

Pennsylvanian Canyon Stratigraphy of North Central Texas

BY

DAN E. FERAY¹ AND JAMES E. BROOKS²

ABSTRACT

The Pennsylvanian strata of North Central Texas are divisible into three main lithostratigraphic units—in ascending order the Strawn, Canyon and Cisco Groups. The Strawn and Cisco are dominated by sandstones and shales, whereas the Canyon comprises alternating limestones and shales with subordinate sandstones. The subdivision of these units into component formations and members is complicated by the broadly lenticular nature of most of the sandstone and limestone bodies. Thus, for instance, shale formations which at one locality may be separated by a limestone formation may, at another locality, where the limestone has changed facies into shale, be in immediate juxtaposition making discrimination difficult if not impossible. These and other problems relating to the taxonomy and genesis of these units are being actively studied by groups from Baylor, Southern Methodist and Texas Christian Universities.

The Pennsylvanian strata of North Central Texas crop out in a belt extending from the Llano uplift on the south to the central portion of the Fort Worth Basin and central Wise and Jack Counties on the north (Figure 1, Tectonic Index Map of Texas). In this area the Pennsylvanian sequence embraces the Strawn, Canyon, and Cisco Groups. Because exposures are excellent, the area has been the subject of stratigraphic study by various workers for the past half century. The relationships between the Pennsylvanian strata exposed in the Llano region and those exposed on the edge of the Fort Worth Basin are partially obscured by a cover of Lower Cretaceous sediments on the Callahan Divide in Eastland, Erath and Johnson counties. Exposures of the Strawn and lower portion of the Canyon are discontinuous across the Divide. The upper Canyon and Cisco on the other hand are continuously exposed from the Fort Worth Basin to the north flank of the Llano uplift. This paper deals principally with the Canyon Group. The group comprises four major sequences of skeletal limestones separated by coarse to fine terrigenous clastics.

¹ Department of Geology, Texas Christian University, Fort Worth, Texas.

² Department of Geological Sciences, Southern Methodist University, Dallas, Texas.

The factors controlling the origin of these deposits are not yet well understood and the relative importance of eustatics, tectonism and sedimentary environment is as yet undetermined.

During the past half century, several stratigraphic studies of the area have demonstrated the cyclical but complex stratigraphic relationships that exist in the Pennsylvanian. These early studies were related to and motivated by the search for coal and oil, both of which occur in the Pennsylvanian strata of North Central Texas. Most of this work took one of two forms, either that of the systematic mapping of quadrangles or of the study of given strata throughout the region. The latter was usually accomplished by measuring stratigraphic sections at various outcrops and correlating these sections on the basis of similarity of lithology or lithologic succession or fossil content. The systematic mapping of cartographic subdivisions by both governmental and industrial organizations produced a series of county geologic bulletins which were published by the Bureau of Economic Geology of the University of Texas. Where county bulletins were not available, a committee of the American Association of Petroleum Geologists compiled geologic maps of several counties during the period 1929 to 1937. These maps are also available through the Bureau of Economic Geology as "County Geologic Maps Without Text", published at a scale of 1 inch equals 4000 feet. Counties in the study area so mapped are Brown (revised in 1951 at a scale of 1 inch equals 1 mile), Eastland, Jack, Palo Pinto, Stephens, Wise and Young. As a result of this piecemeal approach to the study of the Pennsylvanian strata, conflicts and inconsistencies in stratigraphic nomenclature have arisen. In addition to the nomenclatural problems resulting from the studies themselves, further complications are produced by marked facies changes that occur in most of the mappable units in the region, which resulted in frequent miscorrelations. Typical is the Adams Branch Limestone in the Canyon Group in Brown County which has been correlated with what we now know are portions of the Ranger Limestone in the Brazos River drainage.

The problem of lateral discontinuity of stratigraphic units became apparent to Feray in 1951 and he commenced a re-mapping program of the exposed portions of the Pennsylvanian System in North Central Texas. This program was begun in the Colorado River region using the geologic map of Brown County (Bureau of Economic Geology, 1951) as a starting point and extending the stratigraphic

units mapped there northward to the Trinity River sequence in Jack and Wise counties, Texas. All previous literature and maps were assembled and photo mosaics of the entire region were obtained. The photo mosaics were used as a base for the re-mapping. A generalized copy of the resulting map is shown on Plate I-F, B. As a result of this effort, it was recognized that there was a need to re-map the entire Pennsylvanian of North Central Texas in much greater detail. The three major universities in the area agreed to divide the responsibility for the portion of this research which occurs in the drainages of the Brazos and Trinity River. The subdivision of responsibility was established on the basis of work already completed or in progress, with Texas Christian University continuing study of the Strawn, Southern Methodist University the Canyon sequence and Baylor the Cisco.

Mapping by Feray (unpublished) in the Lake Bridgeport area of Wise County and the Possum Kingdom area in Palo Pinto County demonstrated the need for a regional study of the Canyon Group. This work was begun with a detailed study of the type area of the group by Laury (1962). Subsequent work on the Canyon includes that of Bretsky and Brooks (1963), Perkins (1964), Raish (1964), Brooks and Feray (1965), Wermund (1966), Bretsky (1966) and Brooks and Bretsky (1966).

Simultaneously, Brown of Baylor University and his students were engaged in a mapping program of the Cisco sequence which has resulted in theses and publications by McGowen (1964), Seals (1966), Waller (1966), Ray (1966), and Brown (1959, 1960, 1962). Hendricks and his students at Texas Christian University have produced theses and publications by Wilson (1954), Stewart (1961), Lary (1965) and Sloan (1955).

STRAWN GROUP

The Strawn sequence mapped on Plate I-F, B commences with the Brazos River Sandstone Member of the Garner Formation. The thick sequence of conglomerates and sandstones comprising this unit in the Mineral Wells-Brazos River area changes facies to the southwest, giving way to thin bedded sandstones and shales. The nature of this facies change merits detailed study. Research by Briggs (1963) has delimited lateral variations within the Brazos River Member in a portion of the area.

Overlying the Brazos River Member is a sequence of shale in which

four mappable lithologic units occur. They are, the Village Bend Limestone Member of the East Mountain Shale, the Lake Pinto Sandstone, the Dog Bend Limestone Member of the Salesville Shale and the Turkey Creek Sandstone. The Lake Pinto Sandstone is well exposed in its type area at Lake Pinto near Mineral Wells, Texas. Like the Brazos River Sandstone Member, its outcrop is continuous toward the southwest where it undergoes a facies change into a shale sequence near Strawn, Texas. The Turkey Creek is well exposed at its type area on Turkey Creek and can be mapped northeastward from this area until, in Palo Pinto County, it disappears beneath Lower Cretaceous Trinity sediments. The Turkey Creek changes rapidly laterally into shale southwest of the Brazos River. Preliminary study suggests that these sandstones represent mixed continental and marine origins, including both delta and strand line deposits.

Within the upper Strawn there are two mappable limestone units. Both are thin and poorly exposed. The lowermost, the Village Bend can be mapped somewhat continuously from its type area at the Village Bend of the Brazos River northeastward to the vicinity of Mineral Wells in Palo Pinto County. The limestone grades in a northeasterly direction from a skeletal calcarenite to a quartzose calcarenite to a calcilutite. In places the limestone is somewhat oolitic. Southwestward from the type area, the limestone progressively thins and gives way laterally to a shale in the vicinity of Strawn, Texas. Southwest of Strawn a limestone appears in approximately the same stratigraphic position and has been mapped by Reynolds (1954) and others as the Capps Limestone. In northeastern Eastland County, the Capps thickens rapidly and crinoidal remains become an important constituent.

The Dog Bend Limestone is poorly exposed throughout its outcrop belt and is thinner than the Village Bend Limestone. Like the Village Bend, it undergoes a rapid facies change into shale southwest of the Brazos River.

CANYON GROUP

The Canyon Group in North Central Texas is better exposed than either the underlying Strawn or overlying Cisco Group. The major component limestone formations form prominent cuestas that allow the underlying shale sequences and their contained sandstone lenses to be well exposed throughout the outcrop area. The width of the outcrop pattern (Plate 1-F, B) of these stratigraphic units is directly

proportional to the thickness of the units rather than to variations in structural attitude or topography. Where the outcrop width changes dramatically a facies change between limestone and sandstone or shale occurs. The Canyon sedimentary sequence is crudely cyclical. The "Palo Pinto",¹ Staff, Winchell, Ranger, and Home Creek Limestones are interbedded with the Wolf Mountain, Placid and Colony Creek Shales. The Staff Limestone is the only mappable unit within the type area that is confined to the type area. It is a lenticular mass of limestone which undergoes a facies change into the Wolf Mountain Shale in the vicinity of Palo Pinto Creek. The outcrop pattern (Plate 1-F, B) of the Canyon demonstrates its progressive thickening from the type area northeastward to the center of the Fort Worth Basin in the vicinity of the Trinity River.

Frequently lithologically similar, but laterally discontinuous units occur at very nearly the same vertical position within a short distance of each other. Without care direct correlation is often made in these instances and is always erroneous when done in such a way. In an attempt to correlate these rocks with the well defined time stratigraphic units of the Pennsylvanian in the mid-continent, Cheney (1940) altered the original Strawn, Canyon and Cisco Divisions of Drake (1893) to series rank equating them with the Desmoinesian, Missourian, and Virgilian Series of the Kansas-Oklahoma area. Subsequent work has shown conclusively that the fusulinid zones upon which the proper discrimination of the mid-continent series rests are present in North Central Texas. However the position of the various critical zones which mark time stratigraphic boundaries does not coincide with the boundaries of the physical or rock units that comprise the Strawn, Canyon and Cisco. Were the faunal and physical boundaries to coincide, the base of the Canyon Group (marked by the base of the Palo Pinto Limestone) should also carry the fusulinid marker zone characteristic of the base of the Missourian Series. As it turns out this zone occurs several tens of feet below the base of the Palo Pinto within the shales of the Keechi Creek Formation in the Strawn Group. For this reason the present authors and their students and other workers in the area have preferred to work only with the physical units that can be identified by objective criteria in the

¹ The "Palo Pinto" of this report includes the Palo Pinto and the overlying Posideon Shale and Wiles Limestone of Laury (1962). This informal combination of units is necessitated by the thinness of these units which make it difficult, if not actually impossible, to map them at the scale of Plate 1-F, B.

field and have referred the Strawn, Canyon and Cisco to group rather than series status.

The "Palo Pinto Limestone" thickens progressively from the type area of the Canyon to its type exposures in the vicinity of the town of Palo Pinto. Northeastward from this area the unit progressively thins by replacement of the middle and upper limestone units by shales and sandstones. In the vicinity of Oran, in northeastern Palo Pinto County, a thick sandstone, the Oran Sandstone Member, develops within this stratigraphic interval. In the same area the basal limestone of the "Palo Pinto" thins by deposition of shale in place of the upper limestone beds found elsewhere. The entire "Palo Pinto" formation is covered by Cretaceous strata in northeastern Palo Pinto County, western Parker County, and southwestern Wise County. It is again exposed in western Wise County along the drainage of the Trinity River. Here a sequence of thin limestones interbedded with shale and sandstone has been mapped as "Palo Pinto." This latter outcrop belt also merits further careful study for there are indications that this sequence is older than the type Palo Pinto and that the units are not correlative. There is also evidence both in the outcrop and subsurface that the "Palo Pinto Limestone" becomes progressively younger as it is traced from the Fort Worth Basin southwestward onto the Bend Arch.

The Wolf Mountain Shale is well exposed at its type locality along the slopes of Wolf Mountain, south of the Brazos River in Palo Pinto County. Within the formation are several lenticular sandstones that are not mappable at the scale of Plate 1-F, B. Detailed mapping has shown that these sandstones change facies laterally to the west and southwest into marine shales and limestones. Within the Wolf Mountain Shale, north of the Brazos River there is a local development of a coal bed called the Dalton Coal (Plummer and Hornberger, 1935). However this unit is not mappable at the scale of Plate 1-F, B. Detailed mapping has shown that this coal is a local lens. It may, however, have been more extensive in an eastward (updip) direction and its present distribution is simply what remains from updip erosion. The thick sequence of shale of the Wolf Mountain type area becomes progressively sandier as it is traced northeastward into southwestern Jack County where thick sequences of sandstone develop within the shale. These sandstones display numerous sedimentary features including fragments of plants, a variety of channel-like features, differential

compaction phenomena, flute casts, groove casts, convolute bedding, graded bedding, cross bedding, and ripple marks. Small sandstone lenses also develop within the Wolf Mountain southwest of the type area. These sandstones are very similar to those in the northeast outcrop belt, but are not as thick or as extensive.

The Winchell Limestone has been studied from the type area of the Canyon northeastward to the Lake Bridgeport region in Wise County. The sequence of thin-bedded, algal-skeletal limestone in the type area of the Canyon progressively thickens by addition of limestone at its base at the expense of the underlying Wolf Mountain Shale northward to the Brazos River. At Possum Kingdom Dam on the Brazos River, 160 feet of the Winchell Limestone are exposed. Due eastward from Possum Kingdom Dam, a distance of 3-4 miles, the limestone progressively thins and changes laterally into shale and sandstone until only 11 feet of limestone remains. Northeast of the Brazos River, the Winchell Limestone continues to thin by facies change into the overlying Placid and underlying Wolf Mountain Shales until, in south central Jack County, the limestone disappears completely, leaving the overlying Placid Shale resting directly on the underlying Wolf Mountain Shale. This facies change is shown in some detail by Perkins (1964). The "Winchell Limestone" in the vicinity of Lake Bridgeport in the Trinity River drainage is an isolated outcrop which is not demonstrably continuous with the main body of the Winchell. Because of similarity in lithology and stratigraphic position in both the surface and subsurface it is provisionally referred to the "Winchell" in this paper. Previous reports have referred to these limestones as the Rockhill Limestone, the Chico Ridge Limestone, and the Devil's Den Limestone. Detailed mapping of this sequence both in the surface and subsurface by Feray has demonstrated that this is the south end of a large and extensive algal limestone bank which is completely surrounded by the Wolf Mountain-Placid Shale sequence. Some details of this facies change are available in a thesis by Raish (1964). The surface exposures of Winchell from south central Jack County southwestward to the type area of the Canyon represents the outcrop of another large algal bank that extends southwestward into the subsurface and is here termed the Possum Kingdom Algal Bank.

Overlying the Winchell, and in part its lateral equivalent (by virtue of intergradation), is the Placid Shale. Like the other Canyon

stratigraphic units, the Placid progressively thickens from the type area of the Canyon northeastward into the Fort Worth Basin. Throughout its outcrop belt the formation contains numerous lenticular sandstone units. These are too small and restricted to show at the scale of Plate 1-F,B. However, detailed mapping by Laury (1962) in the type area of the Canyon has demonstrated the existence of numerous sandstone lentils within the Placid Shale in this area. Similar detailed mapping by Perkins (1964) in the Jacksboro-Perrin area of Jack County has recorded the presence of numerous small sandstone bodies within the Placid in that area. These sandstone lenses are very similar to those in the Wolf Mountain Shale. Available data suggest that these sandstones are mixed continental and marine deposits. In addition to the sandstone-shale relationships within the formation, the Placid also undergoes a lateral change into limestone in both the lower (with the Winchell) and the upper (with the Ranger) portions. Mapping by Laury (1962), Perkins (1964), and Bretsky (1966) has demonstrated these relationships in several areas. The Placid Shale contains an abundance of marine organisms throughout its outcrop area.

The Ranger Limestone outcrops continuously from northern Eastland County into western Wise County where it disappears beneath Cretaceous sediments. Like the underlying Winchell and Palo Pinto Limestones, the Ranger locally thickens at the expense of the underlying Placid Shale and the overlying Colony Creek Shale. Areas of unusually thick Ranger Limestones occur in northern Eastland County, southeastern Young County, and southwestern and central Jack County. These thick sequences represent the local development of algal banks similar to those in the Winchell. Nowhere in the Ranger outcrop belt in the map area of Plate 1-F,B does the formation give way completely to shale and sandstone.

The Colony Creek Shale is similar in many aspects to the underlying Wolf Mountain and Placid Shales. The outcrop progressively thickens from the Canyon Group type area northeastward into the Fort Worth Basin. Like the other shale units within the Canyon, the Colony Creek Shales contain numerous small lenses of sandstone. These lenses contain sedimentary features that suggest a mixed continental and marine origin. The shales of the Colony Creek appear, on the basis of their contained fauna, to be entirely marine.

The Home Creek Limestone, the uppermost stratigraphic unit of

the Canyon Group, is continuously exposed from northern Eastland County to northeastern Jack County where it disappears laterally into shale. Farther east in Jack County, two discrete limestone lenses develop in the shales of the upper Canyon above the Ranger Limestone. These have previously been mapped as the "Upper" and "Lower" Cundiff Limestones. The exact stratigraphic relationships between these limestone lentils and the Home Creek and Ranger is not now apparent. Stratigraphic position suggests that the "Upper" Cundiff Limestone may be temporally equivalent to the Home Creek Limestone. However, because continuity cannot be demonstrated with the Home Creek no modification of the present nomenclature is suggested here. Like the underlying Ranger, the Home Creek Limestones locally thicken as a result of what must have been algal banks. One of these banks exists at the town of Jacksboro and is well exposed in the creeks and small quarries south of the town. Another thick sequence of Home Creek Limestones exists in eastern Stephens County but nowhere in the outcrop belt of the Home Creek does it reach the thicknesses shown by the Ranger, Winchell, and Palo Pinto Limestones. The nature of the contact between the Home Creek and the overlying Graham Formation of the Cisco Group is not conclusively understood. Previous workers have suggested the existence of a major unconformity between the Canyon and Cisco Groups, as evidenced by the presence of numerous sandstone-filled "channels" which appear to be cut into the upper surface of the Home Creek Limestone. The best known of these "channels" (the Kissinger Channel) is exposed along the Brazos River northwest of Possum Kingdom Lake, south of Graham in Young County. Detailed mapping of the Home Creek-Graham contact in Eastland, Stevens and Jack counties by Feray, Brooks, Laury (1962), Bretsky (1966) and Perkins (1964) has shown what is an apparently conformable relationship. In fact in this area the contact is marked by lateral intergradations of limestone with the shales and sandstones. The areas of maximum "channel sand" development appear to be those where the Home Creek Limestone is thin over a distance of several miles. Detailed mapping of these areas is needed before the interpretation of the contact can be accurately made. A unique lithologic unit within the Home Creek is a coral limestone which has been mapped in detail by Perkins (1964). He has demonstrated that this limestone is a facies of the algal bank in the vicinity of Jacksboro.

Within this bank several smaller algal bioherms can be observed with associated areas of colonial corals. Nowhere do these coral and algal bioherms reach significant thickness.

CISCO GROUP

The detailed mapping of the strata of the Cisco Group has been the responsibility of Frank Brown and his graduate students at Baylor University.

Plate 1-F,B illustrates the principal stratigraphic units of the group. The most readily mappable units are the thin limestones, namely the Gonzales, Bunger, Gunsight, Ivan, Blach Ranch and Breckenridge. The sequence in general consists of thick sequences of shale with lenticular sandstones and thin, but mappable, limestones. The limestones locally thicken at the expense of the overlying and underlying shales. An example of such thickening is shown in the Bunger Limestone south of the Brazos River along the Young-Stephens County line. Another slight thickening of a limestone unit is shown by the Blach Ranch Limestone in northeastern Graham County. The sandstones within the Cisco Group have been mapped in detail by Brown (1960, 1962). His mapping has demonstrated that these sandstones are for the most part "channel sandstones" that are considerably different from the lenticular sandstones in the Canyon and Strawn Groups. The shales in the Cisco contain an abundant marine invertebrate fauna. Locally thin beds of coal occur in the largely marine shale sequences. The upper limit of the Cisco Group has arbitrarily been defined by the writers as the contact between the Harpersville Formation and the Saddle Creek Limestone. Plate 1-F,B shows the limestones of the Saddle Creek to undergo a facies change into shale in north central Stephens County. From this point northeastward the stratigraphic position of the contact between the Pennsylvanian and Permian is questionable. In all cases, however, it appears that the boundary between the Pennsylvanian and the Permian is conformable.

CONCLUSIONS

The outcrop belt of the Pennsylvanian in North Central Texas demonstrates the broadly cyclical nature of the depositional sequence. Although detailed surface mapping has shown some of the cyclical aspects of the sedimentation, the ultimate understanding of the origin of these cycles awaits a three-dimensional study of the Pennsylvanian

and lower Permian extending from the outcrop into the subsurface of west Texas and southern Oklahoma. Part of this three-dimensional study is available from the efforts of Ohlen (1956) and Stark (1961). Studies of a regional nature by Jenkins and Wermund (1964) demonstrate the need of further subsurface data. These outcrop and subsurface studies suggest the lack of major unconformities within the Pennsylvanian sequence in which the marine transgressive units are generally dominant. In addition, these studies have recorded numerous facies changes with rapid lateral changes between the principal lithologic components (limestone, shale, sandstone).

The outcrop sequence of the Strawn appears to represent a mixed continental and marine sequence of strata that is overlain by the dominantly marine beds of the Canyon. These in turn are overlain by the mixed continental and marine strata in the Cisco Group.

Additional paleontological studies should be made in order to establish time relationships within the Pennsylvanian and to delimit paleoecologic patterns. Additional studies should illumine the problem of the origin of the cyclical accumulation of sediments. At present the evidence is inconclusive in support of either the mechanism of eustatic changes or of tectonism. Critical factors in this decision will include an increased precision in the determination of time stratigraphic relationships, a more exact knowledge of the three-dimensional distribution of the various lithologic components, and more precise data on the duration and distribution laterally and vertically of the various interruptions in the rock record.

Furthermore the interpretations of the Pennsylvanian strata of North Central Texas must be consonant with those for the Pennsylvanian elsewhere. Wanless (1963) has provided a regional evaluation of the Pennsylvanian System in the United States. Further work in the southwest should be set in this framework and should serve to amplify and add precision to these interpretations.

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REFERENCES

- Bretsky, Peter, Jr., 1966, Stratigraphy and Carbonate Petrology of the Pennsylvanian Upper Canyon Group in Stephens and Palo Pinto Counties, Texas, Jour. Grad. Research Center, v. 35, no. 2.
- Briggs, Garrett, 1963, Paleocurrent Study of the Brazos River Sandstone Member of the Garner Formation, Palo Pinto County, Texas, Jour. Sed. Petrol., v. 33, p. 97-104.
- Brooks, James E., and Feray, Dan E., 1965, Facies Relationships in Pennsylvanian Canyon Strata of North-Central Texas, Proceedings of the Southwestern Federation of Geological Societies (abst.).
- Brooks, James E., and Bretsky, Peter, Jr., 1966, A Preliminary Report on the Pennsylvanian Canyon Carbonates in North-Central Texas, Jour. Graduate Research Center, v. 35, no. 2.
- Brown, L. F., Jr., 1959, Problems of Stratigraphic Nomenclature and Classification Upper Pennsylvanian, North-Central Texas, Bull. Amer. Assoc. Petrol. Geol., v. 43, p. 2688-2871.
- Brown, L. F., Jr., 1960, Stratigraphy of the Blach Ranch-Crystal Falls Section (Upper Pennsylvanian), Northern Stephens County, Texas, The University of Texas, Bureau of Economic Geology, Rept. of Investigations No. 41, April 1960, 41 pp.
- Brown, L. F., Jr., 1962, A Stratigraphic Datum, Cisco Group (Upper Pennsylvanian), Brazos and Trinity Valleys, North Central Texas; The University of Texas Bureau of Economic Geology, Rept. of Investigations No. 46, November.
- Cheney, M. G., 1940, Geology of North-Central Texas, Bull. Amer. Assoc. Petrol. Geol., v. 24, p. 65-118.
- Drake, N. F., 1893, Report on the Colorado coal field of Texas, 4th Annual Report of the Geol. Survey of Texas, pt. 1, p. 355-446.
- Lary, Bronda Brants, 1965, The Ostracode Fauna of the Pennsylvanian Wolf Mountain Shale of the Possum Kingdom Area, Palo Pinto County, Texas, unpublished Master's thesis, Texas Christian University.
- Laury, Robert L., 1962, Geology of the Type Area Canyon Group, North-Central Texas, Jour. Grad. Research Center, vol. 30, no. 3.
- Lee, Wallace, Nickell, C. O., Williams, James S., and Henbest, Lloyd G., 1938, Stratigraphic and Paleontologic Studies of the Pennsylvanian and Permian Rocks in North-Central Texas, Univ. of Texas Publ. No. 3801, Bureau of Economic Geology, 252 p., illustr.
- McGowen, Joseph H., 1964, Stratigraphy of the Harpersville and Pueblo Formations, Southwestern Stephens County Texas, unpublished Master's thesis, Baylor University.
- Ohlen, Henry R., 1956, A Subsurface Study of a Portion of the Strawn Series in Jack, Palo Pinto, Parker, and Wise Counties Texas, unpublished Master's thesis, Texas Christian University.
- Perkins, Max, 1964, The Geology of the Jacksboro and Bartons Chapel Quadrangles, Jack County, Texas, unpublished Master's thesis, Texas Christian University.
- Plummer, F.B., and Hornberger, Joseph, Jr., 1935, Geology of Palo Pinto County, Texas, Univ. Texas Bulletin, 3534, 240 p.
- Ray, Johnny R., 1966, Stratigraphy of the Moran and Pueblo Formations (Upper Pennsylvanian and Lower Permian), Northern Callahan and Southern Shackelford Counties, Texas, unpublished Master's thesis, Baylor University.
- Reynolds, W. F., 1953, Geology of South Palo Pinto Creek Area, Eastland County, Texas, unpublished Master's thesis, The University of Texas.
- Raish, Henry Dean, 1964, Ecology of a Limestone Bank in the Winchell Formation (Upper

- Pennsylvanian) of Will County Texas, unpublished Master's thesis, Texas Christian University.
- Seals, Mary June, 1966, Lithostratigraphic and Depositional Framework Near-Surface Upper Pennsylvanian and Lower Permian Strata, Southern Brazos Valley, North-Central Texas, unpublished Master's thesis, Baylor University.
- Sloan, R. E., 1955, Paleocology of the Pennsylvanian Marine Shales of Palo Pinto County, Texas, *Jour. of Geology*, vol. 63, p. 412-428.
- Stark, Phillip Herald, 1961, A Subsurface Stratigraphic Study of the Pennsylvanian System in the Marietta Basin of South Central Oklahoma and North Central Texas, unpublished Master's thesis, University of Wisconsin.
- Stewart, Edwin Mack, 1961, Upper Pennsylvanian Rugose Corals from the Possum Kingdom Area of the Palo Pinto County, Texas, unpublished Master's thesis, Texas Christian University.
- University of Texas, Bureau of Economic Geology, 1951, Geologic Map of Brown County.
- Waller, Thomas H., 1966, Stratigraphy of the Graham and Thrifty Formations (Upper Pennsylvanian), Southeastern Stephens County, Texas, unpublished Master's thesis, Baylor University.
- Wanless, Harold R., 1963, Pennsylvanian Period and System (or Epoch and Series), *Lexique Stratigraphique International, Congres. Geologique International*, vol. VIII, 64 p., illust.
- Wermund, E. G., 1966, Missourian Facies in the Possum Kingdom Dam Vicinnty, Palo Pinto County, Texas, *Jour. Grad. Research Center*, v. 35, no. 2.
- Wermund, E. G., and Jenkins, Wm. A., Jr., 1964, Late Missourian tilting of the Eastern Shelf of the West Texas Basin, *Geol. Soc. Amer. Spec. Pap.* 82, pp. 220-221 (abst.).
- Wilson, Francis S., 1954, Foraminifera from the Pennsylvanian Wolf Mountain Shale near Graford, Texas, unpublished Master's thesis, The University of Tulsa.