves (r)
Wellerella? sp. undet., fragment (r)
Dielasma bovidens (Morton), young individuals (r)
Spirifer (Neospirifer) triplicatus Hall (r)

Squamularia perplexa (McChesney) (c)
Punctospirifer kentuckyensis (Shumard) (r)
Hustedia mormoni (Marcou) (r)
Composita subtilita (Hall) (c)
Acanthopecten? sp., fragment (r)
Phanerotrema grayvillense (Norwood and Pratten) (r)
Indeterminate gastropods
"Griffithides" sp. undet., fragment of a pygidium (r)

Five collections, some of them hastily made, were procured in the Colorado River valley from beds thought to belong to the Home Creek of Plummer and Moore. During the field work these beds were tentatively called "*Syringopora* limestone." Of these five collections, one was composed wholly of fusulinids. The other four collections are treated below.

All the collections came from a locality east of Whon. Two, 7509 and 7561, were obtained at the same locality, along a ranch road on the hill south of the ford over Home Creek on the Gill ranch; one, 7578, along the road leading to the ranch house on the Gill ranch, southwest of the house; and one, 7581, along Mukewater Creek, above its junction with Home Creek.

The first two collections, 7509 and 7561, came from beds which contain a considerable number of fossils, as shown in sections and by fragments on weathered surfaces, but which do not readily yield identifiable specimens. *Composita subtilita* (Hall) is the most abundant form. Small crinoid columnals, echinoid spines, and echinoid plates are common on weathered surfaces. Specimens of *Syringopora* sp. undet., *Campophyllum* cf. *C. torquium* (Owen), and *Punctospirifer kentuckyensis* (Shumard) are occasionally seen.

Both the other collections are larger. Collection 7581, from beds along Mukewater Creek, has the following species:

Fusulinids (r)
Campophyllum torquium (Owen) (r to c)
Syringopora sp. undet. (c)
Crinoid columnals (r to c)
Fenestella? sp. undet. (r)
"Productus" (Dictyoclostus) portlockianus, small variety, new? (r)
"Productus" (Linoproductus) prattenianus Norwood and Pratten (r to c)
"Productus" (Linoproductus) sp. undet., two fragments
"Productus" (Linoproductus or Cancrinella) boonensis? Swallow, young? (r)
Marginifera wabashensis (Norwood and Pratten) var. A (r)

Dielasma bovidens (Morton) (r to c)
Spirifer (Neospirifer) triplicatus Hall (c), variety having low convexity
Squamularia perplexa (McChesney) (c)
Composita subtilita (Hall) (c)

Collection 7578 is the largest one made from the Home Creek of Plummer and Moore. It contains the following forms:

Fusulinids (r)
Campophyllum torquium (Owen) (r to c)
Syringopora sp. undet. (r)
Crinoid columnals (r to c)
Echinoid spines and plates (r)
Derbya cf. D. bennetti Hall and Clarke (r)
Meekella striatocostata (Cox) (r)
Meekella striatocostata n. var.? aff. M. convexicosta Dunbar and Condra (c)
"Productus" (Pustula or Echinoconchus) sp. undet., one poorly preserved specimen
Marginifera? lasallensis (Worthen) (r)
Spirifer (Neospirifer) triplicatus Hall (r)
Spirifer (Neospirifer) sp. undet., fragment, possibly S. texanus Meek (r)
Crurithyris planoconvexa (Shumard) (r to c)
Punctospirifer kentuckyensis (Shumard) (r)
Hustedia mormoni (Marcou) (r to c)
Composita subtilita (Hall) (c)
Gastropod fragments (r)

Correlation between the Brazos and Colorado River valleys.—Neither the collections from the Home Creek limestone of the Brazos River valley nor those from the Home Creek limestone of Plummer and Moore of the Colorado River valley are sufficiently distinct from the faunas of other limestones below the Graham formation in these two valleys to establish certain correlation between these two limestones. More species are common to these two limestones than to the Home Creek of Plummer and Moore of the northern area and the Ranger limestone of Plummer and Moore (= Home Creek of Drake of type locality) of the southern area, but as the writer's collections from the last-named limestone are smaller than those from either of the others and as the species common to the Home Creek of Plummer and Moore of the northern area and the Home Creek of Plummer and Moore of the southern area are long-ranging forms, the relatively greater number of species common to them is not certainly significant. The collections from the Home Creek of Plummer and Moore of the northern area lack the Syringoporas, Derbyas, Meekellas, and some of the productids of the Home Creek of Plummer and Moore of the southern area, whereas the Home Creek of Plummer and Moore of the southern area lacks only a few rare forms of the Home Creek of Plummer and Moore of the northern area. Neither the discrepancies between the collections from the two Home Creek limestones of Plummer and Moore nor the likenesses between them are sufficient to affect correlations made by other than faunal means.

Of the faunas of the limestones in the Brazos River valley above the Home Creek of Plummer and Moore and below the ammonoid zone 20 to 40 feet above the Bunger limestone, the fauna of the Bunger limestone has most in common with that of the Home Creek limestone of Plummer and Moore of the southern area. In fact, more species are common to the writer's collections from the Bunger (of the Brazos River area) and the Home Creek of Plummer and Moore of the Colorado River area than to the Home Creek limestones of Plummer and Moore of the two areas. The author is more inclined to attribute the greater number of species common to these beds to the larger faunas of the Bunger and southern Home Creek of Plummer and Moore than to an age equivalence, and to accept the correlation made by nonpaleontologic data of the two Home Creek limestones of Plummer and Moore. This conclusion is supported by the facts that the additional species common to the Bunger and the southern Home Creek are all long-ranging forms and that largely the same differences that exist between the two Home Creek limestones of Plummer and Moore exist also between the Bunger and the Home Creek of Plummer and Moore of the southern area.

COLLECTIONS FROM THE GRAHAM FORMATION

The Graham formation is the source of most of the fossils described in this report. Several zones in it are abundantly fossiliferous. These zones furnish the best collecting the writer has ever seen from a Carboniferous formation. Most of the abundantly fossiliferous zones are shale zones. Literally thousands of specimens were obtained from the various shale members. These specimens represent not only a profusion of individuals but also a profusion of species, including representatives of nearly every order and class of invertebrates represented anywhere in Carboniferous rocks.

In all, 100 collections were made from the Graham formation. Of these, 14 contained only fusulinids and possibly other microfossils. These were referred to L. G. Henbest, of the United States Geological Survey for study. Three collections contained only plants and were referred to C. B. Read, also of the United States Geological Survey. The remaining 83 collections, except the fusulinids contained in them, which were also turned over to Mr. Henbest, form the basis for the part of this report that deals with the Graham formation.

Most of these collections were obtained in the Brazos River valley, partly because a longer time was spent there than in the Colorado River valley but also partly because that area has a greater number of fossiliferous zones and a thicker section.

BRAZOS RIVER VALLEY

The subdivisions of the Graham formation in the Brazos River valley from which collections were obtained are given in stratigraphic order below. The various units are designated by names employed by Mr. Lee in another part of the report.

Base of Avis sandstone (basal member of Thrifty formation in Brazos River valley).

Graham formation:

1 Gb.[2] Limestone 9b of post-Bunger cycle No. 9, 76 feet above basal limestone of Wayland shale member.
2 Gb. Limestone 9a of post-Bunger cycle No. 9.
3 Gb. Fossiliferous shale zone near base of Wayland shale member.
4 Gb. Limestone 9 of post-Bunger cycle No. 9.
4a Gb. Gunsight limestone member not definitely recognized in standard section; may be equal to one or two of beds 3 Gb to 8 Gb.
5 Gb. Limestone of No. 7 post-Bunger cycle.
6 Gb. Limestone of No. 6 post-Bunger cycle.
7 Gb. Limestone of No. 5 post-Bunger cycle.
8 Gb. Limestone of No. 3 post-Bunger cycle.
9 Gb. Shale 60 to 80 feet above Bunger limestone member and below limestone of No. 3 post-Bunger cycle.
10 Gb. Limestone bed, 3 inches thick, 120 feet above Bunger limestone member (possibly in No. 2 post-Bunger cycle).
11 Gb. Shale (ammonoid zone 20 to 40 feet above Bunger limestone member).

[2]G = Graham formation; b = Brazos River valley.

12. Gb. Bunger limestone member.
13 Gb. "Dirty yellow" limestone 20 to 25 feet below Bunger limestone member.
14 Gb. Gonzales limestone member.
15. Gb. Thin limestone 50 to 60 feet above Salem School limestone member.
16 Gb. Marine shale above Salem School limestone member.
17 Gb. Salem School limestone member (no collection except float).
18 Gb. Shale immediately below Salem School limestone member.
19 Gb. Shale above conglomerate in Kisinger channel.

Top of Home Creek limestone of Plummer and Moore (top member of Caddo Creek formation.)

Collections from shale above conglomerate in Kisinger channel deposit (fossil zone 19 Gb).—Only one collection, which was composed wholly of plants and transferred to C. B. Read, was made from the shale above the conglomerate in the Kisinger channel deposit.

Collections from shales below Salem School limestone member (fossil zone 18 Gb).—Two collections, 7488 and 7586, both from Herron Bend of Brazos River, include float from Salem School limestone and extend down to beds within 1 foot of the top of the Home Creek limestone. A composite but partial list of both collections follows.

Lophophyllum profundum (Edwards and Haime) (r to c)
Crinoid stems and plates (c)
Bryozoan, fenestelloid, fragment (r)
Chonetes granulifer Owen (r to c)
Chonetes granulifer var. transversalis Dunbar and Condra (r)
"Productus" (Dictyoclostus) portlockianus Norwood and Pratten, small var., probably new (r to c)
Marginifera lasallensis (Worthen) (r to c)
Marginifera splendens (Norwood and Pratten), var. A (r)
Dielasma bovidens (Morton) (r)
Spirifer (Neospirifer) triplicatus Hall (r to c)
Punctospirifer kentuckyensis (Shumard) (r)
Composita subtilita (Hall) (a)

Collections from marine shale above Salem School limestone member (fossil zone 16 Gb).—The marine shale above the Salem School limestone member is one of the most fossiliferous zones in the Graham. Five collections were obtained from it. One of them contained only Foraminifera. Of the others, three—7441, 7452, and 7591—came from the Graham-Finis road near Connor Creek.

The other, 7367, came from Herron Bend, about half a mile southeast of Salem School. A composite list of the three collections from the Graham-Finis road is given below:

Fusulinids (r to c)
Coelocladia? n. sp.? aff. C. spinosa Girty (c)
Sponge?, boring form
Lophophyllum profundum (Edwards and Haime) (a)
Lophophyllum profundum radicosum Girty (c)
Syringopora sp. undet. (r)
Crinoid stems (c)
Echinoid spines and plates (c)
Fistulipora sp. (r)
Fenestella sp. (r)
Polypora sp. (r)
Rhombopora lepidodendroides Meek (r to c)
Bryozoa, unidentified, several forms
Rhipidomella carbonaria (Swallow) (r to c)
Derbya sp. undet., fragments (r)
Chonetes granulifer Owen (c)
Chonetes granulifer var. transversalis Dunbar and Condra (r)
Chonetes (Lissochonetes) geinitzianus n. var. aff. C. senilis (Dunbar and Condra) (vc)
"Productus" (Juresania) symmetricus McChesney (r)
"Productus" (Juresania) sp. undet. (r)
"Productus" (Echinoconchus) semipunctatus? Shepard (r)
"Productus" (Dictyoclostus) sp. undet. (r)
"Productus" (Linoproductus) n. sp. A (r)
Spirifer (Neospirifer) triplicatus Hall (c)
Spirifer (Neospirifer) texanus Meek (r to c)
Crurithyris planoconvexa (Shumard) (r to c)
Hustedia mormoni (Marcou) (r)
Composita subtilita (Hall) (r)
Nucula anodontoides Meek (vc)
Anthraconeilo taffiana Girty (r)
"Nuculopsis" ventricosa (Hall) (r to c)
Yoldia glabra Beede and Rogers (c)
Myalina sp. undet., fragments (r)
Deltopecten sp. undet., fragment (r)
Astartella concentrica (Conrad) (r to c)
Other pelecypods, represented by poor specimens
Dentalium n. sp. aff. D. semicostatum Girty (r)
Dentalium subleve Hall (r to c)
Plagioglypta cf. P. annulistriata (Meek and Worthen) (r)
Plagioglypta sp. undet., fragments of a large form (r to c)
Bellerophon stevensianus? McChesney, small form (c)
Bellerophon sp. undet., internal mold, large form (r)
Patellostium montfortianum? (Norwood and Pratten) (r to c)
Euphemites carbonarius (Cox) (a)
Pharkidonotus tricarinatus (Shumard) (r to c)
Yunnania? sp., probably new (r to c)
Worthenia tabulata (Conrad) (r to c)
Phanerotrema grayvillense (Norwood and Pratten) (r to c)
Phanerotrema tenuistriatum (Shumard) (c)
"Orestes" brazoensis (Shumard) (r to c)
"Murchisonia" sp. undet. (r to c)

Goniasma lasallensis? (Worthen), poor specimens (r)
Orthonema schucherti Knight (r)
Trepospira depressa? (Cox), immature individuals only (r to c)
Straparollus (Euomphalus) plummeri Knight (r)
Straparollus (Euomphalus or Schizostoma) subrugosus Meek and Worthen (c)
Naticopsis sp. undet., fragmentary (r)
Pseudozygopleura?, two or three species
Meekospira sp. undet. (r)
Soleniscus (Macrochilina) cf. S. paludinaeformis (Hall) or S. brevis (White) (c)
Trachydomia sp. undet., fragmentary specimen (r)
Pseudorthoceras knoxense (McChesney) (vc)
Pseudorthoceras seminolense Girty (c)
"Orthoceras" (Dolorthoceras) ciscoense (Miller, Dunbar and Condra) (r)
"Orthoceras" (Euloxoceras) greenei (Miller, Dunbar and Condra) (r to c)
Domatoceras sculptile? (Girty) (r)
Gastrioceras sp. undet., fragment
Cephalopods, other species, including a large one, represented by fragments.

Collection 7367 is smaller and has *Straparollus (Euomphalus or Schizostoma) subrugosus* Meek and Worthen, *Yoldia glabra* Beede and Rogers, and small individuals of *Astartella concentrica* (Conrad) as the most abundant forms. It also contains *Rhipidomella carbonaria* (Swallow). Other species, with the possible exception of two unidentifiable pelecypods, are the same as those in the other collections from this zone.

Through a comparison of collections, which is given on pages 169–171, this zone may be distinguished from the other shale zones in the Graham by the occurrence together and in the proportions indicated of *Coelocladia* n. sp.? aff. *C. spinosa* Girty (c), *Rhipidomella carbonaria* (Swallow) (r to c), *Chonetes (Lissochonetes) geinitzianus* n. var. aff. *C. senilis* (Dunbar and Condra) (vc), *Bellerophon stevensianus?* McChesney (c), *Euphemites carbonarius* (Cox) (a), and other gastropods (vc). The first two species do not occur in the writer's collections in shales above this zone, but the *Rhipidomella* has been listed by Plummer and Moore from a higher shale zone. The last three species are known from higher zones, but their relative abundance here seems significant. The absence of any considerable number of coiled cephalopods also seems significant and supplies an additional criterion that may be tentatively used to distinguish this shale zone from the shale zone that lies above the Bunger limestone member.

Collections from a thin limestone about 50 to 60 feet above the Salem School limestone member (fossil zone 15 Gb).—Two collections were obtained along the Graham-Finis road, about 9 miles southeast of Graham, from a very thin yellow shaly limestone above fossil zone 16 Gb. One collection contained only fusulinids. The other collection, 7513, contained the following species:

Fusulinids (c)
Crinoid stems and plates (c)
"Productus" (Dictyoclostus) americanus (Dunbar and Condra) (c)
Spirifer (Neospirifer) triplicatus Hall (c)
Pharkidonotus tricarinatus (Shumard) (r to c)
Yunnania? sp. undet., fragment (r)
Straparollus (Euomphalus) plummeri Knight (r)
Pseudorthoceras seminolense Girty (r)
Fragment of a large coiled nautiloid (r)

Collections from Gonzales limestone member (fossil zone 14 Gb).—Five collections were made from the Gonzales limestone member. Three of them contained only fusulinids. The remaining collections are listed below. Both of them were obtained about 9 or 10 miles southeast of Graham. Collection 7512 came from the hill north of Connor Creek School on the Graham-Finis road. It contained the following forms:

Crinoid stems and plates (r to c)
Meekella? sp. undet., fragments (r)
Marginifera wabashensis (Norwood and Pratten) var. B (r)
Squamularia perplexa (McChesney) (c)
Bellerophon? sp. undet., internal mold (r)

Collection 7514 came from the first hill east of the place where Connor Creek crosses the Graham-Graford road, south of the road.

Fusulinids (r to c)
Campophyllum? sp. undet., fragments (r)
Crinoid stems (r)
Echinoid spines (r)
Rhipidomella? cf. R. carbonaria (Swallow), immature forms (r to c)
Squamularia perplexa (McChesney) (r to c)
Crurithyris planoconvexa (Shumard) (r to c)
Phanerotrema? sp. undet., fragments (r)

Collection from dirty-yellow limestone 20 to 25 feet below the Bunger limestone member (fossil zone 13 Gb).—Three collections were made from limestone of the zone 20 to 25 feet below the Bunger limestone member. Two, 7515 and 7516, came from limy zones about 5 feet apart near a house in a saddle about 4 miles east of Graham on the Graham-Graford road. The other, 7519, came from a locality about three-quarters of a mile southeast of Bunger, from a zone 22 feet below the Bunger limestone.

Collection 7515 was obtained from a 6- to 8-inch limestone or limy zone in a shale. This zone is almost a coquina of Compositas, but branching Bryozoa and *"Productus" (Juresania) nebrascensis* are also very common. This zone is recognizable locally by its abundance of these fossils. Collection 7516 came from a bed about 5 feet above 7515. A composite but partial list from both collections follows:

Crinoid stems and plates (c)
Tabulipora? sp. undet. (c)
Fenestella sp. undet. (r to c)
Polypora sp. undet. (r to c)
Other Bryozoa (c)
Orbiculoidea, two species (r to c)
Derbya cf. D. crassa (Meek and Hayden), immature individuals (c)
"Productus" (Juresania) nebrascensis Owen (vc)
"Productus" (Linoproductus) prattenianus Norwood and Pratten (r to c)
Spirifer (Neospirifer) triplicatus Hall (r to c)
Composita subtilita (Hall) (a)
Myalina subquadrata Shumard (fragments common)
Deltopecten texanus Girty (r)
Other pelecypods, represented by unidentified specimens, one species
Bellerophon stevensianus? McChesney (r), one broken specimen
Patellostium montfortianum (Norwood and Pratten) (r)
Bucanopsis sp. undet. (r)

The beds from which collection 7519 was obtained have a very strong lithologic resemblance to those that yielded the collections listed above. They consist of yellow-brown argillaceous sandy limestone, which occurs in thin beds in a shale interval and shows many maroon splotches. The collection is very similar to the other two, except that it lacks *Composita subtilita* (Hall), the most abundant species in the other collections. The horizon of 7519 is thought to be a little higher than that of 7515. The following species were collected:

Crinoid stems and plates (r)
Tabulipora? sp. undet. (r to c)
Other Bryozoa (c)
Derbya cf. D. crassa (Meek and Hayden), immature individuals? (c)
"Productus" (Juresania) nebrascensis Owen (vc to a)
"Productus" (Linoproductus) prattenianus Norwood and Pratten (r)
Spirifer (Neospirifer) triplicatus Hall (r to c)
Myalina sp. undet., fragments (r)

Deltopecten texanus Girty (r)
Allerisma? sp. undet. (r), incomplete specimen
Astartella? sp. undet. (r), incomplete specimen

Collections from Bunger limestone member (fossil zone 12 Gb).—Fossils are rare in the Bunger limestone at most localities. Plummer and Moore give long lists of fossils under the heading "Bunger limestone," but these lists include fossils from the underlying and possibly also the overlying shales.

Six collections were obtained by the writer from the Bunger limestone. One of these, from South Bend, contained only fusulinids. Two of the others, 7517 and 7518, came from a locality about three-quarters of a mile southeast of Bunger; two, 7522 and 7523, from a locality near the bridge over Brazos River, 1.8 miles north of South Bend; and one, 7524, from beds along Clear Fork of Brazos River at South Bend. Only at the last-named locality are fossils at all common.

Collection 7517 was obtained from a fine-grained hard bluish-gray limestone with stringers of brown iron oxide. This limestone weathers olive-brown to dark brown. Fossils are rare and can be seen mainly as sections or as fragments on weathered surfaces. The following collection represents about two hours' work:

Fusulinids (c)
Crinoid columnals (r)
Echinoid plates and spines (r)
Punctospirifer kentuckyensis (Shumard) (r)
Composita subtilita (Hall) (r to c)

Collection 7518 contains the same species in about the same numerical ratio as 7517; also one specimen of *Syringopora* sp.

At the locality of collections 7522 and 7523, the Bunger is a fine-grained hard bluish-gray limestone with small dots and stringers of limonite and with stringers of crystalline calcite. Some coarser crystalline pinkish-gray beds occur in the upper part. The lower 3 feet weathers to slabby yellow-brown beds one-half to 1 inch thick. Most of the fossils (collection 7523) came from this lower zone. Fossils, except for sections and for single crinoid columnals, are rare in the solid limestone bed (collection 7522).

Collection 7522:
"Productus" (Linoproductus or Cancrinella) sp. undet. (r)
Marginifera wabashensis (Norwood and Pratten) var. A (r)
Spirifer (Neospirifer) triplicatus Hall (r)
Composita subtilita (Hall) (r to c)

Collection 7523:

- Syringopora sp. undet. (r)
- Echinoid spines (r to c)
- Rhombopora? lepidodendroides Meek (r)
- "Productus" (Juresania) nebrascensis Owen (r)
- Spirifer (Neospirifer) triplicatus Hall (r)
- Composita subtilita (Hall) (a)

Fossils are common in the Bunger along Clear Fork of Brazos River at South Bend. The Bunger here has the same lithology as at the locality of collections 7522 and 7523, except that it has been partly dissolved and so softened by the water that it is not very compact. Some of the beds are crowded with fusulinids. Compositas are especially abundant and easily obtainable throughout the exposure. The following list represents collection 7524:

- Fusulinids (c)
- Syringopora sp. undet. (r to c)
- Crinoid stems and plates (r to c)
- Echinoid spines (r)
- Polypora sp. undet. (r)
- Rhombopora lepidodendroides Meek (r)
- Marginifera wabashensis (Norwood and Pratten) var. A (c)
- Marginifera? lasallensis (Worthen) (r)
- "Productus" (Juresania) nebrascensis Owen (r to c)
- "Productus" (Echinoconchus) semipunctatus Shepard (r)
- "Productus" (Linoproductus) prattenianus? Norwood and Pratten (r), young
- "Productus" (Cancrinella?) sp. undet. cf. P. boonensis Swallow (r to c)
- Camarophoria? n. sp. (r)
- Spirifer (Neospirifer) triplicatus Hall (c)
- Squamularia perplexa (McChesney) (r to c)
- Crurithyris planoconvexa (Shumard) (r)
- Composita subtilita (Hall) (a)
- Deltopecten? sp. undet., young individuals (r)
- Bellerophon stevensianus? McChesney, one incomplete specimen

Collections from ammonoid zone 20 to 40 feet above Bunger limestone member (fossil zone 11 Gb).—The ammonoid zone above the Bunger limestone member, like the zone above the Salem School limestone, is very fossiliferous. It is especially characterized by the number and variety of its coiled cephalopods. As here considered, this zone lies from 20 to 40 feet above the Bunger limestone but in places it extends down to within 2 feet of the Bunger. Most of the collections were obtained about 25 feet above the Bunger. Ten collections were made from this zone—five (7440, 7440A, 7445, 7446, and 7587) from localities in or very near the town of South

Bend, four (7368, 7588, 7589, and 7597) from Bass Mountain, and one (7444) from the vicinity of Thedford Tank.

A list of the species in the various collections from this zone is given in the table below.

Distribution of species from ammonoid zone 20 to 40 feet above Bunger limestone member of Graham formation, Brazos River valley (fossil zone 11 Gb)

	7368	7440	7440a	7444	7445	7446	7587	7588	7589	7597
Lophophyllum profundum (Edwards and Haime)	x	x	x	x	x	x	x	x		x
Lophophyllum profundum radicosum Girty	x	x	x		x		x			
Crinoid columnals		x								
Conularia sp. undet.						x				
Trigonoglossa nebrascensis (Meek)		x								
Orbiculoidea missouriensis (Shumard)										x
Orbiculoidea sp. undet.	x									
Lindstroemella patula (Girty)								x		
Chonetes granulifer Owen	x						x			
Chonetes (Lissochonetes) geinitzianus n. var. aff. C. senilis (Dunbar and Condra)								x		x
Chonetes sp. undet.	x									
"Productus" (Juresania) nebrascensis Owen			x		x					
"Productus" (Juresania) symmetricus McChesney		x								
"Productus" (Dictyoclostus) sp. undet.			x							
"Productus" (Cancrinella) n. sp. aff. P. boonensis Swallow	x							x		
Marginifera lasallensis (Worthen)	x	x	x	x	x	x	x			x
Marginifera splendens? (Norwood and Pratten) var. A	x						x			
Marginifera wabashensis (Norwood and Pratten) var. A	x									x
Wellerella sp. A, probably new								x		
Spirifer (Neospirifer) texanus Meek	x					x				
Spirifer (Neospirifer) triplicatus Hall							x			
Spirifer sp. undet.	x				x					
Squamularia perplexa (McChesney)			x			x				
Crurithyris planoconvexa (Shumard)	x	x	x					x		x
Punctospirifer kentuckyensis (Shumard)	x									
Hustedia mormoni (Marcou)		x	x		x	x	x			
Composita subtilita (Hall)		x	x		x		x			
Chaenomya? sp. undet.							x			
"Nucula" anodontoides Meek	x									
Anthraconeilo taffiana Girty	x	x	x					x		
Leda bellistriata Stevens	x	x	x			x		x		
Yoldia glabra Beede and Rogers	x	x	x		x			x		
Aviculipinna sp. undet.		x	x		x	x				
Conocardium sp.	x									
Astartella concentrica (Conrad)	x		x		x			x		
Euphemites carbonarius (Cox)	x	x	x					x		
Pharkidonotus tricarinatus (Shumard)			x			x	x	x		
Worthenia tabulata (Conrad)	x	x	x		x	x	x	x		
Phanerotrema grayvillense (Norwood and Pratten)	x	x	x	x	x	x	x	x		x
Phanerotrema tenuistriatum (Shumard)								x		

Distribution of species from ammonoid zone 20 to 40 feet above Bunger limestone member of Graham formation, Brazos River valley (fossil zone 11 Gb)—Continued

	7368	7440	7440a	7444	7445	7446	7587	7588	7589	7597
"Orestes" brazoensis (Shumard)		x	x							
Trepospira depressa (Cox)	x	x	x	x	x	x	x	x		
Trepospira sp. undet.										x
Pseudozygopleura sp. undet.								x		
Meekospira sp. undet.	x									
Solensiscus (Macrochilina) primigenius (Conrad)	x	x						x		
Platyceras? sp. undet.		x								
Gastropoda, miscellaneous								x		
Pseudorthoceras knoxense (McChesney)	x						x	x		
Pseudorthoceras seminolense Girty	x	x			x					
"Orthoceras" (Mooreoceras) aff. O. tuba Girty		x		x	x					
"Orthoceras" (Dolorthoceras) ciscoense (Miller, Dunbar and Condra)	x	x				x				
"Orthoceras" (Euloxoceras) greenei (Miller, Dunbar and Condra)		x	x			x	x	x		
"Orthoceras" aff. O. cribriliratum Girty	x	x								
"Orthoceras" sp.								x		
Brachycycloceras normale Miller, Dunbar and Condra					x					
Coloceras liratum Girty	x								x	
Metacoceras cornutum Girty									x	
Metacoceras cornutum carinatum Girty	x									
Metacoceras cornutum sinuosum Girty	x									
Domatoceras sculptile (Girty)		x	x							
Domatoceras sp. undet.	x									
"Cyrtoceras" sp. undet.			x							
Gastrioceras sp. undet.			x							
Schistoceras sp. undet.	x									
Dimorphoceras texanum Smith	x								x	
Gonioloboceras welleri Smith									?	

Nearly all the species listed from fossil zone 16 Gb (marine shale above Salem School limestone member, Graham formation) are present in the writer's collections from fossil zone 11 Gb (ammonoid zone 20 to 40 feet above Bunger limestone member, Graham formation) and most of the common species occur in about the same relative abundance in both zones. Of the following species, however, which occur in the proportions indicated in this ammonoid zone the forms marked * are rare in the zone 16 Gb, and the others are not present in the collections here treated from that zone.

Trigonoglossa nebrascensis Meek (r)
"Productus" (Cancrinella) n. sp. aff. P. boonensis Swallow (r)
Marginifera wabashensis (Norwood and Pratten) var. A (r)

Wellerella sp. A, probably new (r)
Aviculipinna sp., probably new (r to c)
*Trepospira depressa (Cox) (a)
"Orthoceras" (Mooreoceras) aff. O. tuba Girty (r)
"Orthoceras" aff. O. cribriliratum Girty, large variety (r)
"Orthoceras" aff. O. cribriliratum Girty, small variety (r)
Brachycycloceras normale Miller, Dunbar and Condra (r to c)
Coloceras liratum Girty (r)
Metacoceras cornutum Girty (r)
Metacoceras cornutum var. carinatum Girty (r)
*Domatoceras sculptile (Girty) (r)
"Cyrtoceras" sp. undet. (r)
Schistoceras cf. S. hyatti? Smith (r)
Dimorphoceras texanum Smith (r to c)
Gonioloboceras welleri Smith (c)

On the other hand, some species that are present in zone 16 Gb (shale above Salem School limestone) are either absent or rare in the ammonoid zone 20 to 40 feet above the Bunger limestone member. Some of these are given below. Those rare in this zone are marked *. Others were not collected from it.

Coelocladia aff. C. spinosa Girty (c)
Rhipidomella carbonaria (Swallow) (r to c)
*Chonetes (Lissochonetes) geinitzianus n. var. aff. C. senilis (Dunbar and Condra) (vc)
Productus (Echinoconchus) semipunctatus? Shepard (r)
Dentalium n. sp. aff. D. semicostatum Girty (r)
Dentalium subleve Hall (r to c)
Plagioglypta cf. P. annulistriata (Meek and Worthen) (r)
Bellerophon stevensianus McChesney (c)
*Euphemites carbonarius (Cox) (a)
Yunnania? sp. undet. (r to c)
"Murchisonia" sp. undet. (r to c)
Goniasma lasallensis (Worthen) (r)
Orthonema schucherti Knight (r)
Straparollus (Euomphalus) plummeri Knight (r)
Straparollus (Euomphalus or Schizostoma) subrugosus Meek and Worthen (c)
Trachydomia sp. undet. (r)

Some of the species that are shown in the above lists from only one of the two zones will in all probability be found in the other as well, and their apparently restricted occurrence may therefore be due to the limitations of collecting rather than to the limitations of stratigraphic range. In fact, some of them are so listed by Plummer and Moore,[3] but because of changes in specific and generic references made necessary by revisions and other work, and

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[3]Plummer, F. B., and Moore, R. C., Stratigraphy of the Pennsylvanian formations of north-central Texas: Univ. Texas Bull. 2132, 1922.

because this writer has not examined their collections, it is not possible to give a complete list of them. If the writer's collections are at all representative, the above lists do effectively show, however, that there is a distinct difference between the faunal assemblages of the zone immediately above the Salem School limestone (fossil zone 16 Gb) and this ammonoid zone, 20 to 40 feet above the Bunger limestone (fossil zone 11 Gb).

Collection from a 3-inch limestone bed, about 120 feet above Bunger limestone member (possibly in No. 2 post-Bunger cycle) (fossil zone 10 Gb).—Only one collection, 7447, was obtained from a 2- to 3-inch limestone bed of uncertain relations lying above a thick clay shale deposit that occurs between the horizon of the No. 6 post-Bunger cycle limestone (which is not present here) and the Bunger limestone and is said by Lee to be 120 feet above the Bunger limestone. The locality is on the point of a ridge west of the mouth of Kickapoo Creek. The list of species follows:

Fusulinids
Lophophyllum profundum (Edwards and Haime) (r to c)
Lophophyllum profundum radicosum Girty (r to c)
Campophyllum? sp. undet., fragments
Crinoid stems (r to c)
Echinoid plates (r)
Fenestella? sp. undet. (r)
Other Bryozoa (r)
Orbiculoidea n. sp.? D (r)
Chonetes granulifer Owen (r to c)
Chonetes granulifer transversalis Dunbar and Condra (r)
"Productus" (Dictyoclostus) sp. undet. (r)
Marginifera? lasallensis (Worthen) (c)
Marginifera wabashensis (Norwood and Pratten)
Spirifer (Neospirifer) triplicatus Hall (c)
Squamularia perplexa (McChesney) (r)
Hustedia mormoni (Marcou) (r to c)
Composita subtilita (Hall) (r)
Yoldia glabra Beede and Rogers (r)
Myalina sp. undet., probably new (r)
Pinna sp. undet., large form (r)
Astartella concentrica (Conrad) (r)
Yunnania? sp. undet., one crushed specimen
Worthenia? sp. undet., one crushed specimen
Phanerotrema tenuistriatum (Shumard)
Pseudozygopleura, one species (r)
Pseudorthoceras knoxense (McChesney) (r to c)
Gastrioceras sp. undet. (r)

Collection from shale 60 to 80 feet above Bunger limestone member and below limestone of No. 3 post-Bunger cycle (fossil zone 9 Gb).—The only collection from zone 9 Gb, 7590, was made by Wallace Lee, on Bass Mountain. The following species were collected:

Campophyllum? sp. undet., fragment (r)
Lophophyllum profundum (Edwards and Haime) (r to c)
Lophophyllum profundum radicosum Girty (c)
Crinoid stems and plates
Echinoid plates
Fenestella? sp. undet., one fragment
Chonetes granulifer Owen (r)
"Productus" (Juresania) nebrascensis Owen, young (r)
"Productus" (Dictyoclostus) americanus (Dunbar and Condra) crushed specimens (c)
"Productus" (Dictyoclostus) portlockianus Norwood and Pratten, small var., probably new (r)
"Productus" (Linoproductus) prattenianus Norwood and Pratten (r)
Marginifera lasallensis (Worthen) (r to c)
Marginifera wabashensis (Norwood and Pratten) var. A (r)
Spirifer (Neospirifer) triplicatus Hall (r)
Spirifer sp. undet., fragment (r)
Punctospirifer kentuckyensis (Shumard) (r)
Hustedia mormoni (Marcou) (c)
Yoldia glabra Beede and Rogers (r)
Astartella concentrica (Conrad) (r)
Euphemites carbonarius (Cox) (r to c)
Phanerotrema grayvillense (Norwood and Pratten) (r to c)
"Orestes" brazoensis (Shumard) (r)
Pseudorthoceras knoxense (McChesney) (r)

Collections from limestone of No. 3 post-Bunger cycle (fossil zone 8 Gb).—Two collections, 7453 and 7497, were obtained from the limestone of No. 3 post-Bunger cycle. The first came from an escarpment along the line between Young and Stephens counties, half a mile east of the Graham-Eastland highway. The second was obtained at the place where the county-line road crosses Peveler Creek, about 3 miles west of the Graham-Eastland highway. At the latter locality corals were so abundant that they could be shoveled up. This is the lowest of three *Campophyllum*-bearing beds mapped by Lee.

Collection 7497 contains only the following two species, both corals. The *Campophyllum* is very abundant.

Campophyllum torquium (Owen)
Syringopora sp. undet.

Collection 7453 is more extensive. It contains the following:

Fusulinids
Lophophyllum profundum (Edwards and Haime) (r)
Campophyllum torquium (Owen) (vc)
Crinoid stems (c)
Fistulipora sp. undet. (vc)
Polypora sp. undet. (r)
Rhombopora lepidodendroides Meek (r to c)
Derbya sp. undet., very young (r)
Chonetes granulifer Owen (a)
Chonetes granulifer Owen, large variety (vc)
Chonetes (Lissochonetes) geinitzianus plattsmouthensis? (Dunbar and Condra) (r to c)
"Productus" (Juresania) nebrascensis Owen (r)
"Productus" (Dictyoclostus) americanus (Dunbar and Condra) (r to c)
"Productus" (Dictyoclostus) sp. undet., fragments (r to c)
"Productus" (Linoproductus) cf. P. prattenianus Norwood and Pratten, fragments (a)
Marginifera? lasallensis (Worthen) (a)
Marginifera splendens (Norwood and Pratten) var. A (c)
Wellerella osagensis (Swallow) (c)
Spirifer (Neospirifer) triplicatus Hall (r to c)
Squamularia perplexa (McChesney) (r to c)
Crurithyris planoconvexa (Shumard) (c)
Punctospirifer kentuckyensis (Shumard) (c)
Hustedia mormoni (Marcou) (r to c)
Composita subtilita (Hall) (c)
Astartella concentrica (Conrad) (r)
Bellerophon cf. B. stevensianus McChesney (r)
Euphemites carbonarius (Cox) (r)
Phanerotrema grayvillense (Norwood and Pratten) (r)
"Orestes" brazoensis (Shumard) (r)
Trepospira? sp. undet., fragments of young? (r)
"Orthoceras" (Euloxoceras) greenei (Miller, Dunbar and Condra) (r)

Collections from limestone of No. 5 post-Bunger cycle (fossil zone 7 Gb).—Two collections were obtained from limestone of the No. 5 post-Bunger cycle. One, 7491, came from Sydney Mountain, and the other, 7492, from a butte east of Kickapoo Creek, about a mile above its mouth. Collection 7491 is small. It contains the following species:

Crinoid stems (r to c)
Echinoid plates (r to c)
Derbya crassa (Meek and Hayden) (r)
Marginifera? lasallensis (Worthen) (r to c)
Spirifer (Neospirifer) triplicatus Hall (r)
Myalina subquadrata Shumard (r to c)
Astartella sp. undet., one fragment
Pharkidonotus? sp. undet., crushed specimen (r)
"Orthoceras" sp. undet. (r)

Collection 7492 is larger. It contains the following species:

Fusulinids (r to c)
Campophyllum? sp. undet., one fragment
Crinoid stems (c)
Echinoid plate (r)
Chonetes granulifer Owen (r)
"Productus" (Dictyoclostus) portlockianus Norwood and Pratten, small var., new? (c)
"Productus" (Linoproductus) prattenianus? Norwood and Pratten (c)
Marginifera? lasallensis (Worthen) (a)
Spirifer (Neospirifer) triplicatus Hall, large form (r to c)
Aviculipinna sp. undet., fragments (r to c)
Myalina sp. undet., fragments (r)
Acanthopecten sp. undet., fragment (r)
Astartella concentrica (Conrad) (r)
Patellostium n. sp., large form (r)

Collections from limestone of No. 6 post-Bunger cycle (fossil zone 6 Gb).—Three collections were made from a limestone said to belong to the No. 6 post-Bunger cycle. Collection 7493 came from a butte along the west side of Kickapoo Creek about a mile above its mouth; collection 7494 from the west side of the same butte; collection 7495 from a hill about half a mile north of the Stovall hot-water well, near South Bend.

Collections 7493 and 7494 are composed entirely of individuals of *Campophyllum torquium* (Owen), which are very abundant at each of these localities.

Collection 7495 has, in addition to *Campophyllum torquium,* which is abundant, *Syringopora* sp. undet. (c), crinoid stems (r to c), and *Spirifer (Neospirifer) texanus* Meek (r).

Collections from limestone of No. 7 post-Bunger cycle (fossil zone 5 Gb).—Five collections were obtained from the limestone of the No. 7 post-Bunger cycle. Two of the collections contained only fusulinids. Of the other three, 7496 came from a ridge on the south side of Salt Fork of Brazos River, a short distance above its junction with Clear Fork; 7499 from the top of South Bend Mountain; and 7525 from a pasture north of the road on the first rise east of Graham Lake.

Collection 7525 is a small collection. It was obtained from a hard fine- to medium-crystalline limestone that where fresh is whitish gray to lead-gray with a brownish tinge and with brownish-yellow spots and stringers. It is brown where weathered. This limestone occurs in beds that average about 18 inches in thickness but weathers into blocks 5 or 6 feet long by 2 to 4 feet wide. Solution cavities and networks are common. This limestone, when judged by fossil fragments and sections seen on the surface, is moderately fossiliferous. Gastropod sections are especially common, but identifiable fossils are almost impossible to obtain. The following were collected:

Fusulinids (r)
Campophyllum? sp. undet., fragments (r)
Crinoid stems (r to c)
Composita cf. C. subtilita (Hall), incomplete (r to c)
Bellerophon? sp. undet., internal molds (c)
"Murchisonia"? sp. undet., fragments of molds (r)

Collection 7496 came from beds near the locality of collection 7525. The beds are, however, slightly more fossiliferous here. A list of species collected is as follows:

Fusulinids
Horn coral, indeterminate, much weathered (r)
Crinoid columnals (r)
Marginifera? lasallensis (Worthen) (r to c)
Spirifer (Neospirifer) triplicatus Hall, large var. (r to c)
Composita subtilita (Hall) (c)

Collection 7499 is the largest collection from the limestone of the No. 7 cycle but it contains few identifiable species. The following is a list of forms obtained:

Fusulinids (vc)
Crinoid stems (r)
"Productus" (Linoproductus) sp. undet., fragments of a small form (r)
"Productus" (Cancrinella?) sp. undet., fragments (r)
Marginifera? lasallensis (Worthen) (r to c)
Spirifer (Neospirifer) triplicatus Hall (r)
Composita subtilita (Hall) (r to c)
Pelecypod, undeterminate
Bellerophon? sp. undet., internal molds of large form (c)
"Orthoceras" sp. undet., section in rock (r)
Phillipsia? sp. undet., part of a pygidium (r)

Collections from the Gunsight limestone member (fossil zone 4a Gb).—According to Plummer and Moore, the Gunsight limestone member consists, at the type locality, which is about 40 miles southwest of Graham, and at most places in the Brazos River valley, of two limestones separated by about 20 feet of shale or of shale and sandstone. These limestones, it appears, have been correlated by different geologists with different beds in the region of Graham, and it is difficult to tell which limestones studied there are the Gunsight limestones. Many geologists have assumed that the presence of an abundance of *Campophyllum torquium* (Owen) in a limestone between the shale immediately overlying the Bunger limestone and the Wayland shale was sufficient to warrant its identification as Gunsight. Lee's investigations, however, have shown that this coral is abundant in more than one bed. Because the stratigraphic positions of the various *Campophyllum*-bearing beds in the Graham are not very widely separated, the assumption mentioned has not made great discrepancies in maps of larger structural features. It has, however, caused errors that may be of great importance in mapping local structure and in determining the details of geologic history.

Six collections were made from the Gunsight limestone member at or near the type locality in order to see if faunal peculiarities could be discovered that would provide a means for identification of the Gunsight limestones in the area near Graham. One of these collections from the lower limestone of the member contained only fusulinids. Of the other five, three (7500, 7551, and 7553) came from the upper limestone of the Gunsight member. and two (7502 and 7552) from the lower limestone.

Two of the collections (7500 and 7551) from the upper limestone came from a place about 150 yards south of the post office at Gunsight; the other came from the north edge of Gunsight, about 500 yards north of the post office and across the road north from a cemetery. The following composite list contains the species in all three collections:

Fusulinids (r)
Campophyllum cf. C. torquium (Owen), small individuals (r)
Syringopora sp. undet. (r)
Crinoid columnals (r)
Echinoid plates and spines (r to c)
Bryzoan, fenestelloid, nonporiferous side (r)
"Productus" (Dictyoclostus?) sp. undet., immature individuals (r)
Spirifer (Neospirifer) triplicatus Hall (r)
Dielasma bovidens? (Martin), young (r)
Composita subtilita (Hall) (vc)

The two collections from the lower limestone came from a single locality, along the old Gunsight-Eastland road at a point about 2 miles south of Gunsight. These collections contain the following forms:

Fusulinids (a)
Syringopora sp. undet. (r)
Crinoid stems (r)
Echinoid spines (r to c)
Echinoid plates (r)
"Productus" (Dictyoclostus?) sp. undet., fragmentary young (r)
Composita subtilita (Hall) (vc)
Gastropod, possibly Meekospira, very much crushed and fragmentary, one specimen

The small number of recognizable larger invertebrates in the limestones of the type Gunsight makes their correlation with beds in the Graham area by means of these fossils a difficult task. Nearly all the beds near Graham have larger and more varied faunas than either of the type Gunsight limestones. No bed from which the writer has collected in the Graham area suggests the upper Gunsight, and it may be either not present there or so changed lithologically and faunally that it cannot be recognized. There are some resemblances in fauna and lithology between the lower Gunsight and the limestone of No. 7 post-Bunger cycle but these resemblances are very slight, and when the variability of Pennsylvanian limestones and their faunas in this region and the totally inadequate nature of the lower Gunsight fauna are considered, it is very evident that no adequate basis for the correlation of these two limestones exists. With the knowledge at hand, it seems slightly more likely that, if the lower Gunsight is represented in the Graham area, it is the No. 7 limestone rather than one of the other limestones, but this suggestion rests on very slender evidence. Large fusulinid collections were obtained from these beds, and it is possible that they will give some basis for the correlation of the Gunsight limestones.

Collections from No. 9 post-Bunger cycle limestone (fossil zone 4 Gb).—As treated in the first part of this report, there are three limestones in the No. 9 post-Bunger cycle. The lowest of these is designated the "No. 9 limestone." A limestone designated the "No. 9a limestone" occurs above No. 9, and one designated "No. 9b limestone" is above No. 9a. A very fossiliferous zone in the Wayland shale occurs between limestones Nos. 9a and 9b.

Only one collection, 7443, was obtained from the No. 9 limestone. It came from beds near the head of Kickapoo Creek. The species in it are as follows:

Fusulinids (c)
Lophophyllum profundum (Edwards and Haime) (r to c)
Lophophyllum profundum radicosum Girty (c)
Crinoid stems and plates (c)
Rhombopora lepidodendroides Meek (r)
Other Bryozoa (c)
Marginifera? lasallensis (Worthen) (r)
Squamularia perplexa (McChesney) (r)
Cruritbyris planoconvexa (Shumard) (r)
Punctospirifer kentuckyensis (Shumard) (c)
Hustedia mormoni (Marcou) (r to c)
Composita subtilita (Hall) (c)
Conocardium sp. undet. (r)
Astartella concentrica (Conrad) (r)
Euphemites carbonarius (Cox) (r to c)
Pharkidonotus tricarinatus (Shumard), small individuals (c)
Worthenia tabulata (Conrad) (r to c)
Phanerotrema grayvillense (Norwood and Pratten) (c)
Phanerotrema tenuistriatum (Shumard) (r to c)
"Murchisonia" sp. undet., one fragment
Trepospira depressa? (Cox), small individuals (c)
Straparollus (Euomphalus or Schizostoma) subrugosus? (Meek and Worthen) (r)
Soleniscus (Macrochilina) cf. S. primigenius (Conrad), one incomplete specimen

Collections from the Wayland shale member (fossil zone 3 Gb).—More collections and probably more individuals were obtained from the Wayland shale member than from any other in the Graham formation. At all localities visited fossils are abundant and well preserved and can be collected free from the matrix in almost unlimited quantities.

The total number of collections from this member in the Brazos River valley is 14. These 14 collections were obtained at 10 different localities, most of which are near Graham. A composite but incomplete list of species is given in the table below.

Distribution of species in collections from the Wayland shale member in the Brazos River valley

	7442	7448	7451	7454	7456	7485	7486	7487	7489	7550	7594	7595	7598
Lophophyllum profundum (Edwards and Haime)	x	x	x	x	x	x	x	x		x	x	x	x
Lophophyllum profundum radicosum Girty	x	x	x		x		x			x	x	x	x
Syringopora sp. undet.	x												
Conularia sp. undet.												x	
Crinoid stems and plates	x	x		x	x		x					x	
Echinoid spines and plates					x								
Fenestella sp. undet.						x							
Polypora sp. undet.		x			x								
Rhombopora lepidodendroides Meek					x								
Other Bryozoa			x	x	x	x				x			
Orbiculoidea missouriensis (Shumard)	x									x			
Orbiculoidea n. sp. A	x									x			
Orbiculoidea n. sp. B	x									x			
Lindstroemella patula (Girty)	x												
Crania modesta White and St. John	x	x		x						x			
Derbya crassa (Meek and Hayden)	x											x	
Chonetes granulifer Owen	x	x	x	x	x		x						
Chonetes (Lissochonetes) geinitzianus plattsmouthensis (Dunbar and Condra)			x	x	x		x						
Chonetes sp. undet.		x											
"Productus" (Juresania) nebrascensis Owen	x	x			x	x				x			
"Productus" (Pustula) n. sp. A	x						x			x			
"Productus" (Echinoconchus) semipunctatus? Shepard					x								
"Productus" (Echinoconchus) sp. undet.	x				x		x						
"Productus" (Dictyoclostus) americanus (Dunbar and Condra)					x								
"Productus" (Dictyoclostus) sp. undet.					x						x		
"Productus" (Linoproductus) pratenianus Norwood and Pratten	x	x		x						x			
Marginifera lasallensis (Worthen)	x	x	x	x	x	x	x			x	x		
Marginifera wabashensis (Norwood and Pratten) var. A	x	x				x							
Marginifera splendens (Norwood and Pratten) var. A	x	x	x		x	x	x						
Strophalosia n. sp. A			x	x									
Wellerella osagensis (Swallow)	x	x	x		x		x			x			
Wellerella osagensis (Swallow) n. var.	x												
Wellerella sp. A, probably new	x		x	x									
Rhynchopora illinoisensis (Worthen)		x			x	x							
Rhynchopora sp. undet., probably new	x												
Dielasma bovidens (Morton)						x							
Spirifer (Neospirifer) texanus Meek										x			
Spirifer (Neospirifer) triplicatus Hall	x	x	x		x	x	x				x		x
Spirifer sp. undet.	x	x		x									
Squamularia perplexa (McChesney)			x			x							
Crurithyris planoconvexa (Shumard)	x	x		x	x		x			x	x		x
Punctospirifer kentuckyensis (Shumard)	x	x	x	x			x			x			
Hustedia mormoni (Marcou)	x	x	x	x	x		x			x	x		x

Distribution of species in collections from the Wayland shale member in the Brazos River valley—Continued

	7442	7448	7451	7454	7456	7485	7486	7487	7489	7550	7594	7595	7598
Composita subtilita (Hall)	x		x	x		x	x				x	x	x
Nucula anodontoides Meek	x	x								x			x
"Nuculopsis" ventricosa (Hall)	x	x		x			x						
Leda bellistriata Stevens	x	x	x				x			x			
Yoldia glabra Beede and Rogers		x	x		x								
Parallelodon sp. undet.						x	x						
Aviculipinna sp. undet.	x									x			
Pinna? sp. undet.			x		x								
Conocardium sp., probably new	x	x	x				x					x	
Myalina sp. undet., fragments						x							
Astartella concentrica (Conrad)	x	x	x		x	x	x			x			
Dentalium n. sp. aff. D. semicostatum Girty					x								
Dentalium subleve Hall					x								
Dentalium sp. undet.	x												
Plagioglypta annulistriata (Meek and Worthen)							x						
Plagioglypta sp. undet., large form	x				x				x				
Bellerophon sp. undet., large form						x	x						
Patellostium montfortianum (Norwood and Pratten)		x	x		x	x	x						
Euphemites carbonarius (Cox)	x	x	x		x		x			x		x	
Pharkidonotus tricarinatus (Shumard)	x	x	x	x	x	x	x			x			
Pharkidonotus percarinatus? (Conrad)	x												
Worthenia tabulata (Conrad)	x			x	x	x		x		x			
Phanerotrema grayvillense (Norwood and Pratten)	x	x	x	x	x	x	x			x		x	x
Phanerotrema tenuistriatum (Shumard)					x		x						
"Orestes" brazoensis (Shumard)	x	x			x		x			x			
"Murchisonia" sp. undet.					x								
Orthonema schucherti Knight					x		x			x			
Trepospira depressa (Cox)	x	x	x	x	x	x	x	x		x	x	x	x
Straparollus (Euomphalus or Schizostoma) subrugosus (Meek and Worthen)	x	x	x		x		x						
Meekospira sp. undet.	x			x									
Soleniscus (Macrochilina) primigenius (Conrad)	x				x		x						
Platyceras sp. undet.	x												
Pseudorthoceras knoxense (McChesney)	x	x	x		x		x			x		x	
Pseudorthoceras seminolense Girty		x	x		x	x	x						
"Orthoceras" (Mooreoceras) aff. O. tuba Girty	x	x											
Brachycycloceras normale Miller, Dunbar and Condra	x												
Coloceras liratum Girty			?										
Domatoceras sculptile (Girty)					x								
Gonioloboceras welleri Smith		x											
Nautiloid fragments	x												
Fish teeth													x

The Wayland shale member in the Brazos River valley has yielded several species of cephalopods that are not represented in the table. Among them are the ammonoids collected by Dr. A. B. Gant, of Graham, and described by J. P. Smith. Plummer and Moore also report some species not present in the writer's collections. They have, however, referred to this zone beds found by Lee to belong in the fossiliferous shale 20 to 40 feet above the Bunger limestone.

A study of the author's collections from the Wayland shale suggests that this zone has certain faunal characteristics which when considered in combination are sufficient to distinguish large collections from it from collections obtained in either of the other two fossiliferous shale zones in the Graham. These characteristics include:

1. The absence from or rare occurrence in the Wayland shale of *Coelocladia?* aff. *C. spinosa* Girty (in shales only in zone 16 Gb), *Rhipidomella carbonaria* (Swallow) (in shales only in zone 16 Gb), *Chonetes geinitzianus* n. var. aff. *C. senilis* (Dunbar and Condra) (common in zone 16 Gb, rare in zone 10 Gb), *Productus (Cancrinella)* n. sp. aff. *P. boonensis* Swallow (in shales only in zone 10 Gb), *Bellerophon stevensianus* (McChesney) (common in zone 16 Gb, absent in zone 10 Gb, rare here), *Goniasma lasallensis* (Worthen), *Orthonema schucherti* Knight, *Straparollus (Euomphalus) plummeri* Knight, *Brachycycloceras normale* Miller, Dunbar and Condra (rare here, common in zone 10 Gb), *Metacoceras cornutum* Girty and varieties (absent here, rare in zone 10 Gb), *Gonioloboceras welleri* Smith (rare here, common in zone 10 Gb), and other cephalopods (rare here, more common in zone 10 Gb).

2. The occurrence in the Wayland of the following species which are contained in the author's collections from one of the other shale zones of the Graham formation but not from both:

"Murchisonia" sp. (absent from zone 16 Gb)
Dentalium n. sp. aff. D. semicostatum Girty (absent from zone 10 Gb)
Dentalium subleve Hall (absent from zone 10 Gb)

3. The presence in the Wayland of species not known from the author's collections from any of the other shale zones of the Graham formation in the Brazos River valley, such as the following:

Crania modesta White and St. John
Chonetes geinitzianus var. plattsmouthensis (Dunbar and Condra)
"Productus" (Pustula) n. sp. A
Strophalosia n. sp. A
Rhynchopora illinoisensis (Worthen)

4. The common occurrence in the Wayland of some species known in shales at other horizons but represented there by few or nontypical individuals, such as *Wellerella osagensis* (Swallow) and certain gastropods.

Plummer and Moore show certain of the above-named species occurring at horizons in the Graham at which they are not represented in the author's collections. These include *Rhipidomella carbonaria* (Swallow) (= *R. pecosi* of Plummer and Moore), which they cite from beds in or near the Bunger limestone; *Rhynchopora illinoisensis* (Worthen), which they show in all zones in the Graham from which they list fossils; and *Metacoceras cornutum* Girty, which they list from the Wayland shale member.

Undoubtedly other species have been already found by others, or will be found on further collecting, to occur in beds other than those from which the writer now lists them. However, there does now seem to be enough difference between the fauna of this zone and those of the other zones to furnish a basis for distinguishing the zones in the field.

The faunal characteristics found most useful in recognizing this zone in the field were the common occurrence in it of *Wellerella osagensis*, the occurrence of *Rhynchopora illinoisensis* and *Strophalosia* n. sp. A, the absolute or virtual absence of *Coelocladia?* and *Rhipidomella*, and the lack of any abundance of coiled cephalopods.

Collections from the 9a limestone of post-Bunger cycle No. 9 (fossil zone 2 Gb).—Three collections were made from limestone 9a of the post-Bunger cycle No. 9. One of the collections contained only fusulinids. The other two came from a single locality, from a butte north of Graham Lake. These collections, 7450 and 7526, are here listed together.

Fusulinids (r)
Lophophyllum profundum (Edwards and Haime) (r)
Lophophyllum profundum radicosum Girty (r)
Crinoid columnals (c)
Echinoid plates (r)

Rhombopora lepidodendroides Meek (r)
Other Bryozoa (c)
Spirifer (Neospirifer) triplicatus Hall (r)
Punctospirifer kentuckyensis? (Shumard), one fragment
Hustedia mormoni (Marcou) (r to c)
Composita subtilita (Hall) (r)
"Nuculopsis" ventricosa (Hall) (r)
Worthenia tabulata (Conrad) (r)
"Murchisonia" sp. undet., one fragmentary specimen
Trepospira depressa (Cox), one small individual

Collection from limestone No. 9b of the No. 9 post-Bunger cycle (fossil zone 1 Gb).—One collection, 7498, was obtained from a limestone exposed as an outlier on a butte on the northwest side of Tonk Creek about a mile west of Tonk School. This limestone is said by Lee to be about 76 feet above the No. 9 limestone at the base of the Wayland shale. It is 12 feet below the base of the Avis sandstone member of the Thrifty formation at this locality. A list of species in collection 7498 is given below:

Fusulinids (r to c)
Lophophyllum profundum (Edwards and Haime) (r)
Campophyllum torquium (Owen) (c)
Crinoid stems (r to c)
Echinoid plates and stems (r)
Leptalosia ovalis Dunbar and Condra (r)
Derbya crassa (Meek and Hayden) (r to c)
Meekella striatocostata (Cox) (r)
Chonetes granulifer Owen (r)
"Murchisonia" sp. undet., one broken specimen
Soleniscus (Macrochilina) sp. undet., fragment of mold

COLORADO RIVER VALLEY

In the Colorado River valley the Graham formation is thinner and has fewer stratigraphic units than in the Brazos River valley. Like the units in the Brazos River valley, some are abundantly fossiliferous and others are almost devoid of fossils. All the named units are listed in stratigraphic order below. The names are those used in the stratigraphic part of this report.

Base of *Bellerophon* limestone (basal bed of Thrifty formation in Colorado River valley).

Graham formation:

1 Gc.[4] Wayland shale member (Trickham shale of Drake).
2 Gc. Upper limestone of Gunsight member.
3 Gc. Lower limestone of Gunsight member.

[4]G = Graham formation; c = Colorado River valley.

4 Gc. Bluff Creek shale member, in ammonoid-bearing shale. 10 to 20 feet below Gunsight limestone member.

5 Gc. Bluff Creek shale member, in thin limestone 8 feet above Home Creek limestone of Plummer and Moore.

Home Creek limestone of Plummer and Moore (top member of Caddo Creek formation)

Collection from thin brown limestone 8 feet above Home Creek limestone member of Plummer and Moore (fossil zone 5 Gc).—Collection 7560 came from a 2-foot brown limestone that is 8 feet above the Home Creek limestone of Plummer and Moore. This limestone is considered by Lee to be in the basal part of the Graham formation, in the Bluff Creek shale member. The collection from it was hurriedly made at a locality near the Samuel No. 1 well on the Gill ranch, east of Whon, and is probably not representative of the faunule here. It contains many fusulinids shown on the surface of the beds and one specimen of *Campophyllum torquium* (Owen).

Collections from the ammonoid-bearing shale 10 to 20 feet below the Gunsight limestone member (fossil zone 4 Gc).—Fossil zone 4 Gc is characterized by an abundance of cephalopods and horn corals. Many of the corals may, however, have come from the weathering of the overlying lower limestone of the Gunsight member. Other fossils, especially gastropods, are common.

Three collections, 7369, 7369A, and 7455, were obtained from this zone. All are from the same locality, along a road through the Gill ranch, at a point east of the ranch house, about 1000 feet northeast of the bench mark 1397, as shown on the topographic map of the Waldrip quadrangle. Most of the cephalopods came from a zone about 15 feet or less below the Gunsight member.

The following is a composite list of the three collections:

Lophophyllum profundum (Edwards and Haime) (r)
Camphophyllum torquium (Owen) (a)
Crinoid stems (r to c)
Conularia cf. C. crustula White (r)
Orbiculoidea missouriensis (Shumard) (r)
"Productus" (Echinoconchus) sp. undet. (r)
"Productus" (Cancrinella) n. sp. aff. P. boonensis Swallow (r), large variety
Marginifera lasallensis (Worthen) (r to c)
Spirifer (Neospirifer) triplicatus Hall (r)
Spirifer (Neospirifer) texanus Meek (r to c)

Crurithyris planoconvexa (Shumard) (r)
Hustedia mormoni (Marcou) (r)
Composita subtilita (Hall) (r to c)
Anthraconeilo taffiana Girty (r to c)
"Nuculopsis" ventricosa (Hall) (r to c)
Leda bellistriata Stevens (r to c)
Conocardium sp. undet., possibly new (r to c)
Astartella concentrica (Conrad), large thick variety (c)
Other pelecypods, probably two species
Euphemites carbonarius (Cox), large individuals only (c)
Worthenia tabulata (Conrad) (c)
Phanerotrema grayvillense (Norwood and Pratten) (c)
Trepospira depressa? (Cox), very large individuals (vc)
Soleniscus (Macrochilina) primigenius (Conrad) (vc)
"Orthoceras" (Dolorthoceras) ciscoense (Miller, Dunbar and Condra) (r to c)
"Orthoceras" (Euloxoceras) greenei (Miller, Dunbar and Condra)
"Orthoceras" sp. undet., fragments (r)
Brachycycloceras normale Miller, Dunbar and Condra (r)
Coloceras liratum Girty (r to c)
Tainoceras monifer Miller, Dunbar and Condra (r)
Metacoceras cornutum Girty (r)
Metacoceras cornutum var. sinuosum Girty (r to c)
Domatoceras sculptile (Girty) (r to c)
Gastrioceras angulatum Girty (r to c)
Gastrioceras modestum? Böse (r to c)
Gastrioceras, fragments of two or three species
Schistoceras hyatti Smith (r)
Schistoceras hildrethi? Smith (r)
Dimorphoceras texanum Smith (c)
Gonioloboceras welleri Smith (vc)

The faunal characteristics by which this zone may be differentiated from the higher Wayland (Trickham) shale member are considered in the discussion of the faunas from that member.

Collections from lower limestone of Gunsight limestone member (fossil zone 3 Gc).—If the fusulinids and corals are excepted, then the lower Gunsight in the Colorado River valley contains few fossils. Only two collections, mainly of fusulinids, were made from it, and both were from the Gill ranch, east of Whon.

Larger fossils identified in the field were *Campophyllum torquium* (Owen) (a), *Composita subtilita* (Hall), and a questionably identified *Squamularia perplexa* (McChesney).

Collections from the upper limestone of the Gunsight limestone member (fossil zone 2 Gc).—Two small collections were obtained from the upper limestone of the Gunsight member in the Colorado River region. One of them, 7510, came from a locality about half a mile east and less than a quarter of a mile south from Parks Mountain. The other, 7559, came from the same locality that yielded the three collections from the ammonoid-bearing shale below the Gunsight limestone member. This locality is on a ranch road east of the Gill ranch house and about 1000 feet northeast of bench mark 1397, which is shown on the topographic map of the Waldrip quadrangle.

Collection 7510 contains only crinoid columnals, one specimen of *Deltopecten* n. sp.? aff. *D. mccoyi* (Meek and Hayden), and a fragment probably of a *Myalina.* This collection was hastily made and is therefore not representative.

Collection 7559 is larger, but most of the individual specimens are incomplete. Although some fossils, especially Compositas and gastropods, are frequently seen in section on the rock surfaces, they are difficult to obtain in identifiable condition. Fusulinids are present but are also hard to obtain free from matrix.

Fusulinids (r to c)
Campophyllum torquium (Owen), large forms common (c)
"Productus" (Juresania) sp. undet., very young (r)
"Productus" (Dictyoclostus) or Marginifera sp. undet., fragmentary (r)
"Productus" (Linoproductus) sp. undet., fragment (r)
Spirifer (Neospirifer) triplicatus Hall (r)
Punctospirifer kentuckyensis? (Shumard), fragment (r)
Composita subtilita (Hall) (r to c)
Myalina? sp. undet., small form (r)
Gastropods, sections in rocks (r to c)

Collections from Wayland (Trickham) shale member (fossil zone 1 Gc).—Fossils are very abundant at the horizon of the Wayland (Trickham) shale member. At the one locality from which collections were made they are so abundant and, because they are weathered out, so easily collected that large numbers can be obtained in a short time.

The locality from which the two collections were made is about a mile east of Parks Mountain. Two trips were made to it—the first on July 15 in company with H. D. Miser, Wallace Lee, C. O. Nickell, and Fred Yockstick, when collection 7370 was obtained, and the other on August 29, on which the author was alone. Collection 7449 was obtained on the second trip.

A complete list of collections 7370 and 7449 is given below:

Lophophyllum profundum (Edwards and Haime) (a)
Lophophyllum profundum radicosum Girty (c)
Crinoid columnals (c)

Crinoid plates (c)
Echinoid plates (r)
Fistulipora? sp. undet. (c)
Polypora? sp. undet. (c)
Rhombopora lepidodendroides Meek (c)
Other Bryozoa, two or three species
Orbiculoidea n. sp.? C (r)
Crania modesta White and St. John (r)
Chonetes (Lissochonetes) geinitzianus var. plattsmouthensis (Dunbar and Condra) (r)
"Productus" (Juresania) nebrascensis Owen (r to c)
"Productus" (Juresania) sp. undet., fragments (r)
"Productus" (Dictyoclostus) sp. undet., fragments (r)
"Productus" (Linoproductus) sp. undet. (r)
Marginifera? lasallensis (Worthen) (c)
Marginifera splendens? (Norwood and Pratten) var. A, one quarter of a specimen (r)
Wellerella osagensis (Swallow) (r)
Rhynchopora illinoisensis (Worthen) (r)
Spirifer (Neospirifer) triplicatus Hall (c)
Crurithyris planoconvexa (Shumard) (r to c)
Punctospirifer kentuckyensis (Shumard) (r to c)
Hustedia mormoni (Marcou) (c)
Composita subtilita (Hall) (c)
Nucula anodontoides Meek (r)
"Nuculopsis" ventricosa (Hall) (vc)
Leda bellistriata Stevens (r to c)
Pinna? sp. undet., fragments of large form (r)
Conocardium sp. undet., probably new (r)
Myalina? sp. undet., fragments (r)
Deltopecten texanus Girty (r to c)
Astartella concentrica (Conrad), large and small individuals (c)
Plagioglypta annulistriata (Meek and Worthen) (r)
Euphemites carbonarius (Cox) (c)
Bucanopsis meekiana (Swallow) (r)
Pharkidonotus tricarinatus (Shumard) (r to c)
Pharkidonotus percarinatus? (Conrad), forms gradational to tricarinatus (r to c)
Worthenia tabulata (Conrad) (r to c)
Phanerotrema grayvillense (Norwood and Pratten) (c)
"Orestes" brazoensis (Shumard) (r to c)
Trepospira depressa (Cox)
Straparollus (Euomphalus or Schizostoma) subrugosus Meek and Worthen (c)
Pseudozygopleura, one or two species (r to c)
Meekospira?, probably two species (r to c)
Soleniscus (Macrochilina) sp.?, probably S. brevis (White) (r to c)
Pseudorthoceras knoxense (McChesney) (c)
"Orthoceras" (Euloxoceras) greenei (Miller, Dunbar and Condra) (r)
Coloceras liratum Girty (r)
Metacoceras perelegans? Girty (r)
Metacoceras sp. undet., fragment (r)
Domatoceras sculptile (Girty) (r)
Gastrioceras branneri? Smith (r)

Gastrioceras sp. undet., fragments of two or three species (r)
Dimorphoceras texanum Smith (r)
Gonioloboceras welleri Smith (r)

If the collections here reported are representative, this zone may be distinguished from the ammonoid-bearing shale below the Gunsight limestone member by its lower relative number of coiled cephalopods; the less abundant *Campophyllum torquium;* the absence of *"Productus" (Cancrinella)* n. sp. aff. *P. boonensis*, large variety; the presence of *Chonetes geinitzianus* var. *plattsmouthensis, Wellerella osagensis, Rhynchopora illinoisensis, Plagioglypta annulistriata;* and the greater abundance of *Punctospirifer kentuckyensis, Hustedia mormoni, Pharkidonotus tricarinatus, Soleniscus brevis,* and *Straparollus subrugosus.*

CORRELATION OF MEMBERS OF THE GRAHAM FORMATION

Faunal correlation of thin members within formations is usually difficult, regardless of the class of fossils employed or the age of the rocks being correlated. Especially is this true if many of the members are relatively unfossiliferous. On the other hand, the difficulty of arriving at immediate and seemingly accurate correlations is sometimes increased if some of the members are abundantly fossiliferous and contain fossils belonging to many orders. Under such circumstances, evidence from one class of fossils that would ordinarily be thought sufficient to establish certain correlations is not infrequently found to be at variance with evidence from other classes of fossils found in the same beds. Such discrepancies result in the long run, however, in a more reliable and balanced set of correlations than would otherwise have been obtained.

The Graham formation has several members that have few fossils, but it also has some very fossiliferous members.

The presence of both unfossiliferous and very fossiliferous members in the Graham, the long range of many of the species, and the likelihood of faunal differences because of differences in facies make it desirable to use fully all types of fossil evidence before arriving at any conclusions. This report deals only with the invertebrates exclusive of fusulinids. The correlations arrived at here should be weighed against the evidence from the fusulinids and the plants, and conclusions should be reached only after all three types of evidence have been carefully considered, with due regard for their relative importance.

Not only is it necessary to use all types of fossil evidence in making correlations within the Graham, but because of certain obvious limitations it is also necessary to use and weigh nearly all the types of methods used for faunal correlations. The most common method of establishing faunal correlations is by the process known as "matching species" or matching percentages of species. A more significant criterion, perhaps, is the presence of genera, species, or varieties having elsewhere narrow stratigraphic ranges. Especially important is the presence and proportion of forms appearing for the first time or for the last time in the stratigraphic column. Significant also is the evidence from new or allegedly new species or genera, which may be evaluated in terms of closely related forms occurring elsewhere or of their evolutionary stages. The evidence from the relative abundance of various species is also useful if the correlations are made between areas that are not too widely separated or are not in different sedimentary basins, and with fossils that are not usually spotty in their occurrence.

Each of the above-outlined methods must be used with caution and with full knowledge of its limitations. The matching of species and use of relative abundance of species are, as all competent paleontologists have long known, susceptible to modification by differences in facies, by discrepancies in the completeness and the geographic extent of collecting, and by differences in various parts of the stratigraphic column in the number of long-ranging forms. The use of genera and species which elsewhere have narrow ranges is reliable only if the ever-present possibility of the extension of the range of any species is kept in mind. The consideration of forms which appear for the first time or for the last time in the stratigraphic column is very useful in correlation, but absurd correlations result if it is pushed too far. The consideration of the close relationship of certain species or the degree of evolution of certain species is also useful, but it is limited by the fact that the evolution of a great many forms is admittedly not known and the evolution of many others has been outlined on insufficient and highly speculative data or on the basis of discarded theories.

The shale members of the Graham offer greater possibilities for reliable correlation by the larger invertebrates than the limestone or sandstone members. Three very fossiliferous shale members occur in the Brazos River section and only two occur in the Colorado River section. Other shales which are, however, relatively unfossiliferous occur in both sections.

The collections made for this present study suggest that the fauna of the lowest fossiliferous shale zone (the shale above the Salem School limestone) in the Graham formation of the Brazos River valley does not occur in the Colorado River valley. No shale there is characterized by the common occurrence of *Coelocladia?* cf. *C. spinosa* Girty, *Rhipidomella carbonaria* (Swallow), *Chonetes geinitzianus* n. var. aff. *C. senilis* (Dunbar and Condra), and *Bellerophon stevensianus* McChesney, and by an abundance of *Euphemites carbonarius* (Cox). The *Coelocladia,* insofar as the present collections are representative, is limited to the Brazos River valley and to this shale zone. The *Rhipidomella* has been doubtfully identified by the writer also in a collection from the Gonzales limestone member in the Brazos River valley but does not occur above that member or in any collection from Colorado River valley. Plummer and Moore, however, cite it from beds as high as the Bunger limestone in the Brazos River valley. The other three forms occur in higher beds, but the first two of them are not common at any higher zone. The common occurrence of these five species, together with the absence of any considerable number of coiled cephalopods, of "*Productus*" *(Cancrinella)* n. sp. aff. *P. boonensis* (Swallow), large variety, and of other forms, distinguishes the fauna of this zone from that of the ammonoid-bearing shale below the Gunsight limestone of the Colorado River area. The common occurrence of the species named, together with the absence of *Chonetes geinitzianus* (Swallow) and *Rhynchopora illinoisensis* (Worthen) and the relative scarcity of *Hustedia mormoni* (Marcou), distinguishes the fauna from that of the Wayland shale.

There seems to be an adequate, even if not an impregnable basis for correlating the two other fossiliferous shale zones in the Brazos River valley with the two fossiliferous shale zones in the Colorado River valley. The fauna of the ammonoid-bearing shale above the Bunger limestone in the Brazos River valley has much in common with that of the ammonoid-bearing shale below the Gunsight limestone in the Colorado River valley, and the fauna of the Wayland shale of the Brazos River valley is similar in several respects to that of the Wayland shale of the Colorado River valley.

The correlation of the ammonoid-bearing shale above the Bunger limestone in the Brazos River valley and that below the Gunsight in the Colorado River valley is largely based on (1) the occurrence of many species in both zones, including such forms as *"Productus" (Cancrinella)* n. sp. aff. *P. boonensis* (Swallow) (large variety), *Metacoceras cornutum* Girty, *Gastrioceras modestum?* Böse, and *Schistoceras hyatti* Smith, which are not present in the author's collections from any other zone in the Graham; (2) the presence in both zones in some abundance of coiled cephalopods, especially *Coloceras liratum* Girty, *Domatoceras sculptile* (Girty), *Dimorphoceras texanum* Smith, and *Gonioloboceras welleri* Smith, and of other fossils, such as *Anthraconeilo taffiana* Girty, which, although they may occur scatteringly at other horizons, are less common there; and (3) the absence from or rare occurrence in both these shale zones of certain forms that occur in the other two shale zones, including *Crania modesta* White and St. John (absent here, rare above); *Chonetes geinitzianus* var. *plattsmouthensis* (Dunbar and Condra) (absent here, rare to common above); *Marginifera splendens* (Norwood and Pratten) var. A (absent here, rare to common above); *Wellerella osagensis* (Swallow) (absent here, rare to common above); *Rhynchopora illinoisensis* (Worthen) (absent here, rare to common above); *Punctospirifer kentuckyensis* (Shumard) (rare here, more common above); *Hustedia mormoni* (Marcou) (rare here, more common above); *"Nuculopsis ventricosa"* Hall (rare to common here, more common above); *Plagioglypta annulistriata* (Meek and Worthen) (absent here, rare above); *Pharkidonotus tricarinatus* (Shumard) (rare here, more common above); *Straparollus (Euomphalus* or *Schizostoma) subrugosus* (Meek and Worthen) (absent here, common above).

The strength of the above-outlined evidence for correlation of the two shale zones mentioned is considerably lessened by the facts that some of the species have ranges extending both above and below the Graham, that many have ranges extending below it, and that many of them are listed by Plummer and Moore from horizons in shale other than those to which they are limited in the author's collections. The significance of the differences in relative abundance between the various species is lessened by the relatively long distance between the two outcrop areas. Notwithstanding these limitations, however, the fact that in each of the two areas there are two zones that have like stratigraphic relations and like paleontologic relations seems sufficient to warrant correlation, at least until more contradictory evidence than now exists is discovered.

The reasons for the correlation of the Wayland shale of the Brazos River valley with the Wayland shale of the Colorado River valley are suggested above. They include (a) the presence of many common species, some of which, as indicated above, occur only in these two shale zones and others of which occur elsewhere though not as abundantly, and (b) the absence of certain species which are restricted, at least in the writer's collections, to the fossiliferous shale above the Bunger in the Brazos Basin and that below the Gunsight limestone in the Colorado Basin. These last-mentioned species have also been indicated above. The scarcity of coiled cephalopods in general and of some species of coiled cephalopods that are rather common in the shales just mentioned also leads to the correlation of these two Wayland zones.

The faunal correlation of many of the limestone zones within the Graham cannot be made with any degree of certainty from the information supplied by the larger invertebrates. The thinness of the limestones, together with the facts that some of them vary greatly in thickness or pinch out in short distances and that many of their faunas are largely the same, makes it improbable that reliable correlations can be made by any kind of fossils.

Only three limestones occur in the Colorado River valley in beds here considered Graham. The lowest of these is a thin limestone that occurs in the basal part of the Bluff Creek shale member, 8 feet above the Home Creek of Plummer and Moore. Detailed collections were not made from this limestone. Its generally unfossiliferous character and its thinness suggest that it would be difficult to establish a faunal correlation between it and any bed in the Brazos River area. Certainly the author has no adequate data for making such a correlation.

The other two limestones of the Graham of the Colorado River valley have been assigned to the Gunsight limestone member; they are generally referred to in that area as the upper and lower Gunsight limestones. They occur in the interval between the top of the typical Bluff Creek shale member of the Colorado River valley and the base of the Trickham shale of Drake, which has been correlated with the Wayland shale member of the Brazos River valley and called "Wayland shale" by Plummer and Moore and other workers. The lower of these limestones lies 10 to 20 feet above the ammonoid zone on the Gill ranch, in the Colorado River valley, which is correlated with the ammonoid zone 20 to 40 feet above the Bunger limestone member on Bass Mountain, in the Brazos River valley. In the area near Graham seven limestones have been recognized in this interval. The type locality of the Gunsight limestone member is in the Brazos River valley, but it is some distance south of Graham. The correlation of the type Gunsight limestones with the limestones near Graham has been discussed in connection with the collections from the Brazos River valley (p. 177). The Gunsight limestones of the Colorado River valley, like the Gunsight limestones of the type locality, contain very few of the larger invertebrate fossils, except specimens of *Campophyllum.* The few larger invertebrates collected are all long-ranging forms that are found in nearly all the Graham limestones. There is, then, very little paleontologic evidence with which to confirm or refute the reference of the two limestones in the Colorado River valley to the Gunsight.

AGE AND OUTSIDE CORRELATION OF THE GRAHAM FORMATION

The Pennsylvanian age of the Graham formation has long been generally accepted, but its precise position within the Pennsylvanian is still a matter of some doubt. Plummer and Moore, in 1922, concluded that the Graham fauna was "somewhat younger than the Wewoka fauna of Southern Oklahoma, which has been correlated with the horizon of the Marmaton formation of the Kansas section, but older than the Lansing formation of that State." Rather recently several geologists, including R. C. Moore, have correlated the lower part of the Cisco group, which includes the Graham, with the Virgil series of Moore. This correlation places the Graham in a higher position in the Pennsylvanian. It is said to have been made largely on the basis of the association of the ammonoid *Uddenites* with a certain fusulinid.

The collections the writer has studied do not contain enough species with restricted ranges to fix the age of the Graham within narrow limits. They do, however, indicate that the Graham fauna is as young as that of the Lansing group (upper part of Missouri series of Moore), and that it may be as young as the Virgil series of Moore of the northern Midcontinent region or as the *Uddenites* zone of western Texas. The author's collections are, however, slightly more suggestive of a Lansing age than of a younger one.

COLLECTIONS FROM THE THRIFTY FORMATION

The Thrifty formation, as considered in this report, includes all beds from the base of the Avis sandstone member to the top of the Breckenridge limestone member of the Brazos River region and to the top of the Chaffin limestone member of the Colorado River region. Ten collections were obtained from it in the Brazos River valley and nine collections in the Colorado River valley.

BRAZOS RIVER VALLEY

The members and beds in the Thrifty formation in the Brazos River valley from which collections were obtained are listed in stratigraphic order below:

1 Tb.[5] Breckenridge limestone member.
2 Tb. Blach Ranch limestone member.
3 Tb. Ivan limestone member.
4 Tb. Unnamed limestone above Avis sandstone and below Ivan limestone.

Collection from unnamed limestone above Avis sandstone member and below Ivan limestone member (fossil zone 4 Tb).—One collection, 7527, was obtained from a limestone that is exposed along the drive to a house about 1.1 miles by automobile speedometer due north of Eliasville. This limestone is below the Ivan limestone, which crops out near the house, and is above the Avis sandstone. It is a very argillaceous brown to yellow limestone that weathers granular. Most beds are 4 to 6 inches thick, and some beds are almost a coquina of molluscan shells, few of which are recognizable. Greenish-gray and yellow-brown clay pellets are common. Gastropod sections are common on most of the beds.

[5]T = Thrifty formation; b = Brazos River valley.

Some beds are composed almost entirely of Myalinas; others almost entirely of productoid shells. No fusulinids or crinoids were seen. The list is as follows:

"Productus" (Linoproductus) sp. undet., fragments only (r to c)
Marginifera? lasallensis (Worthen) (c)
Leda bellistriata Stevens n. var. A (r)
Myalina, possibly two species (c)
Bellerophon? crassus? Meek and Worthen, internal molds and poorly preserved specimens, some large (c)
Straparollus (Euomphalus) sp. undet., two poorly preserved specimens

Collections from the Ivan limestone member (fossil zone 3 Tb).—The Ivan limestone is very sparsely fossiliferous at all localities at which it was seen. Intensive collecting has yielded only a very few fossils.

Three small collections were obtained from this limestone—collection 7533 from the same locality as collection 7527 (fossil zone 4 Tb), about 1.1 miles north of Eliasville; collection 7520 from beds along Gage Creek, about 2 miles west and 0.8 mile north of Eliasville; and collection 7592, made by Wallace Lee, from a locality 2 miles south of Ivan.

Collection 7533 came from a neutral-gray dense to finely crystalline limestone at least 4 feet thick. Some beds appear brecciated. Fossils are very rare. A list of those collected follows:

Crinoid columnals (vr)
Composita subtilita (Hall) (r)

Collection 7520 is larger, but it also contains few species. This collection was obtained by Lee and Williams on August 6, 1934, and contains the following forms:

Syringopora sp. undet. (c)
Fistulipora? sp. undet. (r)
Composita subtilita (Hall) (r)

Collection 7592 contains only fragments of brachiopods as shown on weathered surfaces of pieces of limestone, crinoid stems, and separate crinoid columnals.

Collections from Blach Ranch limestone member (fossil zone 2 Tb).—At most localities the Blach Ranch limestone is but sparsely fossiliferous. Only one collection was obtained from it, but the limestone was examined for fossils at several localities. At each of the places where it was examined the Blach Ranch limestone shows fragments and sections of fossils on weathered surfaces. Identifiable fossils could be found, however, at only one locality. The most common fragments seen are crinoid columnals. Fusulinids, horn corals, and brachiopods are the fossils most often seen in section, but they are rare.

The single collection (7501) came from beds along a road half a mile west of the McCann bridge over Salt Fork of Brazos River. It contains the following species:

Fusulinids (r to c)
Lophophyllum profundum Edwards and Haime (r)
Lophophyllum profundum radicosum Girty (r)
Crinoid columnals (r)
Fenestella? sp. undet., only nonporiferous specimens (c)
Rhombopora lepidodendroides Meek (r to c)
Other Bryozoa, one species (r)
Chonetes sp. undet. (r)
Chonetes (Lissochonetes) geinitzianus senilis (Dunbar and Condra) (r)
Chonetes granulifer Owen (c)
"Productus" (Juresania) nebrascensis Owen (r)
"Productus" (Dictyoclostus) americanus? (Dunbar and Condra), one incomplete specimen
Marginifera? lasallensis (Worthen) (r)
Marginifera splendens (Norwood and Pratten) var. A (r)
Marginifera wabashensis? (Norwood and Pratten), one specimen
Wellerella osagensis (Swallow) (r)
Spirifer (Neospirifer) triplicatus Hall (r to c)
Squamularia perplexa (McChesney) (r to c)
Crurithyris planoconvexa? (Shumard) (r)
Punctospirifer kentuckyensis (Shumard) (r)
Hustedia mormoni (Marcou) (r)
Composita subtilita (Hall) (r to c)
Straparollus (Euomphalus or Schizostoma) subrugosus? Meek and Worthen (r)
Naticopsis? sp. undet., part of lateral face of a whorl
Cephalopod cf. Metacoceras? sp. undet., fragment (r)
Griffithides? sp. undet. fragment

Collections from the Breckenridge limestone member (fossil zone 1 Tb).—The Breckenridge member is one of the most fossiliferous limestones of the Thrifty formation of the Brazos River valley. Good collections may be had at several localities by breaking large quantities of rock.

Five collections were obtained from this limestone. One contained only fusulinids. Of the other four, two (7536 and 7537) are from Crystal Falls; one (7542) from a locality 4 miles west of Eliasville, on the Donnell ranch; and one (7504) from a locality about a mile northeast of Crystal Falls.

A composite list of collections 7536 and 7537 is given below. These collections were obtained from the same locality, below the dam at Crystal Falls, from water level up to about 4 feet above water level.

Fusulinids (c)
Crinoid columnals (r to c)
Echinoid spines (r)
Fistulipora sp. undet., massive form (r)
Cyclotrypa? sp. undet. (r)
Fenestella? sp. undet., nonporiferous side (r)
Septopora sp. undet., one fragment
Rhombopora lepidodendroides Meek (c)
Derbya crassa var. texana Dunbar and Condra (r)
Chonetes granulifer Owen (vc)
"Productus" (Linoproductus) sp. undet., two fragments
"Productus" (Dictyoclostus) americanus (Dunbar and Condra) (c)
Marginifera wabashensis (Norwood and Pratten) (vc)
Wellerella osagensis (Swallow) (r to c)
Spirifer (Neospirifer) triplicatus Hall (r to c)
Crurithyris planoconvexa (Shumard) (a)
Punctospirifer kentuckyensis (Shumard) (r to c)
Pelecypod, pectinoid form, one fragment

The following species are contained in collection 7542:

Fusulinids (c)
Crinoid columnals (r to c)
Fistulipora? sp. undet. (r)
Rhombopora lepidodendroides Meek (r)
Derbya crassa texana? Dunbar and Condra, one fragment
Chonetes granulifer Owen (r to c)
"Productus" (Dictyoclostus) sp. undet. (r)
Marginifera wabashensis (Norwood and Pratten) (r)
Wellerella osagensis (Swallow) (r to c)
Spirifer (Neospirifer) triplicatus Hall (r to c)
Punctospirifer kentuckyensis (Shumard) (r)
Crurithyris planoconvexa (Shumard) (r to c)

Collection 7504 was hastily made and is not representative. It contains the following species:

Fusulinids (r to c)
Cyclotrypa sp. undet. (r)
Fenestelloid bryozoan (r)
Spirifer sp. undet., several fragments
Composita subtilita (Hall) (r)

COLORADO RIVER VALLEY

In accordance with previous general practice, the Thrifty formation in the Colorado River valley is here considered as extending from the top of the Wayland shale to the top of the Chaffin limestone member. It would thus include four limestones from which fossils were obtained. These limestones are listed in stratigraphic order below.

1 Tc.[6] Chaffin limestone member.
2 Tc. Thin limestone about 10 feet below Chaffin limestone member.
3 Tc. Speck Mountain limestone member.
4 Tc. Bellerophon limestone.

No animal fossils were collected from the shales between these limestones. A collection of plants was obtained by Fred F. Yockstick from shales between limestone No. 1 and limestone No. 2 of the Chaffin member.

Collection from the Bellerophon limestone (fossil zone 4 Tc).—Only one collection, 7572, was made from zone 4 Tc. It came from a locality near Walkers Crossing on Colorado River. Sections of fossils are very common on the surfaces of the beds at this locality, but recognizable fossils are rare. The following forms are contained in this collection:

Fusulinids (r)
Crinoid columnals (r to c)
"Productus" (Cancrinella) boonensis? (Swallow) (r)
Marginifera? lasallensis (Worthen) (r)
Bellerophon? sp. undet., internal molds only (r to c)

Collection from the Speck Mountain limestone member (fossil zone 3 Tc).—The only collection (7571) obtained from the Speck Mountain member came from beds along Camp Creek, about 2½ miles east and a quarter of a mile south of Rockwood. Fossils are rare in this limestone and are difficult to obtain from the matrix or in recognizable form. Fossil sections of Compositas are frequently seen on weathered surfaces, however, and crinoid stems, though less abundant, are nevertheless rather common. The collection contains the following species:

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[6]T = Thrifty limestone; c = Colorado River valley.

Crinoid columnals (r)
Marginifera? wabashensis (Norwood and Pratten) (r)
Composita subtilita (Hall) (r)
Fragments of unidentifiable shells fairly common

Collections from thin limestone 10 feet below the Chaffin limestone member (fossil zone 2 Tc).—A limestone only a few inches thick occurs 10 feet below the Chaffin limestone member and above a red shale. It is almost entirely composed of fusulinids, so that it might well be called a "fusulinid coquina."

Three collections were obtained from this zone. Two of them were mainly fusulinids. The other, 7570, is listed below:

Fusulinids (va)
Crinoid columnals (c)
Echinoid spines (r to c)
Polypora sp. undet. (r to c)
Rhombopora lepidodendroides Meek (c)
"Productus" (Dictyoclostus) americanus? (Dunbar and Condra) fragments
Spirifer (Neospirifer) triplicatus Hall (r)
Phillipsia major Shumard (r)

Collections from Chaffin limestone member (fossil zone 1 Tc).—Three collections were made from the Chaffin limestone member. One of them was composed wholly of fusulinids. The other two are reported below. Collection 7558 came from the type locality, the Chaffin farm, near the Chaffin crossing of Colorado River. The other, 7569, came from beds along Camp Creek on the Connolly farm, about 2½ miles east of Rockwood.

The following list shows the forms in collection 7558. This collection is not representative, as only a short time was spent in obtaining it.

Crinoid stems (r)
Fenestelloid bryozoan (r)
"Productus" (Juresania) nebrascensis? Owen, very young (r)
"Productus" (Echinoconchus) sp. undet., fragment
Spirifer (Neospirifer) triplicatus Hall (r)

Collection 7569 is larger and more nearly representative. It contains the following forms:

Fusulinids (r to c)
Crinoid columnals (r to c)
Echinoid spines (r)
Fistulipora sp. undet. (r to c)
Cyclotrypa? sp. undet. (r to c)

Polypora sp. undet. (r)
Rhombopora lepidodendroides Meek (c)
Chonetes granulifer transversalis Dunbar and Condra (r)
"Productus" (Dictyoclostus) americanus (Dunbar and Condra) (r)
Spirifer (Neospirifer) triplicatus Hall (r)
Spirifer sp. undet., fragments of very young (r)

CORRELATION OF MEMBERS OF THE THRIFTY FORMATION

Plummer and Moore correlate the Breckenridge and Blach Ranch limestones of the Brazos River valley with the upper and lower parts of the Chaffin limestone member of the Colorado River valley, which bifurcates in the Colorado River valley north of the area studied by Nickell. They do not give the basis for their correlations and do not attempt to correlate individually other limestones included by them in the Thrifty formation.

All the Thrifty limestones are thin. None of them is very fossiliferous, and none contains a fauna so distinctive that it can be recognized in more than one area. With one or two exceptions, all the species found in these limestones are rather long-ranging forms. The excepted species occur only in one or the other of the two outcrop areas. There is, then, no adequate basis indicated by the author's collections for the faunal correlation of individual beds within the Thrifty formation.

The only two limestones that contain faunas of any notable size are the Blach Ranch and Breckenridge limestones of the Brazos River area. No bed in the Colorado River valley has a fauna as large as either of these beds, but the fauna of the Chaffin limestone member of that area most nearly approaches these two more northerly faunas in size.

It is thus evident that the author's data are insufficient either to confirm or to controvert correlations previously made.

Certain lithologic resemblances seen in the field and again noted in the laboratory exist between the *Bellerophon* and Ivan limestones, between the Speck Mountain and Blach Ranch limestones, and between the Chaffin limestone member and the Breckenridge limestone. These resemblances have, however, very little if any weight in correlation, because of the common variability of thin Pennsylvanian limestones and because of the great distance between the Brazos River and Colorado River outcrop areas.

FAUNAL MEANS OF DIFFERENTIATING THE THRIFTY FROM ADJACENT FORMATIONS

The faunal differences between the Thrifty formation and the subjacent Graham formation are so striking that the two can be easily distinguished. These differences are especially well shown by the shales. The shales of the Graham are, in the main, very fossiliferous; those of the Thrifty are unfossiliferous. The Thrifty shales are more generally reddish or purplish or grayish than the Graham shales, most of which are light yellow-brown. Some shales in the Graham are, however, dark gray and therefore resemble some shales in the Thrifty.

Like the shales, the Thrifty limestones are on the average more sparsely fossiliferous than the Graham limestones.

As shown by the fossil lists previously given many species and genera, especially of pelecypods and gastropods, that are common in the Graham are not present in the Thrifty. Mostly because of this difference, but partly also because of an increasing abundance, Bryozoa, including especially *Rhombopora lepidodendroides* Meek, and brachiopods, including especially "*Productus*" *(Dictyoclostus) americanus* (Dunbar and Condra), and Marginiferas, are relatively more numerous in the Thrifty. The author's collections show no species in the Thrifty that is not present in the underlying Graham.

The faunal differences between the Thrifty and the superjacent Harpersville formation are considered in the discussion of the Harpersville.

OUTSIDE CORRELATION OF THE THRIFTY FORMATION

Most of the species in the author's collections from the Thrifty are relatively long-ranging forms, and they therefore supply little evidence for the correlation of the Thrifty with formations outside of north-central Texas. The position of the Thrifty above the Graham, which is probably as young as Lansing, would make the Thrifty of Lansing age or younger. It is possible that the Thrifty might be as young as the Wabaunsee of the Mississippi Valley region, but, though the writer's evidence is not at all conclusive, it does give a slight suggestion that the Thrifty is more probably older than the Wabaunsee. This suggestion is based largely on three species which, although reported from the Wabaunsee and higher beds, are more characteristic of beds below the Wabaunsee than of the Wabaunsee itself. These are *Marginifera wabashensis, Marginifera lasallensis,* and *Squamularia perplexa.*

COLLECTIONS FROM THE HARPERSVILLE FORMATION

The Harpersville formation, though more fossiliferous than the Thrifty, is much less fossiliferous than the Graham. Fossils are more abundant in the upper beds than in the lower, but good collections were obtained from most of the beds in the Brazos River valley. The beds of the Colorado River area are as a rule less fossiliferous than those of the Brazos River area.

The most widely accepted interpretation of the Harpersville formation includes in it all beds between the top of the Breckenridge limestone and the top of the Saddle Creek limestone. This interpretation is followed here. Eighteen collections were made from this formation in the Brazos River valley and 10 from beds referred to in the Colorado River valley.

BRAZOS RIVER VALLEY

The following members, arranged in stratigraphic order, yielded fossils in the Brazos River valley:

1 Hb.[7] Saddle Creek limestone member.
2 Hb. Myalina-bearing limestone.
3 Hb. Belknap limestone member (green crystalline bed).
4 Hb. So-called "Waldrip limestones."
5 Hb. So-called "Upper Crystal Falls limestone."
6 Hb. Crystal Falls limestone member.
7 Hb. "Cl" limestone bed of maps.

Collections from "Cl" limestone beds of maps (fossil zone 7 Hb).—Two collections were made from zone 7 Hb. One contained only fusulinids. The other collection, 7538, which is listed below, was obtained south of the pump house about half a mile north of Crystal Falls,

Fusulinids (c)
Crinoid columnals (r to c)
Echinoid spine (r)

[7]H= Harpersville formation; b= Brazos River valley.

Fenestella? sp. undet., nonporiferous specimens (r)
Rhombopora lepidodendroides Meek (c)
Chonetes granulifer Owen (r), some very young
Derbya? sp. undet., young individual (r)
Spirifer (Neospirifer) triplicatus Hall (r)
Straparollus (Euomphalus or Schizostoma) sp. undet. (r)

Collections from Crystal Falls limestone member.—Four collections were made from the Crystal Falls limestone member. Two collections were composed of fusulinids. One of the others, 7539, came from beds along the railroad at Crystal Falls, and the other, 7541, came from the Donnell ranch, about 4 miles west of Eliasville. Collection 7539 contains the following species:

Fusulinids (vc)
Crinoid stems (vc)
Fenestelloid Bryozoa (c)
Polypora sp. undet. (r to c)
Septopora? sp. undet. (r)
Rhombopora lepidodendroides Meek (a)
Derbya wabaunseensis? Dunbar and Condra (r)
Derbya sp. undet., very young individual (r)
Chonetes granulifer Owen (r to c)
"Productus" (Juresania) nebrascensis? Owen, young? (r)
"Productus" (Echinoconchus) semipunctatus moorei? Dunbar and Condra (r)
"Productus" (Linoproductus) prattenianus Norwood and Pratten (r)
"Productus" (Dictyoclostus) americanus (Dunbar and Condra), one crushed individual
Marginifera? lasallensis (Worthen) (r)
Spirifer (Neospirifer) triplicatus Hall (c)
Crurithyris planoconvexa (Shumard) (r)
Composita subtilita (Hall) (r to c)
Myalina sp. undet.

The following species were identified in collection 7541:

Fusulinids (r to c)
Crinoid stem joints and plates (c)
Chonetes granulifer Owen (r to c)
Derbya sp. undet., large form, one poor dorsal valve
Derbya sp. undet., piece of a small ventral valve
"Productus" (Echinoconchus) sp. undet., part of one dorsal valve
"Productus" (Linoproductus) sp. undet., fragment
Spirifer (Neospirifer) triplicatus Hall (c)

Collections from the so-called "Upper Crystal Falls limestone" (fossil zone 5 Hb).—Four collections were studied from zone 5 Hb; two, 7547 and 7593, came from the Donnell ranch, 4 miles west of Eliasville; and two, 7540 and 7540A, from Crystal Falls.

The following list of species combines those in collections 7540 and 7540A. The Upper Crystal Falls at the locality of these collections consists of two limestone beds separated by a shale parting and has a total thickness of 38 to 40 inches. Collection 7540A came from the parting. The surfaces of the limestone beds are covered with shell fragments and crinoid stems. Many fragments are of Myalinas.

Fusulinids (r to c)
Crinoid stems (c)
Echinoid spines (r)
Tabulipora? sp. undet. (r)
Rhombopora lepidodendroides Meek (c)
Derbya sp. undet., possibly D. ciscoensis Dunbar and Condra, one fragment
Chonetes granulifer Owen (r)
Chonetes granulifer meekianus? Girty (r to c)
"Productus" (Juresania) nebrascensis? Owen, fragments only (c)
Spirifer (Neospirifer) triplicatus Hall (r)
Composita? subtilita (Hall) (r)
Myalina sp. undet., fragments only (c)
Pseudorthoceras knoxense (McChesney) (r)

Collection 7547 came from a locality near a tank on the Donnell ranch. It contains the following species:

Horn coral, unidentifiable fragments (r to c)
Crinoid columnals (vc)
Echinoid spines (r)
Fenestella? sp. undet. (r)
Rhombopora lepidodendroides Meek (r to c)
Derbya ciscoensis? Dunbar and Condra, young only (r to c)
Chonetes granulifer Owen (c)
Chonetes granulifer meekianus? Girty (r)
"Productus" (Juresania) nebrascensis Owen (r)
"Productus" (Echinoconchus) semipunctatus moorei (Dunbar and Condra) (r)
Spirifer (Neospirifer) triplicatus Hall (r to c)
Leda? sp. undet. (r)
Allerisma terminale? Hall, one internal mold
Gastropod fragments (r)

Collection 7593 was made by Wallace Lee. It is labeled "Wagon Timber Branch, Donnell ranch." It contains one specimen, on which are crinoid stems and part of the pygidium of "*Griffithides*" sp. undet.

Collections from so-called "Waldrip limestones" (fossil zone 4 Hb).—Three limestones occurring in the Colorado River valley have been called by geologists "Waldrip limestones Nos. 1, 2, and

3," or "upper, middle, and lower Waldrip beds." In the Brazos River valley, geologists working on the hypothesis that all three of those limestones continue northward have designated three limestones as the "upper, middle, and lower Waldrip limestones." A collection of fossils was obtained from only one of the three beds in the Brazos River valley. This collection (7549) came from an 8- to 10-inch bed of soft, crumbly brown limestone, exposed about 8 inches above a thin coal on Wagon. Timber Branch about 7½ miles west of Eliasville. The list is as follows:

Fusulinid, one specimen seen in field (r)
Crinoid columnals (a)
Rhombopora lepidodendroides Meek (r to c)
Enteletes hemiplicatus (Hall) (r)
Derbya sp. undet., one fragment (r)
Chonetes granulifer Owen (r to c)
"Productus" (Dictyoclostus) americanus (Dunbar and Condra) var. A? (r to c)
Spirifer (Neospirifer) triplicatus Hall (r to c)

Although no fossils were collected from the lower limestone, they were observed on the surface of a lower bed exposed along Wagon Timber Branch. Crinoid stem joints were common. Echinoid spines and a *Chonetes*, probably *C. granulifer meekianus* Girty were also observed.

Collections from the Belknap limestone member (fossil zone 3 Hb).—Five collections were made from the Belknap limestone member. One, 7543, came from beds along the road to Crystal Falls about 7 miles west of Eliasville; another, 7596, was obtained along the same road but only about 5 miles west of Eliasville; two others, 7521 and 7545, the largest collections made, and a fifth collection, composed mainly of fusulinids, came from the Vick ranch, about 12½ miles west of Graham.

The following composite list shows the species in collections 7521 and 7545. These two collections came from the same horizon and precisely the same locality, on a ranch road west of the Nash & Windfohr oil pool on the Vick ranch.

Fusulinids (c)
Lophophyllum profundum (Edwards and Haime) (c)
Lophophyllum profundum radicosum Girty (r to c)
Crinoid stems and plates (a)
Echinoid spine (r)
Fistulipora? sp. undet. (r to c)

Cyclotrypa sp. undet. (vc)
Fenestella? sp. undet. (r)
Polypora sp. undet. (r to c)
Pinnatopora sp. undet. (r)
Septopora sp. undet. (c)
Rhombopora lepidodendroides Meek (r)
Enteletes hemiplicatus Hall (r)
Derbya cymbula? Hall and Clarke, dorsal valves only (r)
Derbya wabaunseensis? Dunbar and Condra, fragments of large ventral valves (r)
Chonetes granulifer Owen (c)
Chonetes granulifer meekianus? Girty (r to c)
"Productus" (Juresania) nebrascensis Owen (r to c)
"Productus" (Juresania) nebrascensis? Owen var., unusually large variety close to P. symmetricus (c)
"Productus" (Linoproductus) prattenianus Norwood and Pratten
"Productus" (Dictyoclostus) americanus (Dunbar and Condra) (r to c)
Marginifera? sp. undet., crushed specimen (r)
Rhynchopora sp. undet., (r)
Spirifer (Neospirifer) triplicatus Hall (c)
Spirifer (Neospirifer) kansasensis Swallow (r)
Punctospirifer cf. P. kentuckyensis (Shumard) (r to c)
Pinna? sp. undet., large form (r to c)
Pseudomonotis? cf. P. hawni Meek and Hayden (r)
Aviculipecten herzeri Meek (r)
Deltopecten vanvleeti (Beede) (r)
Allerisma terminale Hall (r)

Collection 7543 came from two 8- to 10-inch beds of green, finely crystalline argillaceous limestone. These beds are separated by 12 to 18 inches of blue-gray clay. Species in this collection are as follows:

Fusulinids (r to c)
Horn corals, unidentifiable fragments (r to c)
Crinoid columnals, large and small (vc)
Delocrinus hemisphericus (Shumard) (r)
Fistulipora? sp. undet. (r)
Fenestella? sp. undet. (r)
Polypora sp. undet. (r)
Rhombopora lepidodendroides Meek (c)
Enteletes hemiplicatus (Hall) (r)
Chonetes granulifer Owen (c)
Chonetes granulifer meekianus? Girty (r)
"Productus" (Juresania) nebrascensis Owen((r to c)
"Productus" (Linoproductus) prattenianus Norwood and Pratten (r to c)
"Productus" (Dictyoclostus) americanus (Dunbar and Condra) (r to c)
Marginifera wabashensis? (Norwood and Pratten) (r)
Spirifer (Neospirifer) triplicatus Hall (r)
Pinna? sp. undet., rather large form (r to c)

Collection 7596 came from beds along the road between Eliasville and Crystal Falls, at a point about 5 miles west of Eliasville. It was obtained by Wallace Lee and consists of only one specimen, a large, robust individual of *Enteletes hemiplicatus* (Hall).

Collections from Myalina-bearing limestone (fossil zone 2 Hb.).—This *Myalina*-bearing limestone is said to be a rather persistent horizon marker. One collection, 7534, was obtained from it at an outcrop along a small stream west of the road about 5 miles almost due north of Crystal Falls. Myalinas are abundant, the bed being almost a coquina of them. Only one species was recognized, *Myalina subquadrata* Shumard. Most of the specimens are large, an average height being about 3½ inches.

Collections from the Saddle Creek limestone member (fossil zone 1 Hb).—At the localities from which collections were made the Saddle Creek limestone is recognizable by the large number of crinoid stems and plates and echinoid spines and plates that weather out from it. Most of the crinoid stems are small. In places the thin limestones are reduced by weathering to crumbly masses of crinoid and echinoid fragments. In other places they cover the shale slopes for some distance below the outcrops.

Two collections were made from this member. One, 7535, came from a locality about 3 miles north and 3 miles west of Crystal Falls; the other, 7544, from a locality about 5½ miles north and an eighth of a mile east of Crystal Falls.

Collection 7535 contains the following species:

Crinoid stems and plates (vc)
Echinoid spines and plates (c)
Fenestella sp. undet. (r to c)
Rhombopora lepidodendroides Meek (r to c)
"Productus" (Linoproductus) sp. undet., fragment of a large form (r)
Spirifer (Neospirifer) triplicatus Hall (r)
Composita subtilita (Hall) (r to c)
Myalina sp. undet., fragments (r to c)

The following is a list of species comprised in collection 7544:

Crinoid stems and plates (vc)
Echinoid spines (r to c)
Septopora sp. undet., fragment (r)
Rhombopora lepidodendroides Meek (r)
"Productus" (Linoproductus) sp. undet., fragment

COLORADO RIVER VALLEY

In the Colorado River valley fossils were obtained from the following subdivisions of the Harpersville formation:

1 Hc.[8] Saddle Creek limestone member.
2 Hc. Waldrip limestone No. 3.
3 Hc. Waldrip limestone No. 2.
4 Hc. Red shale.
5 Hc. Waldrip limestone No. 1.

Collections from Waldrip limestone No. 1 (fossil zone 5 Hc).— Two collections were made from the Waldrip limestone No. 1. Both of them came from a barnyard east of the south end of a bridge on the north edge of Rockwood. One of these collections consisted entirely of fusulinids. The other collection, 7568, is listed below. This limestone is but sparsely fossiliferous.

Fusulinids (vc)
Crinoid columnals, large and small (vc)
Fistulipora? sp. undet. (r)
Cystodictya sp. undet. (r to c)
Enteletes sp. undet., fragment of large individual (r)
"Productus" (Linoproductus) cf. P. prattenianus Norwood and Pratten (r)
Spirifer (Neospirifer) triplicatus Hall, fragments common

Collection from a red shale between Waldrip limestones Nos. 1 and 2 (fossil zone 4 Hc).—A collection of fossil plants was made from zone 4 Hc at a locality west of the cotton gin at Rockwood.

Collection from Waldrip limestone No. 2 (fossil zone 3 Hc).— Two collections were made from the Waldrip limestone No. 2. Both came from the same locality, the first projecting point on the east side of the first gully west of the cotton gin at Rockwood. One consisted chiefly of microfossils. The other one (collection 7562) is here listed.

Fusulinids (r to c)
Crinoid columnals (c)
Crinoid arm plates (r to c)
Echinoid spines (r)
Fistulipora? sp. undet. (r)
Cystodictya sp. undet. (r to c)
Septopora sp. undet. (r)
Rhombopora lepidodendroides Meek (a)

[8]H= Harperville formation; c= Colorado River valley.

"Productus" (Juresania) nebrascensis? Owen, two dorsal valves
Spirifer (Neospirifer) triplicatus Hall (c)
Spirifer (Neospirifer) kansasensis Swallow (r)
Composita subtilita ovata (Mather) (a)
Pinna? sp. undet., large form (r)
Allerisma terminale Hall (r to c)
Bellerophon? sp. undet., internal mold (r)

Collections from Waldrip limestone No. 3 (fossil zone 2 Hc).—Two collections were made from the Waldrip limestone No. 3 near Rockwood. The bed is very sparsely fossiliferous, and fossils are obtained with difficulty. One of the collections consisted mainly of fusulinids and very small fossils. The other one (collection 7563) is listed below.

Fusulinids, common as sections on slabs
Crinoid columnals, many small and few large ones (c)
Chonetes flemingi alata? Dunbar and Condra (r)
Chonetes granulifer? Owen (r)
Marginifera? sp. undet., fragment (r)
Spirifer (Neospirifer) triplicatus? Hall, fragment (r)
Astartella? sp. undet., one specimen (r)

Collections from the Saddle Creek limestone member (fossil zone 1 Hc).—Three collections were made from the Saddle Creek limestone of the Colorado River valley. One contained only fusilinids. Neither of the other collections is very large. At the two localities from which the collections came the Saddle Creek is very sparsely fossiliferous, and at no other locality on Colorado River at which the writer saw it did it appear to contain numerous fossils. Collection 7565 came from a point across Colorado River from what the author was told was the mouth of Saddle Creek. If so, the locality is very near the type locality of the member. The species in this collection are as follows:

Fusulinids (r)
Axophyllum rude? White and St. John (c)
Crinoid stems (r)
Echinoid spine (r)
Fistulipora sp. undet., massive form (r)
Chonetes granulifer Owen (r)
"Productus"? sp. undet. (r)
Marginifera wabashensis? var. A (r)
Spirifer (Neospirifer) triplicatus Hall (r to c)
Puntospirifer kentuckyensis (Shumard) (r)
Composita subtilita (Hall) (c)
Econospira? sp. undet., internal mold (r)
Bellerophon? sp. undet., internal molds (r to c)

Collection 7564 was obtained from a ridge west of Rockwood. The species identified are given in the following list:

Crinoid stems (r)
Fenestelloid Bryozoa on slabs (r)
Axophyllum? sp. undet., fragment (r)
Spirifer (Neospirifer) triplicatus Hall (r)
Composita subtilita (Hall) (r to c)
Gastropod sections on slabs (r)

CORRELATION OF MEMBERS OF THE HARPERSVILLE FORMATION

The lack of reliable results usually obtainable in attempting to make faunal correlations between thin limestones within formations, of whatever age, is well shown by the collections from the Harpersville formation. Few of the limestone beds in the Harpersville of the Brazos River valley have many species in common with beds of the Harpersville of the Colorado River valley. The species that are common to beds in these two areas are long-ranging and hence of comparatively small correlative value. The collections here studied indicate, as is of course well known, that under such conditions as exist in this area a large number of common species is not necessarily a valid basis for correlation. As so many of the species making up the collections are long-ranging, it would naturally be expected that one large collection would have more species in common with another large collection than with a small collection, regardless of age. The effect, if correlations were made solely on number of common species, would be virtually to base correlations on the degree to which a bed was fossiliferous. Such a basis may furnish trustworthy results, but on the other hand it may give results that are easily seen to be in error.

However, there seems to be a reasonably good paleontologic basis for correlating the Belknap limestone of the Brazos River valley with the Waldrip No. 2 limestone of the Colorado River valley, even if the evidence from the number of common but long-ranging species is partly discounted. About 80 per cent of the fauna of the Waldrip No. 2 limestone occurs in the Belknap, and over 30 per cent of the fauna of the Belknap occurs in the Waldrip No. 2 limestone. In addition, the distribution of classes and orders is nearly the same in both. Both have rather large bryozoan and brachiopod faunas and subordinate but more or less similar pelecypod faunas. Added strength is given to this evidence for correlation by the occurrence in both beds of *Spirifer (Neospirifer) kansasensis* (Swallow), a brachiopod species that is as yet known in northern Texas only from these two beds. As before stated, correlations from evidence like that given are susceptible to modification or even nullification by new information, but, for that matter, so are all conclusions regarding correlation.

The Saddle Creek limestone of the Brazos River valley lacks the coral *Axophyllum rude?* White and St. John, which is common in the Saddle Creek of the type region (Colorado River valley), and the Saddle Creek of the Colorado River region lacks the relatively great abundance of crinoids and echinoid spines, stems, and plates that occur at the outcrops of the Saddle Creek of the northern area. Otherwise the faunas do not differ greatly. Fossils are relatively scarce in both areas.

Plummer and Moore give a rather large fauna from a shale below the Saddle Creek of the Colorado River area. The author does not have collections from this shale.

If the Saddle Creek and Belknap of the Brazos River valley are the same respectively as the Saddle Creek and Waldrip No. 2 limestone of the Colorado River valley, then the Waldrip No. 3 limestone is not present in the Brazos River valley and the *Myalina*-bearing bed is not present in the Colorado River valley.

No data that are not manifestly inadequate are afforded by the author's collections for the correlation of the limestones or other zones of the Harpersville below the Belknap of the Brazos River area and below the Waldrip No. 2 limestone of the Colorado River area.

FAUNAL DATA FOR DISTINGUISHING THE HARPERSVILLE FROM ADJACENT FORMATIONS

Although the Harpersville faunas differ in a general way in several respects from the faunas of the underlying Thrifty formation, the differences are not so clear that they can always be used in drawing a precise contact. Of use in a general way, however, are the greater proportion and variety in the Harpersville of Bryozoa, especially the Cystodictyas of the Colorado River area and the fenestelloids; the greater proportion of brachiopods, especially of "*Productus*" *(Dictyoclostus) americanus*. *Chonetes granulifer* var. approaching *meekianus*, large species of *Derbya*, and *Enteletes hemiplicatus*; and the greater proportion of certain pelecypods, such as large Pinnas and *Allerisma terminale*.

The Harpersville is the lowest formation represented in the author's collections in which occur *Derbya wabaunseensis*, *D. ciscoensis*, *D. cymbula*, *Chonetes granulifer* var. approaching *meekianus*, "*Productus*" *(Echinoconchus) semipunctatus* var. *moorei*, *Spirifer (Neospirifer) kansasensis*, *Deltopecten vanvleeti* and *Aviculopecten herzeri*. The second species of this list has, however, been reported from the Thrifty by Dunbar and Condra, and the fourth has been reported from the Graham by two or three writers.

The differences between the Harpersville fauna and the fauna of the overlying Pueblo are discussed in connection with that formation.

OUTSIDE CORRELATION OF THE HARPERSVILLE FORMATION

The Harpersville faunas are more closely related to the Wabaunsee than to any other group in the northern Midcontinent region. A great many species are common to these two stratigraphic units, and some of the common species are not known below either zone. Wabaunsee species that, so far as the writer can ascertain, occur in the Harpersville but are not known in the Texas section below the Harpersville are *Derbya wabaunseensis*, "*Productus*" *(Echinoconchus) semipunctatus moorei*, and *Spirifer (Neospirifer) kansasensis*. Some Harpersville species, however, range up into the beds currently referred to the Permian in Nebraska and Kansas.

COLLECTIONS FROM THE PUEBLO FORMATION

The Pueblo formation as here considered includes all beds from the top of the Saddle Creek limestone up to the top of the Camp Colorado limestone. A very short time was spent in collecting from these beds, and the collections reported are probably not representative. Only one collection was obtained from the Brazos River valley. Five collections were made in the Colorado River valley.

BRAZOS RIVER VALLEY

Camp Colorado limestone member.—The only collection from the Pueblo formation of the Brazos River valley came from the Camp Colorado limestone. It was obtained by Wallace Lee at a locality about 4 miles east of Woodson. This collection, 7554, contains the following species:

Crinoid stems (c)
Crinoid plates (r)
Rhombopora lepidodendroides Meek (r to c)
Derbya multistriata? (Meek and Hayden), fragments
"Productus" (Juresania) nebrascensis Owen
Astartella concentrica (Conrad) var.?
Myalina cf. M. permiana Swallow

COLORADO RIVER VALLEY

The following beds in the Pueblo formation yielded collections in the Colorado River valley. The beds are arranged in stratigraphic order.

1 Pc.[9] Camp Colorado limestone member.
2 Pc. Limestone 60 feet below the Camp Colorado limestone.
3 Pc. Drake's bed No. 13 ("limestone with yellow chert"), the Stockwether limestone member of Plummer and Moore.
4 Pc. Thin limestone about 20 feet above Saddle Creek limestone member of Harpersville formation.

These units differ somewhat from those given by Plummer and Moore for the Pueblo of the Colorado River valley.

Collection from a thin limestone about 20 feet above Saddle Creek limestone member (fossil zone 4 Pc).—A collection composed almost entirely of *"Productus" (Linoproductus) prattenianus* var. *magnispinus* was obtained from a thin limestone exposed on the side of a hill capped by the Coon Mountain sandstone member. The exposure is along a dry tributary of Colorado River, about 2½ miles west of the point where the concrete road to the southwest of Rockwood crosses Bull Creek. The limestone is about 12 feet below the Coon Mountain sandstone and within the Camp Creek shale member. It is the second or third thin limestone above the Saddle Creek. The species in this collection, 7566, are as follows:

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[9]P = Pueblo formation; c = Colorado River valley.

Crinoid stems (r)
"Productus" (Juresania) nebrascensis Owen (r to c)
"Productus" (Linoproductus) prattenianus Norwood and Pratten (r to c)
"Productus" (Linoproductus) prattenianus magnispinus (Dunbar and Condra) (a)
Spirifer (Neospirifer) triplicatus Hall (r)

Collections from Drake's bed No. 13 ("limestone with yellow chert"), the Stockwether limestone member of Plummer and Moore (fossil zone 3 Pc).—Only one collection, 7567, was made from zone 3 Pc. It came from exposures along a road, on the north bank of Colorado River, about 3½ miles (map distance) west of Waldrip.

Fusulinid (r)
Crinoid stems (c)
Echinoid spine (r)
Cyclotrypa sp. undet. (r)
Chonetes granulifer var. near meekianus Girty (r)
"Productus" (Juresania) nebrascensis Owen (r)
Marginifera wabashensis? (Norwood and Pratten) var. A., (c)
Spirifer (Neospirifer) triplicatus Hall (r)
Composita subtilita (Hall) (c)

Collection from thin limestone 60 feet below Camp Colorado limestone member (fossil zone 2 Pc).—One collection, 7579, was made from zone 2 Pc by F. F. Yockstick. It came from a prominent hill about half a mile north of Colorado River, at the west edge of the Waldrip quadrangle. The only species in the collection is *Allerisma terminale* Hall.

Collection from the Camp Colorado limestone member (fossil zone 1 Pc).—Only one collection, 7585, was made from the Camp Colorado limestone member of the Colorado River area. It was obtained by F. F. Yockstick at a locality about 4½ miles southeast of Gouldbusk.

Horn corals, fragments, undet.
Crinoid stems
Tabulipora sp. undet.
Fenestelloid bryozoan
Derbya wabaunseensis Dunbar and Condra, one dorsal valve
Chonetes granulifer Owen
"Productus" or Marginifera sp. undet.
Crurithyris planoconvexa (Shumard)
Composita subtilita (Hall)
Pinna? sp. undet.

CORRELATION OF MEMBERS OF THE PUEBLO FORMATION

The collections from the Pueblo formation are too small and too lacking in distinctive characters to allow correlations to be made between the members in the Brazos and Colorado River sections. Plummer and Moore correlate the Camp Colorado limestones of the two areas. The author's collections from these two beds are very dissimilar, but as the collections are small these dissimilarities are probably not significant.

The faunas of the Pueblo are not very different from those of the underlying Harpersville, and therefore faunal criteria have not been used in drawing contacts between the two formations.

The collections from the overlying Moran formation are so incomplete that they are insufficient for a discussion of the faunal relations of the Moran and Pueblo formations.

OUTSIDE CORRELATION OF THE PUEBLO FORMATION

The position of the Pueblo above the Harpersville (which is here thought to be of Wabaunsee age) makes the Pueblo itself Wabaunsee or younger. The slight evidence for a closer correlation afforded by the author's collections is somewhat contradictory. *Derbya wabaunseensis* is, as the name suggests, characteristic of the Wabaunsee group. So also is "*Productus*" *(Linoproductus) prattenianus magnispinus*. On the other hand, *Derbya multistriata* and *Myalina permiana* are more characteristic of beds in the northern Midcontinent region now regarded by Dunbar and Condra as Permian. The strength of the evidence from these last two species is diminished, however, by the fact that both are questionably identified. Other species in the rather meager collections are not helpful in distinguishing between late Wabaunsee and early Permian (as considered by Dunbar and Condra and others).

COLLECTIONS FROM THE MORAN FORMATION

With one exception, all collections from the Moran formation came from the Colorado River valley, which was the only area in which the writer was able to study it even casually. The excepted collection (7555) came from an unknown horizon near the base of the Moran. It was obtained by Wallace Lee at an exposure in the bed of a stream south of the road and about 200 yards from a bridge about 3 miles east of Woodson. The bed that yielded it is a brownish-red to red argillaceous limestone, which is almost a coquina of unidentifiable pelecypods and *Bellerophon*-like gastropods.

COLORADO RIVER VALLEY

The following beds in the Moran formation of the Colorado River valley yielded collections. The beds are listed in stratigraphic order.

1 Mc.[10] Sedwick limestone member.
2 Mc. Limestone below Sedwick limestone.
3 Mc. Shale, 8 feet above Horse Creek limestone.
4 Mc. Thin limestone 5 feet above Horse Creek limestone.
5 Mc. Horse Creek limestone member.

Collections from the Horse Creek limestone member (fossil zone 5 Mc).—One collection, 7577, was made from the Horse Creek limestone member. It came from beds along a road about 7½ miles southwest of Gouldbusk, about 100 to 200 feet east of the point where the road crossed Panther Creek.

Axophyllum? sp. undet. (c)
Crinoid stems (c)
Fenestelloid Bryozoa (r to c)
Chonetes sp. undet. (r)
Productoid shell (r)
Wellerella? sp. undet. (r to c)
Composita subtilita (Hall) (c)
Gastropods, indeterminate (r)

Collections from a thin limestone 5 feet above Horse Creek limestone member (fossil zone 4 Mc).—A collection was made from an exposure in a gully tributary to Panther Creek, about 7½ miles southwest of Gouldbusk. It came from a 4- to 6-inch argillaceous limestone 5 feet above the Horse Creek member. The species identified in the collection, which is No. 7575, are as follows:

Sponge spicules (r)
Crinoid columnals (a)
Fenestella, two or three species (a)
Rhombopora lepidodendroides Meek (r to c)

[10]M= Moran formation; c= Colorado River valley.

Other Bryozoa (r to c)
Derbya sp. undet., fragments of large form (r)
Meekella striatocostata (Cox) (r)

Collection from a shale 8 feet above Horse Creek limestone member (fossil zone 3 Mc).—Collection 7574 was obtained at the same locality as collection 7575, but from a slightly higher zone (zone 3 Mc), in a shale bed. The collection came from 6 to 8 inches of shale which is literally crowded with *"Productus" (Dictyoclostus).*

Fistulipora sp. undet. (r)
Fenestelloid Bryozoa (r to c)
Derbya, a large and a small? species
Meekella striatocostata (Cox), two large individuals
"Productus" (Dictyoclostus) americanus (Dunbar and Condra) var. A. (a)
Myalina cf. M. permiana Swallow (r)

Collection from a limestone below Sedwick limestone member (fossil zone 2 Mc).—A blue to "iron-rust" yellow or brown limestone about 1½ feet thick occurs between fossil zone 3 Mc and the Sedwick limestone. This limestone contains many clay pellets. It is estimated to be from 35 to 40 feet above the Horse Creek limestone. A collection, 7576, was made from it along Panther Creek, near locality 7577, as follows:

Echinoid spine (r)
Astartella? sp. undet., fragments of a small form
Aviculipecten? sp. undet., fragments
Gastropods, undet. (r)
Fish teeth (r to c)
Sections of indeterminate fossils on surface of bed (c)

Collection from the Sedwick limestone member (fossil zone 1 Mc).—One collection, 7584, was made from the Sedwick limestone member by Fred F. Yockstick after the writer had left the field. The locality from which it came is on the west side of Panther Creek about 7½ miles southwest of Gouldbusk.

Crinoid stems (vc)
Echinoid spines and plates (r to c)
Fenestella? sp. undet. (r)
Derbya? sp. undet., fragment of young (r)

"Productus" (Dictyoclostus) americanus (Dunbar and Condra)
var. A (c)
Pinna? sp. undet., large form (c)
Myalina cf. M. permiana Swallow (r to c)
Metacoceras? sp. undet., one fragment

CORRELATION OF THE MORAN FORMATION

The writer's collections are manifestly insufficient to permit correlation of the Moran formation of the Colorado River area with beds in the Brazos River area. They are also insufficient to permit a reliable age assignment in terms of sections elsewhere.

This formation has been included by Sellards in the Permian largely on the basis of the occurrence of the genus *Schwagerina* in it. As the collections here studied are in no sense diagnostic, the author does not feel that it would be pertinent in this report to attempt a survey of the "Permian question" or to define the limits of the Permian in the United States.

COLLECTIONS FROM THE PUTNAM FORMATION

Collections were made from only two zones in the Putnam formation, but exposures were examined only in the Colorado River valley. The two zones are the Coleman Junction limestone member and a limestone said to be 77 feet below the Coleman Junction.

Collection from a limestone 77 feet below the Coleman Junction limestone member.—The only collection from the limestone 77 feet below the Coleman Junction limestone member was made by F. F. Yockstick at a locality along Colorado River about 8 miles southwest of Gouldbusk. It is collection No. 7582.

Crinoid columnals
Fistulipora? sp. undet., fragments (r)
Fenestella? sp. undet., nonporiferous side (r)
Septopora? sp. undet., nonporiferous side (r)
Rhombopora lepidodendroides Meek (r)
Derbya cymbula Hall and Clarke (c)
Myalina cf. M. permiana Swallow (r)
Allerisma terminale Hall (c)

Collections from the Coleman Junction limestone member.—Although Plummer and Moore state that the Coleman Junction limestone is abundantly fossiliferous in places, it was very sparsely fossiliferous at the few places where the author saw it. Only two collections were made from it. One, 7583, was made by F. F. Yockstick; the other, 7573, by the writer.

Collection 7573, listed below, came from exposures along a road where it trends southward over an escarpment, about 6½ miles southwest of Gouldbusk. The collection was obtained in 3 hours.

Fusulinids (r)
Lophophyllum profundum radicosum? Girty (r), young
Crinoid columnals (r to c)
Echinoid spines (r)
Fenestelloid bryozoan (r)
Rhombopora lepidodendroides Meek (r)
"Productus" sp. undet., one fragment
Wellerella? sp. undet. (r)
Crurithyris? sp. undet., very young (r to c)
Composita subtilita (Hall) (c)

A small collection, 7583, was obtained about 8½ miles southwest of Gouldbusk. It contains several individuals of a gastropod described by Shumard in 1859 as *Pleurotomaria obtusispira* and sections of fossils shown on the surfaces of the beds. This gastropod is very common in the Hueco limestone in Hudspeth and other counties in Texas and in Arizona and New Mexico. It is soon to be placed by G. H. Girty in a new genus.

CORRELATION OF THE PUTNAM FORMATION

As all the collections from the Putnam here reported came from the Colorado River valley, they furnish no basis for correlating beds between the two areas studied by Mr. Lee. These collections are also insufficient to warrant a definite age assignment. Some of the species are suggestive of equivalence to beds assigned to the Permian in Kansas and Nebraska, but the evidence from them is not conclusive. The gastropod "*Pleurotomaria*" *obtusispira* suggests equivalence to the Hueco limestone of west Texas.

Distribution of species in collections studied from various formations within areas of investigation

	Brazos River Valley						Colorado River Valley								
	Caddo Creek formation	Graham formation	Thrifty formation	Harpersville formation	Pueblo formation	Moran formation	Graford formation	Brad formation	Caddo Creek formation	Graham formation	Thrifty formation	Harpersville formation	Pueblo formation	Moran formation	Putnam formation
Fusulinids. (See pp. 237–243.)	x	x	x	x					x	x	x	x	x		x
Spongiae:															
Coelocladia? n. sp.? aff. C. spinosa Girty		x													
Sponge, boring form		?													
Sponge spicules														x	
Coelenterata:															
Axophyllum rude White and St. John												?			
Axophyllum sp. undet.												?		?	
Lophophyllum profundum (Edwards and Haime)		x	x	x						x					
Lophophyllum profundum radicosum Girty		x	x	x						x					?
Campophyllum torquium (Owen)		x						x	x	x					
Campophyllum sp. undet.		x													
Syringopora sp. undet.		x	x						x						
Chaetopoda:															
Spirorbis sp. undet.							x								
Conularia cf. C. crustula White										x					
Conularia sp. undet.		x													
Echinodermata:															
Crinoid columnals and plates	x	x	x	x	x		x	x	x	x	x	x	x	x	x
Delocrinus hemisphericus (Shumard)				x											
Echinoid spines and plates	x	x	x	x					x	x	x	x	x	x	x
Bryozoa:															
Fistulipora sp. undet.	x	x	x	x						x	x	x		x	?
Cyclotrypa sp. undet.			x	x							x		x		
Tabulipora sp. undet.		?		x									x		
Fenestella sp. undet.		x	?	x			x		x		x	x	x	x	x
Polypora sp. undet.		x		x			x			x	x				
Pinnatopora sp. undet.				x											
Septopora sp. undet.			x	x								x			?
Rhombopora lepidodendroides Meek		x	x	x	x		x			x	x	x		x	x
Cystodictya sp. undet.												x			
Other Bryozoa		x	x				x			x				x	
Brachiopoda:															
Trigonoglossa nebrascensis (Meek)		x													
Orbiculoidea missouriensis (Shumard)		x								x					
Orbiculoidea n. sp. A		x													
Orbiculoidea n. sp. B		x													
Orbiculoidea n. sp. C										x					
Orbiculoidea sp. undet.		x													
Lindstroemella patula (Girty)		x													
Crania modesta White and St. John		x								x					
Rhipidomella carbonaria (Swallow)		x													

Distribution of species in collections studied from various formations within areas of investigation—Continued

	Brazos River Valley						Colorado River Valley								
	Caddo Creek formation	Graham formation	Thrifty formation	Harpersville formation	Pueblo formation	Moran formation	Graford formation	Brad formation	Caddo Creek formation	Graham formation	Thrifty formation	Harpersville formation	Pueblo formation	Moran formation	Putnam formation
Enteletes hemiplicatus (Hall)				x				x							
Enteletes sp. undet.												x			
Derbya cf. D. bennetti Hall and Clarke									x						
Derbya ciscoensis Dunbar and Condra				?											
Derbya crassa (Meek and Hayden)		x					x								
Derbya crassa var. texana Dunbar and Condra			x												
Derbya cymbula Hall and Clarke				?											x
Derbya multistriata (Meek and Hayden)					?										
Derbya wabaunseensis Dunbar and Condra				?									x		
Derbya sp. undet.		x		x										x	
Meekella striatocostata (Cox)		x							x					x	
Meekella striatocostata n. var. aff. var. convexicosta Dunbar and Condra	?								x						
Meekella sp. undet.		x													
Chonetes flemingi alata? Dunbar and Condra												x			
Chonetes granulifer Owen		x	x	x								x	x		
Chonetes granulifer meekianus Girty				x									x		
Chonetes granulifer transversalis Dunbar and Condra		x									x				
Chonetes (Lissochonetes) geinitzianus plattsmouthensis (Dunbar and Condra)		x								x					
Chonetes (Lissochonetes) geinitzianus n. var. aff. C. senilis (Dunbar and Condra)		x	x												
Chonetes sp. undet.		x	x											x	
"Productus" (Juresania) nebrascensis Owen		x	x	x	x					x	?	x	x		
"Productus" (Juresania) nebrascensis var. ovalis (Dunbar and Condra)							x								
"Productus" (Juresania) symmetricus McChesney		x													
"Productus" (Juresania) sp. undet.		x								x					
"Productus" (Pustula) n. sp. A		x													
"Productus" (Echinoconchus) semipunctatus? Shepard		x													
"Productus" (Echinoconchus) semipunctatus moorei (Dunbar and Condra)				x											
"Productus" (Echinoconchus) sp. undet.		x		x				x	x	x	x				
"Productus" (Dictyoclostus) americanus (Dunbar and Condra)		x	x	x						x	x				
"Productus" (Dictyoclostus) americanus (Dunbar and Condra) var. A			x	?										x	

Distribution of species in collections studied from various formations within areas of investigation—Continued

	Brazos River Valley						Colorado River Valley								
	Caddo Creek formation	Graham formation	Thrifty formation	Harpersville formation	Pueblo formation	Moran formation	Graford formation	Brad formation	Caddo Creek formation	Graham formation	Thrifty formation	Harpersville formation	Pueblo formation	Moran formation	Putnam formation
"Productus" (Dictyoclostus) portlockianus Norwood and Pratten		x					x		x						
"Productus" (Dictyoclostus) sp. undet.	x	x	x							x					
"Productus" (Linoproductus) prattenianus Norwood and Pratten		x		x				x	x			x	x		
"Productus" (Linoproductus) prattenianus magnispinus (Dunbar and Condra)													x		
"Productus" (Linoproductus) sp. undet. or n. sp.		x	x	x					x	x					
"Productus" (Cancrinella) boonensis Swallow									x		?				
"Productus" (Cancrinella) n. sp. aff. P. boonensis Swallow		x								x					
"Productus" (Cancrinella) sp. undet.		x													
"Productus" sp. undet.							x			x		?		x	x
Marginifera lasallensis (Worthen)		x	x	x				x	x	x	?				
Marginifera splendens (Norwood and Pratten) var. A		x	x							x					
Marginifera wabashensis (Norwood and Pratten)		x	x	?							?				
Marginifera wabashensis (Norwood and Pratten) var. A	x	x						x	x			?	?		
Marginifera wabashensis (Norwood and Pratten) var. B		x													
Marginifera sp. undet.				?								?	x		
Camarophoria n. sp.		x													
Leptalosia ovalis Dunbar and Condra		x													
Strophalosia n. sp. A		x													
Wellerella osagensis (Swallow)		x	x							x					
Wellerella osagensis (Swallow) n. var.		x													
Wellerella sp., probably new		x													
Wellerella sp. undet.	?													?	?
Rhynchopora illinoisensis (Worthen)		x								x					
Rhynchopora sp. undet.		x		x											
Dielasma bovidens (Morton)	x	x							x						
Spirifer (Neospirifer) kansasensis Swallow				x								x			
Spirifer (Neospirifer) texanus Meek		x								x					
Spirifer (Neospirifer) triplicatus Hall	x	x	x	x			x	x	x	x	x	x	x		
Spirifer sp. undet.		x	x				x		x		x				
Squamularia perplexa (McChesney)	x	x	x						x	x					
Crurithyris planoconvexa (Shumard)		x	x	x					x	x			x		
Crurithyris sp. undet.															x
Punctospirifer kentuckyensis (Shumard)	x	x	x	x				x	x	x		?			
Hustedia mormoni (Marcou)	x	x	x						x	x					

Distribution of species in collections studied from various formations within areas of investigation—Continued

	Brazos River Valley						Colorado River Valley								
	Caddo Creek formation	Graham formation	Thrifty formation	Harpersville formation	Pueblo formation	Moran formation	Graford formation	Brad formation	Caddo Creek formation	Graham formation	Thrifty formation	Harpersville formation	Pueblo formation	Moran formation	Putnam formation
Composita subtilita (Hall)	x	x	x	x			x	x	x	x	x	x	x	x	x
Composita subtilita ovata Mather												x			
Composita sp. undet.											x				
Pelecypoda:															
Chaenomya? sp. undet.		x													
Nucula anodontoides Meek		x								x					
Anthraconeilo taffiana Girty		x								x					
"Nuculopsis" ventricosa (Hall)		x								x					
Leda bellistriata Stevens		x	x							x					
Leda sp. undet.				?											
Yoldia glabra Beede and Rogers		x													
Parallelodon sp. undet.		x													
Aviculipinna sp. undet.		x													
Pinna sp. undet.		x		x						x		?	?	?	
Conocardium sp. undet.		x								x					
Pseudomonotis cf. P, hawni Meek and Hayden				?											
Myalina cf. M. permiana Swallow					x									x	x
Myalina recurvirostris Meek and Worthen							?								
Myalina subquadrata Shumard		x		x			x								
Myalina sp. undet.		x	x	x						x					
Aviculopecten herzeri Meek				x											
Aviculopecten sp. undet.														x	
Deltopecten n. sp. aff. D. mccoyi (Meek and Hayden)										x					
Deltopecten texanus Girty		x					?			x					
Deltopecten vanvleeti (Beede)				x											
Deltopecten sp. undet.		x													
Acanthopecten sp. undet.	x	x													
Allorisma terminale Hall				x								x	x		x
Allorisma sp. undet.		?													
Astartella concentrica (Conrad)		x					x			x					
Astartella concentrica (Conrad) n. var.					x										
Astartella sp. undet.		?										?		x	
Scaphopoda:															
Dentalium n. sp. aff. D. semi-costatum Girty		x													
Dentalium subleve Hall		x													
Dentalium sp. undet.		x													
Plagioglypta cf. P. annulistriata (Meek and Worthen)		x								x					
Plagioglypta sp. undet.		x													

Distribution of species in collections studied from various formations within areas of investigation—Continued

	Brazos River Valley						Colorado River Valley								
	Caddo Creek formation	Graham formation	Thrifty formation	Harpersville formation	Pueblo formation	Moran formation	Graford formation	Brad formation	Caddo Creek formation	Graham formation	Thrifty formation	Harpersville formation	Pueblo formation	Moran formation	Putnam formation
Gastropoda:															
Bellerophon stevensianus McChesney		?													
Bellerophon crassus Meek and Worthen			?												
Bellerophon sp. undet.		x				?	?	?			?	?			
Patellostium montfortianum (Norwood and Pratten)		x													
Patellostium n. sp.?		x													
Euphemites carbonarius (Cox)		x								x					
Bucanopsis meekiana (Swallow)										x					
Bucanopsis sp. undet.		x													
Pharkidonotus percarinatus? (Conrad)		x								x					
Pharkidonotus tricarinatus (Shumard)		x								x					
Pharkidonotus sp. undet.		x													
"Pleurotomaria" obtusispira Shumard															x
Yunnania sp. undet.		?													
Worthenia tabulata (Conrad)		x								x					
Worthenia sp. undet.		?													
Phanerotrema grayvillense (Norwood and Pratten)	x	x								x					
Phanerotrema tenuistriatum (Shumard)		x													
Phanerotrema sp. undet.		x													
Euconospira sp. undet.												x			
"Orestes" brazoensis (Shumard)		x								x					
"Murchisonia" sp. undet.		x													
Goniasma lasallensis (Worthen)		?													
Orthonema schucherti Knight		x													
Trepospira depressa (Cox)		x								x					
Trepospira sp. undet.		x													
Straparollus (Euomphalus) plummeri Knight		x													
Straparollus (Euomphalus or Schizostoma) subrugosus Meek and Worthen		x	?							x					
Straparollus (Euomphalus) sp. undet.			x	x											
Naticopsis? sp. undet.		x	x												
Pseudozygopleura sp. undet.		x								x					
Meekospira sp. undet.		x								x					
Soleniscus (Macrochilina) cf. S. brevis White or cf. S. paludinaeformis (Hall)		x								x					
Soleniscus (Macrochilina) primigenius (Conrad)		x								x					
Soleniscus (Macrochilina) sp. undet.				x											
Trachydomia sp. undet.		x													
Platyceras sp. undet.		x													

Distribution of species in collections studied from various formations within areas of investigation—Continued

	Brazos River Valley						Colorado River Valley								
	Caddo Creek formation	Graham formation	Thrifty formation	Harpersville formation	Pueblo formation	Moran formation	Graford formation	Brad formation	Caddo Creek formation	Graham formation	Thrifty formation	Harpersville formation	Pueblo formation	Moran formation	Putnam formation
Cephalopoda:															
Pseudorthoceras knoxense (McChesney)		x		x						x					
Pseudorthoceras seminolense Girty		x													
"Orthoceras" (Mooreoceras) aff. O. tuba Girty		x													
"Orthoceras" (Dolorthoceras) ciscoense (Miller, Dunbar and Condra)		x								x					
"Orthoceras" (Euloxoceras) greenei (Miller, Dunbar and Condra)		x								x					
"Orthoceras" aff. O. cribriliratum Girty		x													
"Orthoceras" sp. undet.		x								x					
Brachycycloceras normale Miller, Dunbar and Condra		x								x					
Coloceras liratum Girty		x								x					
Tainoceras monifer Miller, Dunbar and Condra										x					
Metacoceras cornutum Girty		x								x					
Metacoceras cornutum carinatum Girty		x													
Metacoceras cornutum sinuosum Girty		x								x					
Metacoceras perelegans? Girty										x					
Metacoceras sp. undet.			x							x				?	
Domatoceras sculptile (Girty)		x								x					
Domatoceras sp. undet.		x													
"Cyrtoceras" sp. undet.		x													
Gastrioceras angulatum Girty										x					
Gastrioceras branneri? Smith										x					
Gastrioceras modestum? Böse										x					
Gastrioceras sp. undet.		x								x					
Schistoceras hyatti Smith		?								x					
Schistoceras hildrethi Smith										?					
Schistoceras sp. undet.		x													
Dimorphoceras texanum Smith		x								x					
Gonioloboceras welleri Smith		x								x					
Trilobita:															
"Griffithides" sp. undet.	x		?	x											
Phillipsia major Shumard											x				
Phillipsia sp. undet.		?													
Vertebrata:															
Fish remains		x						x	x					x	

REGISTER OF LOCALITIES

7367. Mercury quadrangle. On north side of Herron Bend of Brazos River, about half a mile east of Salem School and thence a quarter of a mile south. Shale in basal part of Graham formation, immediately below Salem School limestone member.

7368. Graham quadrangle. Bass Mountain, 2 miles northeast of South Bend, hill above and 100 feet north of Brazos River. Graham formation, in shales 25 feet above Bunger limestone member, which crops out near water level.

7369, 7369A. Waldrip quadrangle. Locality adequately described in text. Graham formation, fossil zone 4 Gc, 10 to 20 feet below the Gunsight limestone member.

7370. Waldrip quadrangle. About 4 miles south of Whon and three-quarters of a mile east of Parks Mountain. To reach the locality from Whon, go south 4 miles, take first turn west, go for three-quarters of a mile, then go through gate and continue about half a mile north and a quarter of a mile west to southeast point of an isolated hill. Wayland shale member of Graham formation.

7440, 7440A. Graham quadrangle. West edge of town of South Bend, from flat between railroad that runs along Clear Fork and road to Throckmorton. Graham formation, fossiliferous zone 20 to 40 feet above Bunger limestone member.

7441. Young County. About 9 miles southeast of Graham on Graham-Finis road, in road cut north of Brushy Mound, which is first hill west of Connor Creek School, outcrops in roadside ditches. Graham formation, fossil zone 16 Gb, marine shale about 40 feet above Home Creek limestone of Plummer and Moore (top member of underlying Caddo Creek formation).

7442. Graham quadrangle. About 2½ miles northwest of Graham, in railroad cut south of road and across road from a dam on Salt Creek. Graham formation, Wayland shale member, thin No. 9 limestone of post-Bunger cycle No. 9 and associated shale.

7443. Graham quadrangle. Near head of Kickapoo Creek, 100 yards north of point where road crosses creek. Graham formation, No. 9 limestone in post-Bunger cycle No. 9.

7444. Graham quadrangle. About 3 miles south of Graham, near Thedford Tank, on north side of North Tonk Branch, about three-eighths of a mile northwest of point where railroad crosses branch and about one-eighth of a mile northeast of road. Graham formation; the fossiliferous shale zone 40 feet above Bunger limestone member.

7445. Same locality and horizon as 7440.

7446. Graham quadrangle. In west edge of town of South Bend, in breaks about 300 to 400 feet west of main street (highway 67) and 200 feet south of road to Throckmorton. Graham formation; the fossiliferous shale zone 25 to 30 feet above Bunger limestone member.

7447. Graham quadrangle. Locality adequately described in text. Fossil zone 10 Gb of Graham formation.

7448. Graham quadrangle. Cliffs along west side of Salt River in west edge of Graham, north of Graham-South Bend road, one-eighth of a mile north on road to dam, from beds near top of bluffs. Wayland shale member of Graham formation, about horizon of No. 9 post-Bunger cycle limestone.

7449. Waldrip quadrangle. Same locality and horizon as 7370.

7450. Graham quadrangle. About 2½ miles west of South Bend, Young County, on southeast point of hill, north of Graham Lake, about halfway up. Graham formation, No. 9 limestone of No. 9 post-Bunger cycle.

7451. Graham quadrangle. Same locality and horizon as 7442.

7452. Young County. Same locality and horizon as 7441.

7453. Ivan quadrangle. At side of east-west road that runs along Young-Stephens County line, about half a mile east of Graham-Breckenridge highway, at first escarpment. Graham formation, No. 3 post-Bunger cycle limestone.

7454. Graham quadrangle. Northwestern part of hill about 1 mile northeast of Graham (first hill beyond twin hills in Graham), less than 200 feet south of Chicago, Rock Island & Pacific Railway, above oil pit and below a sandstone. Near base of Wayland shale member of Graham formation.

7455. Waldrip quadrangle. Same locality and horizon as 7369.

7456. Graham quadrangle. About 4 miles northeast of Graham and 1 mile southwest of Rocky Mound School, on southwest side of Rocky Mound, near base of hill, a quarter to half a mile southeast of road from Graham. Graham formation, Wayland shale member, below 9a limestone of No. 9 post-Bunger cycle.

7485. Graham quadrangle. Locality near 7454, but about halfway up west face of hill 150 to 200 feet north of south point of hill, under a conglomerate. Graham formation, near base of Wayland shale member.

7486. Ivan quadrangle. On main road from Eliasville to South Bend, 3.2 miles from Eliasville, on long hill northwest of road, between two bridges. Collection from point where hill is nearest road, up nearly to top of hill and 5 or 6 feet above a sandstone ledge. Graham formation, 9a limestone of No. 9 post-Bunger cycle. Limestone is thin and discontinuous under a conglomerate.

7488. Graham quadrangle. Same locality and horizon as 7367, except that it contains float from Salem School limestone member immediately above.

7489. Graham quadrangle. Same locality and horizon as 7456.

7490. Graham quadrangle. Herron Bend of Brazos River, on road that passes Salem School; about three-quarters of a mile east from school, thence south and east to a point about a quarter of a mile south of bench mark 1005, shown on topographic map. This point is about 1½ miles southeast of school, where road begins to turn southeast away from Herron Bend. Exposures about 5 feet above creek and on creek in field west of road, a little south of northeast point of bend. Caddo Creek formation, Home Creek limestone member of Plummer and Moore.

7491. Graham quadrangle. About 3 miles north and slightly east of South Bend, on east side of Sidney Mountain, downhill east of Wadley oil well, about a quarter of a mile north of bench mark 1082, at altitude shown on topographic map as 1180 feet. Graham formation, limestone of No. 5 post-Bunger cycle.

7492. Graham quadrangle. About 2¼ miles north of South Bend. Southwest point of butte on east side of Kickapoo Creek, about a quarter of a mile west of bench mark 1082, at about 1100-foot contour line as shown on topographic map. Graham formation, limestone of No. 5 post-Bunger cycle.

7493. Graham quadrangle. On west side of Kickapoo Creek, about half a mile S. 45° W. from 7492. Graham formation, limestone of No. 6 post-Bunger cycle.

7494. Graham quadrangle. About 1½ miles north of South Bend and six-tenths of a mile north of where Clear Fork joins Brazos River, about one-eighth of a mile north of southwest corner and on west side of a butte, which is the first butte north of river here. On west side of same butte as 7492. Graham formation, a "*Campophyllum*" bed about 120 feet above Bunger limestone, below horizon of Kickapoo limestone.

7495. Graham quadrangle. About 1 mile west and 1½ miles north from South Bend, on hill about half a mile north of Stovall hot-water well on southwest side of Salt Fork of Brazos River, along road shown on topographic map as a temporary road going northwest from bench mark 1036 to bench mark 1116, near point where road crosses 1080-foot contour line shown on map. Graham formation, limestone of No. 6 post-Bunger cycle.

7496. Graham quadrangle. About 3 miles N. 45° W. of South Bend, as measured on map, along stream tributary to Salt Fork of Brazos River, about three-eighths of a mile upstream from Salt Fork. This tributary enters Salt Fork at south point of second sharp bend southward, west of point of entrance of Clear Fork. About half a mile east of bench mark 1153, shown on topographic map, on east side of tributary stream, 10 to 12 feet below top of hill. Graham formation, limestone of No. 7 post-Bunger cycle.

7497. Ivan quadrangle. Locality adequately described in text. Graham formation, limestone of No. 3 post-Bunger cycle.

7498. Graham quadrangle. Locality adequately described in text. Graham formation, limestone 9b of No. 9 post-Bunger cycle.

7499. Ivan quadrangle. About 1½ miles south of South Bend. Top of South Bend Mountain, which is the first crest south of South Bend that is more than 1200 feet in altitude. Graham formation, limestone of No. 7 post-Bunger cycle.

7500. Stephens County. Locality adequately described in text. Upper limestone of Gunsight limestone member of Graham formation.

7501. Graham quadrangle. About half a mile west of McCann bridge over Brazos River, about 1½ miles south and 8½ miles west from Graham. Thrifty formation, Blach Ranch limestone member.

7502. Breckenridge quadrangle. About 2 miles due south from Gunsight, along "old" road to Eastland. To reach locality go past post office at Gunsight, turn left at first fork, and continue until speedometer shows 2 miles from post office. Lower limestone of Gunsight limestone member of Graham formation.

7504. Breckenridge quadrangle. About 1½ miles northeast of Crystal Falls, on diagonal road to Eliasville north of Clear Fork of Brazos River. Breckenridge limestone member of Thrifty formation.

7505. Mercury quadrangle. Along north bank of Colorado River, about 2¾ miles east of Winchell, where road comes close to river at first really prominent northward bend east of Winchell, on old "river road." On bank of river within about 10 to 15 feet of water. Graford formation, thin brown limestone in basal member.

7506. Mercury quadrangle. Same locality and member as 7505 but in a zone about 10 feet lower.

7507. Mercury quadrangle. Locality adequately described in text. Adams Branch limestone member of Graford formation.

7508. Mercury quadrangle. Locality adequately described in text. No. 2 limestone (second limestone from base of Winchell member of Graford formation, equivalent to top bed of Drake's Clear Creek limestone).

7509. Mercury quadrangle. About 4 miles east of Whon, on road that crosses Home Creek in Gill ranch, on hill above and south of creek, about one-eighth of a mile south of elevation No. 1403, shown in northwest corner of map of Mercury quadrangle. Caddo Creek formation, Home Creek limestone member of Plummer and Moore.

7510. Waldrip quadrangle. About 4½ miles slightly west of south of Whon, in bed of stream where road from east side of Parks Mountain turns from southward to southeastward, about a quarter of a mile above junction with a northeast-southwest road, about five-eighths of a mile south of point 1518 (see topographic map) on Parks Mountain and about three-eighths of a mile east of Colorado River. Upper limestone of Gunsight limestone member of Graham formation.

7511, 7512. Young County. About 9½ miles east of Graham, on a hill about 500 feet north of Connor Creek School and across road from it. This school is on Graham-Finis highway. Locality is near top and on south side of hill, east of the stone fence on the hill. Upper 3 feet of Gonzales limestone member of Graham formation, as exposed here.

7513. Young County. Same locality as 7441, but collection made from a thin yellow limestone below a thick sandstone and above marine shale of fossil zone 17 Gb and below horizon of Gonzales limestone member, exposed on first flat south of road and above roadside ditch. Limestone 50 to 60 feet above horizon of Salem School limestone member of Graham formation.

7514. Young County. Locality adequately described in text. Gonzales limestone member of Graham formation.

7515. Graham quadrangle. About 4 miles S. 20° E. of Graham, as measured on map. Collection from top of road 2 to 3½ feet below level of house and barn to which road leads. These buildings are in a saddle north of Graham-Graford road, 2.3 miles east of place where road to Bunger turns off and 1.8 miles west of place where road to Herron Bend turns off. Graham formation, "dirty yellow" limestone 22 feet below Bunger limestone member.

7516. Same locality as 7515 but from a zone about 5 or 6 feet higher, exposed on first flat above and west of saddle.

7517. Graham quadrangle. About 6 miles south of Graham, near Bunger. To reach locality from town of Bunger, go south one-third of a mile, turn east and go half a mile to place where a limestone crosses road at first rise. Collection obtained along road and in pasture south of road, from an olive-brown fine-grained limestone. Bunger limestone member of Graham formation.

7518. Same locality as 7517, but collection made from a weathered zone in side ditch north of road. Float but probably from Bunger limestone member of Graham formation and not over 4 feet below it. Could have washed from beds 8 to 10 feet above Bunger.

7519. Same locality as 7517, but 500 to 600 feet west. From roadside ditches and fields on each side of road. Soft brown sandy limestone with red splotches below a red weathering zone. Graham formation, "dirty yellow" limestone about 20 to 25 feet below Bunger limestone member.

7520. Breckenridge quadrangle. On Gage Creek about 1½ miles west of Eliasville. To reach locality go west from bridge at Eliasville on Throckmorton road; at about 1½ miles from Eliasville turn right through wooden gate, pass cemetery, and bear left to Gage Creek as far as a water hole with a spring box. Upstream 100 feet or more east of spring box is a limestone below Ivan limestone. Thence continue upstream to Ivan limestone. Ivan limestone member of Thrifty formation.

7521. Young County. About 3½ miles west of McCann Bridge, on Vick ranch, across road south of ranch house, on hill above creek in pasture. To reach locality from a point in road opposite ranch house, go east 2.2 miles to a gate on south side of road that leads to Nash & Windfohr oil pool. Collection from ridge west of oil wells. Belknap limestone member of Harpersville formation.

7522. Graham quadrangle. Locality adequately described in text. Bunger limestone member of Graham formation.

7523. Graham quadrangle. Locality adequately described in text. About 2 feet above base of Bunger limestone member of Graham formation.

7524. Graham quadrangle. Locality adequately described in text. Bunger limestone member of Graham formation.

7525. Graham quadrangle. About 2½ miles (measured on map) west of South Bend, in field 50 to 200 feet north of road on crest of hill, which is about 1½ miles due west of Stovall hot-water well. A road turns south about 100 feet south of this locality opposite bench mark 1131, which is shown on topographic map. Graham formation, limestone of No. 7 post-Bunger cycle.

7526. Graham quadrangle. Same locality and horizon as 7450.

7527. Breckenridge quadrangle. About 1.1 miles north of Eliasville. To reach locality from Eliasville cross bridge over Clear Fork, take road to left about a quarter of a mile, turn right (north) where first road comes in, continue north until road makes an almost right angle jog to east and continues up a sandstone and shale hill. Instead of turning, continue on through an open iron rod-floored gate into a drive that goes around hill to a house not visible from road. Collection from limestone at first rise above gate. Thrifty formation, 4- to 6-inch unnamed limestone above Avis sandstone member and below Ivan limestone member.

7533. Breckenridge quadrangle. Same locality as 7527, but collection made from flat on which house stands. Ivan limestone member of Thrifty formation.

7534. Breckenridge quadrangle. Along roadside west of road and along a gully 100 feet west of road that enters Crystal Falls from north. Collection came from a point on road one-third of a mile south of Huffstettle School south of a hill and north of a bridge over a gully. *Myalina*-bearing limestone of Harpersville formation.

7535. Breckenridge quadrangle. To reach locality from Crystal Falls, go 5¼ miles north, thence 3 miles west, then turn into field and go 1.8 miles south to a hill in pasture. On first bluff on Clear Fork east of mouth of Kings Creek there is a stone fence on hill and also stone fences in pasture. Outcrops near top of hill and east of temporary road in pasture. Saddle Creek limestone member of Harpersville formation.

7536, 7537. Breckenridge quadrangle. Crystal Falls, exposure along Clear Fork of Brazos River, from water level up to 3 feet above water level at a place 50 to 100 feet below a dam, which is about 300 feet below bridge where highway crosses Clear Fork. Breckenridge limestone member of Thrifty formation.

7538. Breckenridge quadrangle. Crystal Falls, north of railroad, about 80 to 100 feet west of road north out of Crystal Falls and about 300 feet south of a pump house on Clear Fork of Brazos River, on south side of first ravine south of pump house. "Cl" limestone bed of maps, in basal part of Harpersville formation.

7539. Breckenridge quadrangle. Crystal Falls, across railroad in northern part of town, in field east of tracks in first railroad cut northwest of Crystal Falls crossing, almost due west of pump house for Breckenridge water supply. Exposure in "humps" on a ridge back of pump house and also in beds in railroad cut. Crystal Falls limestone member of Harpersville formation.

7540. Breckenridge quadrangle. Crystal Falls, along railroad northwest of town, second cut northwest of road crossing in north edge of Crystal Falls, opposite a house on same lot as pump station of Magnolia Petroleum Company. Thin limestone and shale on southwest side of railroad. So-called "Upper Crystal Falls limestone," in Harpersville formation.

7540A. Same locality and horizon as 7540 but collection made from shale parting.

7541. Breckenridge quadrangle. Four miles west of Eliasville, to left, beyond west edge of Eliasville oil pool, through cattle guard on short road to Crystal Falls, a quarter of a mile; locality on top of a hill. Crystal Falls limestone member of Harpersville formation.

7542. Same locality as 7541, but collection made in ravine to the north. Breckenridge limestone member of Thrifty formation.

7543. Breckenridge quadrangle. West of Eliasville, on Throckmorton road, 6.9 miles by speedometer; in roadside ditch at head of Wagon Timber Branch. Belknap limestone member of Harpersville formation.

7544. Breckenridge quadrangle. About 7 miles by speedometer west of Eliasville. To reach locality go 5½ miles north of Crystal Falls to place where road turns, thence 700 feet east to place below top of first hill. Thin limestone between a shale and limestone that caps hill and light blue and gray to purplish shale exposed in roadside ditch and field south of road. Saddle Creek limestone member of Harpersville formation.

7545. Same locality and horizon as 7521.

7546. Ivan quadrangle. About 9 miles (measured on map) east of South Bend, 4½ miles east and 2¼ miles south of Bunger, near Ming Bend School. Outcrops in field adjoining school on south and on a flat across a ravine near the school, also along a road through a field south of school and through two gates from main road that passes school, about 500 to 600 feet south of school, in State game preserve. Caddo Creek formation, Home Creek limestone member of Plummer and Moore.

7547. Same locality as 7541, but collection made on sides of a tank 0.3 mile around hill to the west. Exposures about 15 feet above tank, nearly at base of hill. So-called "Upper Crystal Falls limestone," in Harpersville formation.

7548. Same locality and horizon as 7486.

7549. Breckenridge quadrangle. To reach locality go 7½ miles west of bridge at Eliasville, turn left through a gate into a pasture, and go southeast to place where Wagon Timber Branch is crossed by a fence. Exposures a few hundred feet upstream. Collection from an 8- to 10-inch limestone about 8 inches above a coal. So-called "Waldrip limestone," in Harpersville formation.

7550. Same locality and horizon as 7442.

7551. Same locality and horizon as 7500.

7552. Same locality and horizon as 7502.

7553. Breckenridge quadrangle. Locality adequately described in text. Upper limestone of Gunsight limestone member of Graham formation.

7554. Throckmorton County. Four miles east of Woodson, in a gully southeast of road forks, at place where road turns south. Camp Colorado limestone member of Pueblo formation.

7555. Throckmorton County. About 3 miles east of Woodson, in stream bed 200 feet south of road and bridge. Collection from bed of stream. Unknown horizon in lower part of Moran formation.

7558. Waldrip quadrangle. About 4 miles south and half a mile west of Rockwood, about 1¼ miles due south of Chaffin crossing over Colorado River, on Chaffin farm, along banks of a small stream below mines, east of Chaffin house. Chaffin limestone member of Thrifty formation.

7559. Waldrip quadrangle. Same locality as 7369 but near top of hill south of road. Upper limestone of Gunsight limestone member of Graham formation.

7560. Waldrip quadrangle. Locality adequately described in text. Thin brown limestone near base of Graham formation, 8 feet above Plummer and Moore's Home Creek limestone member of Caddo Creek formation.

7561. Same locality and horizon as 7509.

7562. Waldrip quadrangle. Northwestern part of Rockwood, on first gully about 500 feet west of cotton gin. So-called "Waldrip No. 2 limestone," in Harpersville formation.

7563. Waldrip quadrangle. West of northern part of Rockwood, near top of an eastward-facing isolated hill, about 1500 feet westward across a reddish shale valley from cotton gin. So-called "Waldrip No. 3 limestone," in Harpersville formation.

7564. Waldrip quadrangle. Ridge west of Rockwood. To reach locality turn west into field from highway that goes south into town, immediately south of bridge in north edge of town, continue on farm roads, keeping near but north and west of "breaks," 1 mile westward to a gate, thence to ridge north of gate and a few hundred feet west. Saddle Creek limestone member of Harpersville formation.

7565. Waldrip quadrangle. About 2 miles south and 4 miles west of Rockwood, about 1½ miles west of highway bridge southwest of Rockwood over Bull Creek. To reach locality from this bridge, go west from south side of bridge, follow road through two gates—one gate at 1 mile from turn (bridge and road) and the next due west of the first, at 1.4 miles from bridge. Hill left of second gate overlooks Colorado River. Collection made at top of cliff that borders a draw, a few hundred feet east of point of this hill and a gravel flat in river visible from it. Saddle Creek limestone member of Harpersville formation.

7566. Waldrip quadrangle. From locality 7565, go westward, passing through a gate at point 1½ miles west of 7565, thence west a few hundred feet farther, turn right, and continue up a ravine for about 1000 feet to hill west of this ravine, 12 feet below top of escarpment. Thin limestone near base of Pueblo formation, 20 feet above Saddle Creek limestone member of Harpersville formation.

7567. Waldrip quadrangle. Along Colorado River, 4 miles south and 7 miles west of Rockwood (measured on map), on point above river about 0.9 mile southeast of conspicuous round hill where the first big draw east of the round hill cuts into bluff, near west margin of Waldrip quadrangle. Pueblo formation, in Drake's bed No. 13 ("limestone with yellow chert"), the Stockwether limestone member of Plummer and Moore.

7568. Waldrip quadrangle. Rockwood; flat around barn and between house and barn of first house south and east of south end of bridge on highway on north edge of Rockwood. So-called "Waldrip limestone No. 1," in Harpersville formation.

7569. Waldrip quadrangle. About 2.4 miles east and 0.2 mile south of Rockwood (measured on map), on west bank of Camp Creek, about a quarter of a mile north of road from Rockwood to Whon, across a draw. Bench marks 1459 and 1422 (see topographic map) are on this road. Chaffin limestone member of Thrifty formation.

7570. Same locality as 7569, but collection made about 50 feet north and at about 10 to 12 feet lower in altitude, the bed being only about 4 feet above stream and above a red shale, which is exposed nearly to creek bed on west side of Camp Creek. Thin limestone 10 feet below Chaffin limestone member of Thrifty formation.

7571. Waldrip quadrangle. About 2½ miles east and a quarter of a mile south of Rockwood, on same road as 7569 but farther east, at a point where this road turns south instead of crossing Camp Creek. Exposure in bed of Camp Creek and on an abandoned road on east side of Camp Creek in line with road. Speck Mountain limestone member of Thrifty formation.

7572. Waldrip quadrangle. About 3¼ miles south and half a mile east of Rockwood (measured on map), about a quarter of a mile west of Parks Mountain, at a point where road around west side of Parks Mountain to Colorado River crosses a ravine shown on map of Waldrip quadrangle as first ravine west of Parks Mountain and north of river. Road goes through a sharply constricted place where it crosses this ravine. Yellow shale exposed to left (east?) at crossing. The *Bellerophon* limestone caps hill. *Bellerophon* limestone, in Thrifty formation.

7573. Coleman County. About 6.2 miles southwest of Gouldbusk, where road crosses escarpment of Coleman Junction limestone. To reach locality from Gouldbusk, go 0.3 mile south, 0.7 mile west, 0.5 mile south, 2 miles west, and about 2.7 miles south. Collection from both sides of road in big valley to the south below escarpment. Coleman Junction limestone member of Putnam formation.

7574. Coleman County. About 7¾ miles by speedometer southwest of Gouldbusk. To reach locality from locality 7573, go south about 1 mile, east half a mile to place where Panther Creek crosses an east-west road, up Panther Creek to point near south end of a hill, west of first house east of Panther Creek. Collection obtained less than 1 foot above base of a small gully east of hill, between sheep pen and house. Shale 8 feet above Horse Creek limestone member of Moran formation.

7575. Same locality as 7574 but farther down same gully, due south of south end of hill. This gully is first gully south of south end of hill. Thin limestone about 5 feet above top of Horse Creek limestone member of Moran formation.

7576. Same locality as 7574, but collection made from blue limestone about halfway up hill, on east and southeast side. Limestone in Moran formation between Horse Creek and Sedwick limestone members.

7577. Same locality as 7574, but collection made in public road, which goes in front of house, and in field south of road, on first bench above and east of point where road crosses Panther Creek. Horse Creek limestone member of Moran formation.

7578. Waldrip quadrangle. Locality adequately described in text. Caddo Creek formation, in Home Creek limestone member of Plummer and Moore.

7579. Waldrip quadrangle. Isolated hill half a mile north of Colorado River and a quarter of a mile east of west line of quadrangle. Limestone 60 feet below Camp Colorado limestone member of Pueblo formation.

7580. Coleman County. Three and one-fourth miles east and three-quarters of a mile north of Whon (measured on map), on west side of Mukewater Creek about three-eighths of a mile above its junction with Home Creek, first escarpment west of creek and below a sandstone. Brad formation, in Ranger limestone member of Plummer and Moore.

7581. Same locality as 7580 but higher on hill and above the sandstone. Caddo Creek formation, in Home Creek limestone member of Plummer and Moore.

7582. Coleman County. About 8 miles southwest of Gouldbusk, about 1¼ miles westward and across a hill from locality 7577. Limestone 77 feet below Coleman Junction limestone member of Putnam formation.

7583. Nearly same locality as 7582. Coleman Junction limestone member of Putnam formation.

7584. Coleman County. About 7.1 miles southwest of Gouldbusk. From locality 7577, go west across Panther Creek and north into gate about 0.2 mile west of Panther Creek crossing; continue about half a mile to outcrop of Sedwick limestone on west side of Panther Creek. Sedwick limestone member of Moran formation.

7585. Coleman County. Four and one-half miles southeast of Gouldbusk, on Sam Gray's ranch. Camp Colorado limestone member of Pueblo formation.

7586. Same locality and horizon as 7367.

7587. Same locality and horizon as 7440, but collection made on flats on both sides of Throckmorton road.

7588, 7589. Same locality and horizon as 7368.

7590. Same locality as 7368, but collection made from shales 60 to 80 feet above Bunger limestone member of Graham formation.

7591. Same locality and horizon as 7441.

7592. Breckenridge quadrangle. Two miles south of Ivan, on hill west of paved highway. Ivan limestone member of Thrifty formation.

7593. Breckenridge quadrangle. Wagon Timber Branch, Donnell ranch, about 7 miles west of Eliasville. So-called "Upper Crystal Falls limestone," in Harpersville formation.

7594. Graham quadrangle. About 7 miles southwest of Graham and 3 miles northwest of South Bend, near mouth of a small ravine, half a mile east of Medlin ranch house. Graham formation, Wayland shale member, at about horizon of 9a limestone of No. 9 post-Bunger cycle.

7595. Same locality and horizon as 7448.

7596. Same locality and horizon as 7543.

7597. Same locality as 7368, but collection made from shales above and within 2 feet of Bunger limestone member of Graham formation.

7598. Graham quadrangle. Two miles west of Stovall hot-water well, which is near South Bend; base of bluff near mouth and on west side of a small unnamed creek that flows northward into Brazos River about 1½ miles southwest of Medlin ranch house. Graham formation, Wayland shale member near horizon of 9a limestone of No. 9 post-Bunger cycle.

ADDENDA

This paper was completed for publication before the comprehensive monograph on the cephalopods of the Carboniferous and Permian of Texas (The University of Texas Bulletin 3701) by Plummer and Scott was published. Consequently, most of the cephalopod names, as well as the names of many other fossils listed herein, follow the usage in the earlier report by Plummer and Moore (The University of Texas Bulletin 2132). The names which would have been used had Plummer and Scott's treatise appeared sooner may be determined by an inspection of that paper.

NOTES ON THE RANGES OF FUSULINIDAE IN THE CISCO GROUP (RESTRICTED) OF THE BRAZOS RIVER REGION, NORTH-CENTRAL TEXAS

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INTRODUCTION

The following brief account of the fusulinid record in north-central Texas is confined mainly to species of *Triticites* in the Cisco group (restricted) of the Brazos River region. On Brazos River no fusulinids were found higher than the Belknap limestone member of the Harpersville formation. To complete the section, samples are included from the Pueblo formation of the Colorado River area. The Cisco group (restricted) lies near the middle of the *Triticites* zone. This zone, in broad terms, occupies the upper one-third of the Pennsylvanian and extends into the lower part of the *Pseudoschwagerina* zone, now generally considered as of lower Permian age. Cisco time, however, included the period of greatest expansion of genus *Triticites,* and as a consequence the Cisco contains the best examples of their rapid evolution, abundance of individuals, and wide distribution—the most essential qualities of good guide fossils except in oil geology, where size and recoverability in small samples are also important.

From the Brazos and Colorado River regions Mr. Lee and members of his party collected over 280 samples of Fusulinidae. The collections represent in considerable detail the standard localities and known occurrences of the different members of the section, as well as a large number of the problematical or unidentifiable horizons that were encountered in field work. The small amount of time and assistance available permitted only the preparation of that part of the collections which was the most closely connected with the stratigraphic problems. Accordingly, the study of collections of known position in the section was reduced to the bare essentials of erecting a standard and is not exhaustive. It was necessary to spend practically all the time on the Brazos River collections. For this reason it is to be expected that future studies

[1]United States Geological Survey.

may alter the ranges as indicated on the accompanying chart, Plate XI.

Though incomplete, the record that was worked out for a local standard is interesting and useful. The ranges of different species are so distributed that an average complement of fusulinids appears to be sufficient for rather close correlation in most positions within the area. This apparent situation needs to be checked against the record in the Colorado River valley and considered critically with the possibility in mind that perhaps ecology may be a stronger influence than is recognized in the vertical distribution of fusulinid species.

It seemed worth while to present a record of the Brazos River succession as it now stands, as an aid to further work. The identifications are intended to be conservative, in order that the list may be used with more than the usual confidence accorded to routine faunal lists.

To promote further accuracy and confidence, "Notes on Species" are included to qualify certain of the identifications appearing on the chart. This will enable other students of the group to compare the list with the results of their own studies.

Several new or undescribed forms have been discovered, but as it is inappropriate to include here the writer's descriptions of these new forms, they have been listed as related to ("aff.") known species wherever it seemed possible by so doing to convey an accurate notion of their character. Certain forms, however, are so distinct that they cannot be identified as relatives of known species without inviting misunderstanding.

As indicated by the distribution of the fusulinids, only the upper part of the Missouri group is the age equivalent of the Cisco. Species of the lower part of the Missouri group are omitted from the chart, as they do not occur in the Cisco. The stratigraphic positions of the collections from the Brazos River area shown on the chart are those described in other papers in this volume. Specific data on the collections are listed by number at the end of this paper.

NOTES ON SPECIES

The following notes on the species are included only for stratigraphic information. The temporary and informal designations of species or varieties by letters of the alphabet have been purposely devised to avoid the complications that arise from the use of manuscript names. Accordingly the writer's manuscript names will be withheld until the descriptions are published.

TRITICITES BEEDEI Dunbar and Condra, 1927

Triticites beedei Dunbar and Condra, Nebraska Geol. Survey Bull. 2, 2d ser., pp. 96–98, pl. 5, figs. 1, 2; pl. 6, figs. 7–10, 1927. [Not *T. beedei* in White, Univ. Texas Bull. 3211, pl. 1, figs. 16(?), 17, 18a–e; pl. 2, figs. 7–9, 1932.]

?*Triticites consobrinus* Galloway and Ryniker (MS.), in White, Univ. Texas Bull. 3211, p. 41, pl. 2, figs. 16–18, 1932.

Triticites plummeri Dunbar and Condra var.?, in White, Univ. Texas Bull. 3211, pp. 65–67, pl. 6, figs. 7–9, 1932.

This species is well represented in the Texas region in typical form. Specimens from the post-Bunger cycle No. 9a limestone are so exactly similar to those illustrated by Dunbar and Condra that they might be mistaken for specimens in the same collection. At this next limestone below (post-Bunger cycle No. 9) the species appears in very slightly less typical form and is a member of the triad (*T. beedei*, *T. moorei*, and *T. plummeri* along with their variants) that characterize that zone. In the post-Bunger cycle No. 9b, *T. beedei* is a very minor element in the fauna. It is probably most abundant in the No. 9a zone.

Earlier forms and variants of this species may easily be confused with *T. cullomensis* Dunbar and Condra.

TRITICITES (sp. A) aff. (?) T. BEEDEI Dunbar and Condra, 1927

This form was found in post-Bunger cycle No. 9b limestone. It has several features in common with *T. beedei* and may be related to that species, but it is slightly less ventricose and less closely enrolled. The walls appear thinner. It might as reasonably be considered a variety of *T. ventricosus*.

TRITICITES CONSOBRINUS Galloway and Ryniker (MS.) in White, 1932

Triticites consobrinus Galloway and Ryniker (MS.), in White, Univ. Texas Bull. 3211, p. 41, pl. 2, figs. 16–18, 1932.

The specimens illustrated by White seem so much like typical *T. beedei* from the middle limestone of the Wayland shale member that the name *T. consobrinus* is not used in this list.

TRITICITES CULLOMENSIS Dunbar and Condra, 1927

In the collections that this author has examined from the north-central Texas area no certain occurrences of *T. cullomensis* have been discovered. At various horizons in the middle and upper parts of the Graham a few specimens resembling *T. cullomensis* have been seen, but most of them may reasonably be considered an immature stage of one of the associated forms. For these reasons and owing to a certain degree of uncertainty about the distinctness of the species, the writer has been chary about recognizing it, and wherever listed its identification is questioned.

TRITICITES MOOREI Dunbar and Condra, 1927

Triticites moorei Dunbar and Condra, Nebraska Geol. Survey Bull. 2, 2d ser., pp. 99–101, pl. 9, fig. 4; pl. 11, figs. 1–5, 1927.
Triticites moorei Dunbar and Condra, in White, Univ. Texas Bull. 3211, pp. 57–59, pl. 5, figs. 1–9, 1932.

In the original description of this species no thin sections were figured. White, however, has ably supplied the needed figures based on topotypes. In its typical form the present writer has found the species only in the post-Bunger cycle No. 9 limestone. *T. moorei* is easily recognized by its small size and abrupt expansion in the second or third volution. By its great numbers it may be considered the most prominent member of the *Triticites beedei-moorei-plummeri* triad.

TRITICITES (sp. B) aff. T. MOOREI Dunbar and Condra, 1927

This form is larger than typical *T. moorei* and expands slightly less abruptly in the second or third volution. Owing to difficulty in distinguishing juvenile or dwarfed *T. secalicus* from this form, it is not possible to say with complete assurance that this is a variety of *T. moorei.* The range is likewise in doubt. A similar and possibly identical form was observed in the Salem School limestone. The definitely known range is the same as that of *T. moorei.*

TRITICITES PLUMMERI Dunbar and Condra, 1927

Triticites plummeri Dunbar and Condra, Nebraska Geol. Survey Bull. 2, 2d ser., pp. 98–99, pl. 6, figs. 1–6, 1927.
Triticites plummeri Dunbar and Condra, in White, Univ. Texas Bull. 3211, pp. 63–65, pl. 6, figs. 1–6; pl. 9, figs. 1–3; pl. 10, figs. 1–4, 1932.
?*Triticites beedei* Dunbar and Condra var.?, in White, Univ. Texas Bull. 3211, pp. 36–38, pl. 2, figs. 7–9, 1932.

This unique species is abundant in the lower and middle parts of the Wayland shale member and may (according to collection 647) extend through the Thrifty formation. So far, observations seem to indicate that the most typical form is restricted to the *Triticites* species *beedei-moorei-plummeri* zone, as the Thrifty specimens generally are less compactly enrolled or in other varieties are very large.

Occurrence in the Home Creek limestone member should be looked for, as the writer has encountered some evidence, of very uncertain value, which suggests that lower range.

TRITICITES (sp. C) aff. T. PLUMMERI Dunbar and Condra, 1927

?*Triticites beedei* Dunbar and Condra, in White, Univ. Texas Bull. 3211, pp. 34–36, pl. 1, figs. 16–18, 1927.

This variant is obviously closely related to *T. plummeri* but differs mainly in being ventricosely fusiform instead of spherical and extremely inflated. Its proportions and form are rather similar to those of *T. beedei*, from which, however, it is easily distinguished by its deeply plicated and basally fused, massive septa and thick keriotheca, which are characteristic of *T. plummeri.*

Specimens of this general description are most common in the upper part of the Graham formation and possibly in the lower part of the Thrifty formation, but a few have been observed in the lower Graham.

TRITICITES (sp. D) aff. T. PLUMMERI Dunbar and Condra, 1927

Another variant of *T. plummeri* is prominent in the upper part of the Wayland shale member. This form is considerably larger than typical *T. plummeri* and is proportionately less closely coiled. Definite evidence of the upward limits of its range has not yet been worked out.

TRITICITES SECALICUS (Say), 1823

Triticites secalicus (Say), in Dunbar and Condra, Nebraska Geol. Survey Bull. 2, 2d ser., pp. 104–108, pl. 7, figs. 1–7; pl. 8, fig. 6; pl. 11, fig. 7, 1927.

A generalized, extensively distributed species such a *T. secalicus* easily becomes a taxonomic catch-all. The range of variation is so great that it is a difficult form to work with in attempts at precise taxonomy and age determination. The author has used as the standard for identification Plate 7, figures 2, 3, and 5, of Dunbar and Condra, which seem to represent the typical form of the species.

TRITICITES SECALICUS Dunbar and Condra, 1927 var. ORYZIFORMIS Newell, 1934

This variety appears to be distinguishable in the Brazos River succession, although the identifications are not entirely clear.

TRITICITES VENTRICOSUS (Meek and Hayden)

The specimens of *T. ventricosus* from collection 654 are more like those described by Dunbar and Condra from the Hughes Creek shale of Condra in the Kansas-Nebraska region than the higher form of the species. The range of this species (not including the lower, supposed prototypes) extends from the top of the Pennsylvanian into lower Permian. Collection 654, however, is older than the Hughes Creek shale of Condra and probably belongs near the lower limits of the *T. ventricosus* range.

TRITICITES (sp. H)

Species H is new and is distinct from *T. secalicus,* with which it may perhaps have been identified in the past. The outstanding characteristics of this form are its slender, distinctly ellipsoidal shape, small number of septa, relatively slight septal plication throughout the central region, and very slight amount of epitheca. The chambers are so wide and so closely meridional in trend that many of the axial sections intersect very few septa in the central region.

TRITICITES (sp. I)

Near the middle of the range covered by species H described above is a ventricosely ellipsoidal species that differs from form H by its shorter and thicker shape and greater number of volutions. At the present state of study species I seems to be distinct from *Triticites secalicus oryziformis* Newell.

TRITICITES (sp. J)

This large species is similar in shape and size to *T. tumidus* Skinner but has a massive wall structure somewhat more like that of *T. plummeri.* Even though epitheca is extensively deposited, the structure remains typically *Triticites*-like.

GROUP OF SPECIES N TO P

In this category stands a group of three or possibly four species. They extend from the upper part of the Graham formation into the lower Permian. They are characterized by very deeply and closely plicated septa, extensive epitheca, and numerous, rather compactly enrolled volutions. The keriotheca is generally obscured, more or less, by extensive epitheca and generally is composed of rather short, wide alveoli and thin alveolar walls.

A description of these forms has been begun.

Species N.—One of the most distinct members of the group is a fusiform species in post-Bunger cycle No. 9a limestone. This species is associated with *T. beedei* and *T. plummeri.* It is very easily distinguished by its *Wedekindellina*-like appearance, with the addition of deep and closely spaced septal plications. Its known range is restricted to the post-Bunger cycle No. 9a limestone, but according to collection 675 it may range into the No. 9b zone as well.

Species O.—This species is very large and spherically inflated. In form and appearance it resembles *T. tumidus* Skinner.

Species P.—Though it belongs to the same group as species N and O, this form is smaller and less ventricose than species O.

SCHWAGERINA sp.

In the Coleman Junction limestone (at station 664, Colorado River region) occurs a species of *Schwagerina* Möller emend. Dunbar and Skinner which is probably not identifiable with *S. emaciata.* This writer's specimens are sufficiently well preserved to exhibit the generic characters with assurance. This genus belongs to the *Pseudoschwagerina* zone and accordingly indicates Permian age in the same measure that *Pseudoschwagerina* does.

IDENTIFICATION OF FUSULINID FAUNAS BY EXTERNAL FEATURES

Even though a person should be chary about identifying *Triticites,* and in fact most fusulinids, by their external features, an exception exists in the assemblage composed of *T. beedei, T. moorei,* and *T. plummeri.* Wherever these three are present, identification can be made with reasonable assurance of accuracy. Identification by external appearance of other assemblages of Thrifty or high Graham *Triticites* which included *T. plummeri* is probably less safe.

REGISTER OF LOCALITIES

600. (W. Lee No. 1.) Young County, 7½ miles southeast of Graham, north bank of Brazos River, opposite and northeast of Herron Bend, base of steep bluff below road. Home Creek limestone (top member of Caddo Creek formation, of Canyon group).

601. (W. Lee No. 2.) Young County, 7½ miles southeast of Graham, near base of steep bluff below road, northeast of Herron Bend of Brazos River. Shale below thin yellow limestone overriding channel deposit (Salem School limestone).

603. (W. Lee No. 4.) Young County, 7½ miles southeast of Graham on Finis road, in road cut north of Brushy Mound, in R. J. Kelly survey, abstract 1813. Limy iron-stained bed about 4 inches thick and about 40 to 45 feet above Home Creek limestone.

604. (W. Lee No. 5.) Young County, 8 miles south-southeast of Graham, on top of high bluff on southeast side of Salem Bend of Brazos River. Shale break in thick section of Gonzales limestone just above 10-foot massive limy sandstone.

605. (W. Lee No. 6.) Young County, 3½ miles south of Graham, on top of bluff above north bank of Brazos River, one-fourth mile south of Wichita Falls & Southern Railroad, midway between mouth of Tonk Creek and mouth of Salt Creek. Just below lower bed of Bunger limestone.

606. (W. Lee No. 7.) Stephens County, 10½ miles south-southwest of Graham and 3 miles south of South Bend, just south of Young-Stephens County line and 0.6 mile east of Graham-Breckenridge highway, on east side of Duff Branch, on road near base of escarpment. Just under post-Bunger cycle No. 3 limestone, an impure limestone about 100 feet above the Bunger limestone.

609. (W. Lee No. 10.) Stephens County, 5 miles southwest of South Bend, where road along county line crosses Peveler Creek. *Campophyllum* and *Syringopora* zones. Believed to be same bed as No. 8 (6 feet below post-Bunger cycle No. 3 limestone).

611. (W. Lee No. 12.) Young County, 3 miles northeast of South Bend, at top of hill northwest of Breckenridge-Graham highway, on Sidney Mountain about one-half mile north of highway bridge over Brazos River. Near base of impure limestone about 135 feet above Bunger limestone. Post-Bunger cycle No. 5 limestone.

613. (W. Lee No. 14.) Young County, 2½ miles northeast of South Bend, 1 mile northwest of Graham-Breckenridge highway bridge over Brazos River, at south end of butte between forks of Kickapoo Creek. Collected from an ant hill. Equivalent to stations 611 and 612. Post-Bunger cycle No. 5 limestone.

614. (W. Lee No. 15.) Young County, 2½ miles north of South Bend, on west side of Kickapoo Creek one-fourth mile west of station 613, 0.6 mile south of secondary road crossing head of Kickapoo Creek. Post-Bunger cycle No. 6 limestone, 135 feet above Bunger limestone.

618. (W. Lee No. 19.) Young County, 3¼ miles west-northwest of South Bend, one-fourth mile northwest of highway west of Stovall hot-water well,

one-fourth mile south of Salt Fork of Brazos River, in small drain above sandstone bluff. Post-Bunger cycle No. 7 limestone, about 165 feet above Bunger limestone.

619. (W. Lee No. 20.) Young County, 3½ miles west-northwest of South Bend, on shoulder on east side of mouth of small creek entering Salt Fork of Brazos River from south, 1½ miles slightly west of south of Medlin ranch house and one-half mile southwest of Salt Fork of Brazos River. Middle of three beds equivalent to post-Bunger cycle No. 7 limestone.

619A. (W. Lee No. 21.) Same locality as 619. Shale below lower of three beds equivalent to post-Bunger cycle No. 7 limestone. Collection washed from shale.

625. (W. Lee No. 26.) Young County, three-fourths mile northwest of courthouse at Graham, on west side of Salt Creek below dam, about 80 feet above creek (Cummins' locality). Post-Bunger cycle No. 9, No. 9 limestone (in Wayland shale member).

628. (W. Lee No. 29.) Young County, 1½ miles west-southwest of Tonk Valley School, in road ditch about 150 yards south of Lindsey-Seddon well. Post-Bunger cycle No. 9, No. 9 limestone (in Wayland shale member).

629. (W. Lee No. 30.) Young County, 2 miles west-southwest of Tonk Valley School and 100 yards north of secondary road west from Tonk Valley School, at head of Kickapoo Creek. Post-Bunger cycle No. 9, No. 9 limestone (in Wayland shale member).

630. (W. Lee No. 31.) Young County, 2¼ miles west-southwest of Tonk Valley School, on Laquey farm, at southwest corner of A. Irvin survey, abstract 1779, at foot of small butte about 200 yards north of road and about 200 yards west of Laquey house. Post-Bunger cycle No. 9, No. 9 limestone (in Wayland shale member).

631. (W. Lee No. 32.) Young County, 7½ miles southwest of courthouse at Graham, one-half mile east of Medlin ranch house, at mouth of small drain north of Salt Fork of Brazos River, at north end of sandstone bluff. Post-Bunger cycle No. 9, No. 9a limestone (in Wayland shale member).

633. (W. Lee No. 34.) Young County, 2½ miles west of South Bend, on side of butte north of Graham Lake, northwest of Clear Fork of Brazos River and south of highway running west from Stovall hot-water well. Post-Bunger cycle No. 9, No. 9a limestone (in Wayland shale member), 28 feet above post-Bunger cycle No. 7 limestone. Hand-picked collection.

634. (W. Lee No. 35.) Same as locality 633 but taken from ant hill.

635. (W. Lee No. 36.) Young County, 3½ miles southwest of South Bend, on north side of Clear Fork of Brazos River, 100 yards north of South Bend-Eliasville highway. Post-Bunger cycle No. 9, No. 9a limestone (in Wayland shale member).

642. (W. Lee No. 43.) Young County, 5½ miles southwest of Graham, 1¼ miles southeast of Medlin Chapel, on north side of Choate Creek, below high butte capped with Blach Ranch limestone. Post-Bunger cycle No. 9, No. 9b limestone (in Wayland shale member).

645. (W. Lee No. 46.) Young County, 1½ miles west-northwest of Eliasville, on south bank of Gage Creek. About 20 feet below Ivan limestone member of Thrifty formation.

647. (W. Lee No. 48.) Young County, 3 miles west of Eliasville, on ridge one-half mile south of Eliasville-Throckmorton road. Breckenridge limestone member of Thrifty formation. (The specimens are strikingly similar to those from post-Bunger cycle No. 9, No. 9a limestone (in Wayland shale member).)

652. (W. Lee No. 53.) Stephens County, on north side of Clear Fork of Brazos River, 1½ miles northeast of Crystal Falls bridge over Clear Fork, on hill northwest of Crystal Falls-Eliasville road. Collection hand-picked. Crystal Falls limestone member of Harpersville formation.

654. (W. Lee No. 55.) Same locality as 652. "Cl" bed, about 20 feet above Breckenridge limestone and in lower part of Harpersville formation.

655. (W. Lee No. 56.) Young County, 8½ miles southwest of Graham, near top of high bluff one-half mile southwest of Graham-Graford road and nearly due south of Christie oil pool, on J. H. McLauren land. Middle bed of Gonzales limestone member of Graham formation.

659. (W. Lee No. 59.) Young County, one-half mile northeast of Newcastle, 300 yards north of Plummer and Moore locality 55.1 and north of road corner. Belknap limestone member of Harpersville formation.

663. (W. Lee No. 63.) Coleman County, 4 miles southeast of Santa Anna, at Gladys Belle-Shaffer Pope lease warehouse, at southwest corner of block 11, north one-half of M. Martinez survey 751. Top of Saddle Creek limestone member of Harpersville formation, Colorado River section. Collected by M. G. Cheney.

664. (W. Lee No. 64.) Coleman County, on north side of highway on escarpment immediately north of Coleman Junction. Yellow bed at top of Coleman Junction limestone member of Putnam formation (Colorado River section).

666. (W. Lee No. 66.) Young County, 1 mile west of courthouse at Graham, on west side of Salt Creek above dam (Cummins' locality). Wayland shale member, 1 foot below No. 9 limestone of post-Bunger cycle No. 9 (in Wayland shale member).

668. (W. Lee No. 68.) Young County, one-half mile northeast of Newcastle, south of corner of old road crossing. Plummer and Moore locality 55.1. Belknap limestone, according to Plummer and Moore.

672. (W. Lee No. 72.) Young County, 4½ miles southeast of Bunger, on north side of Ming Bend road by Newby house, at top of hill and across road from United States Geological Survey bench mark H 11, 1924. Gonzales limestone member of Graham formation.

673. (W. Lee No. 73.) Young County, 2 miles northeast of Graham, at north end of hill east of oil field. Post-Bunger cycle No. 9, No. 9 limestone (in Wayland shale member).

674. (W. Lee No. 74.) Young County, about 3 miles northeast of Graham, north of oil field and west of Graham-Loving road. Post-Bunger cycle No. 9, No. 9 limestone (in Wayland shale member).

675. (W. Lee No. 75.) Young County, about 4 miles northeast of Graham, 600 feet southeast of road leading by Rocky Mound Schoolhouse, one-fourth mile southwest of schoolhouse. Just below Wayland limestone No. 9b limestone of post-Bunger cycle No. 9 (in Wayland shale member).

676. (W. Lee No. 76.) Young County, about 4 miles northeast of Graham, near Rocky Mound Schoolhouse, on south side of ridge, at top of Wayland shale section below outcrop of Rocky Mound limestone under Avis sandstone on spur above tank. Probably residual material from limestone No. 9b. (The specimens in this lot are giants. They agree rather closely otherwise with the typical forms of the species.)

677. (W. Lee No. 77.) Young County, about 4 miles northeast of Graham, about one-half mile southeast of road by Rocky Mound Schoolhouse, at washed-out head of gully 200 yards west of old road, at south corner of Rocky Mound. Twin beds of limestone at top of Wayland shale section. Post-Bunger cycle No. 9b limestone (in Wayland shale member). (See note to station 676.)

678. (W. Lee No. 78.) Same locality as 677. Bed 40 feet below twin limestone beds (No. 9b limestone of Wayland shale member). Post-Bunger cycle No. 9, No. 9(?) limestone (in Wayland shale member).

679. (W. Lee No. 79.) Young County, 5½ miles northeast of Graham along Chicago, Rock Island & Pacific Railway, on hill one-fourth mile northwest of Dakin switch. Limestone No. 9(?) of post-Bunger cycle No. 9.

683. (W. Lee No. 83.) Young County, about 8 miles northwest of Eliasville, at top of low ridge west of Nash & Windfohr oil pool, on Vick ranch. Belknap limestone member of Harpersville formation.

684. (W. Lee No. 84.) Young County, 5½ miles west of Eliasville, beside east-west road. Greenish crystalline limestone. Belknap limestone member of Harpersville formation.

685. (W. Lee No. 85.) Young County, about 3½ miles northeast of Graham, at head of ravine southeast of Graham-Loving road and second ravine west of road across Rocky Mound. Upper part of Rocky Mound limestone member of Graham formation, in post-Bunger cycle No. 8.

689. (W. Lee No. 89.) Young County, about 5 miles northwest of Eliasville, in Donnell pasture at head of Gage Creek. Belknap limestone member of Harpersville formation.

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